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Collaboration patterns and motives in NEST/FP 6 projects - Final report

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1 Introduction and outline of the research task

This paper is the final report of a specific study conducted as part of the project Network Models, Governance and R&D Collaboration Networks (NEMO). The aim of this study was to understand the internal dynamics of collaborative research projects funded from the European Union's Framework Programmes for Research and Technology. A sample comprising seven research projects from the FP6/NEST Programme was selected to highlight the partner selection and knowledge production dynamics in collaborative research projects. The expected outcome of the study was a set of stylised rules guiding internal collaboration dynamics in NEMO's agent-based model, SKEIN (Simulating Knowledge dynamics in EU-funded Innovation Networks).

This paper combines two analytical exercises conducted with the data from the NEST projects. The first of these highlights the internal collaboration dynamics, focussing criteria for partner choice, learning and knowledge production in collaborative projects, and finally factors promoting and impeding research collaboration. The internal collaborations rules for the agent-based model are produced in the second analytical exercise. These exercises have been reported in greater detail in Nokkala et al 2008, and Nokkala 2009. The paper is structured as follows. The contextual framework of European R&D collaborations is outlined in the following section. The empirical data is described section three, and the two separate analytical exercises outlined in sections four and five. Finally, short conclusions are drawn in section six.

2 Context: collaborative knowledge production in Europe

Alongside traditional, university led research, new collaborative research arrangements have proliferated (Hagedoorn & van Kranenburg 2003). Academic and technological knowledge production increasingly takes place in collaborative arrangements comprising many different types of actors, universities, research institutes, large corporations and SMEs. Collaborative arrangements also often involve societal partners such as NGOs and various government agencies. Gibbons et al (1994) argue that this new mode of knowledge production ("mode 2") stems from the need for more socially accountable, applicable and transdisciplinary knowledge.

In mode 2 knowledge production, the entire process from setting of research priorities and defining research problems to interpreting and diffusing its results is increasingly socially accountable. This requires negotiating the interests and expectations of the multiple users, investors and stakeholders of knowledge, thus also contributing to the increasing reflexivity of producers of knowledge. Finally, the quality control of the mode 2 knowledge production has broadened to take into account a set of intellectual, political, economic and social aspects such as the social acceptability and market viability of the solutions. (Gibbons et al 1994.)

One the other hand, this shift in the knowledge production is facilitated by institutional mechanisms, such as the institutional regulations of academic research emerging from the activities of the agencies funding research (Benner & Sandström 2000). By encouraging tighter cooperation between various knowledge producing actors, national and international policy makers aim to establish more integrated innovation system, building on the Triple Helix of the university-industry-government relations (Etzkowitz & Leydesdorff 2000). Most countries and regions, including the European Union, have introduced funding structures to enable collaborative knowledge production. The objective is to create a knowledge-based economy with an innovative environment through university spin-off firms, strategic alliances among firms, government laboratories and academic research groups, as well as fostering other trilateral initiatives for knowledge based economic developments and ventures (Leydesdorff & Etzkowitz 1996, Etzkowitz & Leydesdorff 2000).

The European Framework Programmes for research and technology, established in 1984, have been especially successful in encouraging collaborative research. The integration between collaborating R&D organisations has increased over time, as has the involvement of organisations in 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 (Pohoryles 2002b, Barber et al 2006, Georghiou 1999, Caloghirou et al 2001.) Furthermore, the clustering of organisations seems to have increased over time. (Roediger-Schluga & Barber 2007.)

Research collaboration is facilitated by the perceived resource interdependence of the knowledge producing institutions (Geisler 1995). Funding opportunities provided by the EU Framework Programmes, intellectual interests and opportunities for interdisciplinary collaboration are important motivations for researchers to engage in EU-funded collaborative research projects (Pohoryles 2002b). Achieving research synergies, keeping up with major technological developments, sharing R&D costs or developing particular products and processes, and markets for them, are key motivations for industry to get involved in joint ventures. (Caloghirou et al 2001, Luukkonen 2002.) Inter-organisational collaboration enables organisations to develop their absorptive capacity (Cohen & Levinthal 1990), increase their skills to manage cooperation and increase their awareness of new developments and possible further collaboration possibilities, as well as helping them to develop a reputation as a valuable partner (Powell et al 1996). Good personal relations, institutional ties, availability of funds, joint publications, easy communication and sharing a research paradigm are indicative of sustained collaboration (Pohoryles 2002, Okubo & Zitt 2004).

3 Empirical data

The dataset used in the analytical exercises was collected from on the EU's New and Emerging Science and Technology (NEST) programme in the Sixth Framework Programme (FP6). The NEST programme was an initiative introduced in the FP6, which aimed to support unconventional and visionary research with the potential to open new fields for European science and technology. It was chosen as the focus of the study because the characteristics of the research task in NEST projects, i.e. searching for new and innovative approaches in high-risk settings, was seen to lend a common framework for the projects. It was also seen to complement the other datasets used for identifying the internal collaboration rules, namely a survey of FP5 funded research projects, and case studies of five selected Integrated Projects in FP6 (Nokkala et al 2008).

NEST projects were characterised by high risk and high reward. Interdisciplinarity was encouraged and there were no restrictions on the scientific fields to be addressed except that the research carried out under NEST should cut across or lie outside the

FP6 thematic priority areas. The NEST programme was divided into three parallel action lines. Adventure projects were 'visionary' research projects that aimed to develop new scientific and technological opportunities in areas identified by the researchers themselves, Insight projects assessed new discoveries or newly-observed phenomena which could indicate risks or problems to society; and finally Pathfinder initiatives focussed on specific, highly challenging objectives in emerging scientific and technological fields, and involve groups of complementary projects. The NEST projects may have been Networks of Excellence or Specific Targeted Research Projects. They were mostly small, more often academic than industrial projects.

In selecting the individual projects from the NEST programme, five criteria were taken into account. The projects should represent the different action lines of the NEST programme: Adventure, Insight and Pathfinder. They should represent different disciplines, and have different types of organisations as participants. They should also represent a broad geographical spectrum, but ideally it should be possible to identify certain geographical areas where there would be several participants from different projects, to facilitate economies of scale in conducting face-to-face interviews. The projects should have been still be ongoing at the time planned for interviews in Spring 2008. Seven projects were eventually selected, each comprising three to ten partners from three to six countries. The projects represented Adventure or Insight action lines, and comprised multidisciplinary applications in physics, medicine and biology, basic research in physics and application in engineering.

Prior to the interviews, an interview protocol was designed. It included 34 questions under seven broad themes: History of the project, Structures and roles in the project, Previous collaboration history, Future plans, General collaboration rules, Knowledge production, learning and internal dynamics and finally, Evaluation. The list of interview questions can be found in Annex 1. The interview themes were sent to the interviewees beforehand.

Altogether 22 in-depth qualitative interviews were conducted with 25 individuals working in the selected research projects. For all projects, the coordinator and at least one work package leader were interviewed, but also managers, ordinary participants and subcontractors representing universities and research institutes were approached.

Fourteen of the interviews were conducted by telephone, and the remaining eight were conducted face to face.

Two analytical exercises were conducted based on the empirical material. The first exercise focussed on uncovering partner choice criteria, internal collaboration dynamics, and factors perceived to facilitate or impede international collaboration. The findings were reported in the NEMO Working paper #13 (Nokkala et al 2008). The second exercise focussed on identifying internal collaboration rules extracted from the studied cases, as well as formulating a set of stylised rules for the purposes of the NEMO agent based model (SKEIN). These rules were reported in the NEMO Working paper #15 (Nokkala 2009). In the following sections, both exercises are briefly described.

Although a small qualitative sample cannot provide widely generalisable findings, qualitative real life data does offer clear benefits for the study of collaborative R&D projects. It 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. By providing insights into the motivations and experiences of the individuals whose work is greatly influenced by the structures and processes of collaborative research, it complements the various quantitative data sources and statistical network analysis in the NEMO project, thus contributing to a more realistic, fuller picture.

4 Internal integration and collaboration[1]

The aim of the first exercise was to take a closer look at the intra-project collaboration that has been induced by EU Framework Programmes, with the focus on individual projects and researchers. The analysis focussed on the criteria for partner choice in current and future R&D projects; internal project dynamics related to communication, learning and joint knowledge production between the partners; and factors seen to promote and impede collaboration in EU-funded R&D projects. The same questions

[1] This exercise has been reported to a greater detail in Nokkala et al 2008.

were also addressed with the help of two other datasets on FP5 and FP5 (see Nokkala et al 2008).

4.1 Analysis

In order to analyse self-organisational features of the projects, the recorded interviews were transcribed, then coded using the qualitative data analysis software ATLAS.ti. The coding produced 71 first order codes. These first order codes were mostly codes at a low level of abstraction describing the content of each segment of data, such as various aspects of communication, structures, knowledge production, partners or proposal. Some first order codes were at a higher level of abstraction (analytical codes), indicating the phenomena the interviewees were describing, such as team work, science or unpredictability. Additionally, twelve background codes were used to denote the academic status, project role, organisational background and gender of the interviewees. The codes are described in Nokkala (2009).

The coding partly stemmed from the theoretical and practical framework of the study, and partly arose from the texts themselves. Altogether 51 of the 71 codes were used to inform the three main analytical focuses, presented below.

4.2 Criteria for partner choice

This section focuses on 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, the personal and organisational characteristics of the partners and their formal status in past or current collaborative projects were found to be important criteria in partner choice.

According to the empirical data from the NEST projects, 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. Previous research has yielded very similar results (c.f. Pohoryles 2002b). The interviewees emphasised the importance of trust and reliability as important motivations for selecting prior collaborators as partners in current EU projects. It was argued that, by selecting previous collaborators, one would know that the partners would "do their job" and would have the needed expertise. One

interviewee also said 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 "scientific friendship", as described by an interviewee, 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.

Partner choice was also 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 as 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 a criterion for partner choice, although most of the included projects also had very specific requirements in terms of the infrastructure.

Motivations to continue working with the same partners included 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 requiring 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 were seen to have a favourable influence on future collaboration opportunities, the coordinators and work package leaders were seen as especially desirable partners for future collaboration. 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 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 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 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.

4.3 Learning and knowledge production in collaborative projects

Learning and joint knowledge production represent the primary aims of establishing R&D collaboration networks.

In the following section, learning refers to internal processes of acquiring new skills, norms, values and new ways of thinking within the inter-organisational collaboration, 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.)

Three kinds of learning can be identified in the NEST data. First, the partners 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 team and learning a shared terminology to facilitate communication were listed as primary learning effects during the project. Third, the project participation lead to a 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.

While learning can be seen as an intra-project function, knowledge production is primarily an extra-project function, and refers 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 (c.f. Gibbons et al 1994.) In the NEST projects, knowledge outputs take the form of, for example, articles, books, conference papers, equipment, software and servers.

The Framework Programmes aim to enable large scale research projects and encourage joint knowledge production. Although there is considerable willingness for collaborative partners to forge durable formal collaboration links, there seems to be considerable variation in the extent to which the formal links translate to shared knowledge production within the projects. Intra-project communication is essential for shared 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, typically there 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.

Although for many scientists joint knowledge production is an inherent value in the collaborative projects (c.f. also Pohoryles 2002b), there are, however, also individuals who prefer working alone. 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.

Perceptions of the interviewees about the success of the collaborative projects were varied, and based on three different aspects. A procedural view of the success of the project was based on achieving the goals set in the work plan and producing the required deliverables and milestones in time. A communal view was based on fruitful teamwork and scientific benefit derived from that. Finally, a scientific view emphasised the unique scientific discoveries and scientific impact. Perceptions of non-success included too ambitious work plans or some partners not pulling their weight in the project.

4.4 Factors promoting and impeding collaboration

The third aspect highlighted by the analysis of NEST projects are the intra-consortium factors promoting and impeding collaboration within the collaboration projects.

The size of the project consortium, or in case of large projects (for discussion on other datasets, see Nokkala et al 2008, 17), 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 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 numbers 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 as requiring well-organised hierarchical substructures and different levels of communication.

Communication in larger projects was said to be often 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 higher.

Also, 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.

Trust, teamwork, the feeling of a shared purpose and good personal relationships, were all seen to contribute to the effective cooperation and to a successful project, as did emphasising the communication and conscious collaboration between the partners. Similar results are reported by previous research on FP collaborations (Geisler 1995, Okubo & Zitt 2004) as well as inter-organisational collaboration more generally (Ring & van de Ven 1994). Positive previous experiences about international collaboration and a supportive attitude of the institution towards international collaboration also play a role in facilitating cooperation and contributing to the perceived success of project.

Besides the number of partners, another significant factor in determining the smoothness of collaboration is their disciplinary background. The interviews highlight the challenges of interdisciplinary research and emphasise the importance of careful coalition building and communication in facilitating it. Establishing a shared

terminology and understanding of the research questions were deemed as challenging and time consuming, especially in projects bringing together very different disciplinary fields. Bruce et al's (2004) study of interdisciplinarity in FP5 funded research projects shows similar results.

On the other hand, interdisciplinary cooperation was seen as an 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, enquiring mindset, while another one argued that this should also be cultivated in young researchers early on in their career. A 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.

The interviews also highlighted the importance of the organisational background of partners. Inter-organisational collaboration between different types of partner 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 projects, 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, whereas research centres and companies were primarily 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 in the same field. Companies may have a secretive attitude to knowledge production or limited creativity due to the wish to achieve 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. In the NEST projects, which tend to be oriented towards basic rather than applied research, most interviewees demonstrated a preference towards working with academic rather than commercial organisations.

On the other hand, the interviewees sometimes also saw different dynamics 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. 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 was seen to diminish the need for formal rules and formalised communication procedures (c.f. Coleman 1988).

Other background factors, related to the language spoken by partners or their geographic proximity, were not seen by most as factors significantly affecting collaboration. 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. Only few interviewees regarded 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.

Other extra-project factors such as the availability of funding, cultural and procedural issues may have an effect on the collaboration at the European level. The need of universities and research institutions to find funding acts as a significant motivation for European collaboration, while the availability of funding acts as a stimulant for it.

On the other hand, one interviewee considered that having to start collaboration just to get funding is a wrong motivation, while another one pointed out that partners may also act selfishly, and once they have secured the funding for the project, everyone goes on to do their own research without any genuine interaction.

Structural factors such as visa waivers, cheap air travel and developing communication systems make collaboration both easier and more attractive. Some interviewees pointed out that once organisations and individuals get more experience

in European collaboration with its specific application and reporting procedures, it becomes regarded as a normal everyday activity. On the other hand, many procedural restrictions related to the Framework Programmes, such as short funding cycles, changing rules, cumbersome application and reporting processes and limited flexibility in allocating the funding inside the project once the contract has been signed were seen as de-motivating for European collaboration.

5 Internal collaboration rules[2]

The aim of the second exercise was to contribute to the NEMO Agent-based model, SKEIN – Simulating Knowledge dynamics in EU-funded Innovation Networks. The SKEIN model is aimed at simulating the emergence of collaboration networks and knowledge production in EU-funded R&D projects. The model is informed by empirical analysis of, on the one hand, the external governance rules set by the European Commission, and on the other hand, the internal collaboration rules defining the consortium formation and knowledge production processes inside the projects. The external governance rules, which have been constructed based on the analysis of European Union policy documents related to the Framework Programmes, are explicit rules and thus command compliance (see Kruckenberg et al 2008). They are operationalised in the model as changeable parameter values that enable the user of the model to run various policy experiments. The internal collaboration rules are based on three different empirical datasets. The main contribution came from the afore-mentioned data from NEST projects, which was supported by case studies of five Integrated Projects from FP6, and a quantitative survey from FP5. They comprise norms and patterns of behaviour describing either what participants have done or what they would do under certain circumstances pertaining to the different stages of the collaboration process. They are integrated into the model as attributes and properties of the agents, such as their kene, partnering strategy or research network; or inform the other basic assumptions and decision conditions in the model. (See Scholz et al 2009 for further details on the model.) The following sections outline the construction of the rules from the NEST data and their implementation in the SKEIN model.

[2] This exercise has been reported to a greater detail in Nokkala 2009.

5.1 Analysis

In the SKEIN model, internal collaboration rules refer to *if-then* conditionals which are applied to the attributes and activities of the agents, and the framework conditions of the model. The interviewees were not directly asked or prompted about rules of behaviour. Instead, they were asked about typical actions in certain situations, such as how they would proceed when inviting other partners to join a project; or what they thought the European Commission paid attention to when selecting which projects to fund. The "rules" were derived from a content analysis of the transcribed data. The concept of "rules" was imposed on the data in order to comply with the requirements of the agent-based model. Thus, rather than strict rules which would command compliance, the internal collaboration rules comprise norms and patterns of behaviour or even expectations of causality in events independent of the actor.

In order to produce the rules required to construct the SKEIN model, the interviews were analysed and all activity guidelines or prescriptions that could be formulated as 'if-then' conditionals were extracted. These broad constructs pertain to the internal organisation of the projects at the different stages of the collaboration process. This amounted to 333 if-then conditionals in the 22 interviews. At the next stage, those if-then conditionals were standardised across the empirical data and duplicates were removed. The basic if-then conditional, or "rule", was only counted once even when additional modifiers were added to it. If contrasting opinions were expressed by the interviewees, counter-rules were also included. Rules pertaining to tasks which were not included in the SKEIN model were removed, as were rules pertaining solely to the activities of individuals, as the agents in the model are organisations rather than individuals. The final rule list for use in the construction of the SKEIN model included 67 rules[3].

In the rules, some of the conditions ("ifs") refer to the conditions of the call, or other regulations of the European Union. They may also refer to intra-consortium factors, intra-partner factors, personal factors, or to the research project itself. Similarly the

[3] Further details on the coding procedure and the list of rules are in Nokkala (2009).

outcomes ("thens") may refer to activities of the individual, partner, consortium, or to the outcomes of the project. Thus the "rules" pertain to the activities of the project partners, the activities of the European Commission, or its evaluators. However, many of the rules do not directly describe an animate actor, but to attributes of inanimate objects such as proposals, and what effect these attributes might have on their success of being funded. The rules are based on perceptions of the interviewees, rather than empirically tested causalities.

5.2 Collaboration rules for six stages

The rules resulting from the analysis were divided into six categories according to the context they related to: (A) consortium formation, (B) proposal submission, (C) funding decision and (D) task division, (E) intra-project collaboration structures, processes and context, and finally, (F) the future collaboration and its framework conditions.

Consortium formation rules (19 rules) pertain to a situation where a partner is being invited to a project; or a situation where a partner is inviting other potential partners to the project. Joining the project when invited was the most widely quoted rule in the entire rules list, being mentioned in 14 out of 22 interviews. However, many additional qualifiers were attached to it: partners reported they would join a project if they knew the coordinator, if the project was interesting, if it fitted the research profile, if it had a good chance of being funded, and so on. Other rules for situations when one was being invited include e.g. not joining projects if one already had too many other commitments, or being asked to join projects when one had relevant expertise in the area. Rules pertaining to situations where one was inviting other partners to join include e.g. inviting partners one already knows or partners with suitable expertise. If the inviting partner does not know suitable partners personally, they might rely on the recommendation of another partner, or other trusted person, or look for partners in the CORDIS database or EU seminars.

Proposal submission rules (4) pertain to the procedure of proposal submission and to the call for submissions, as well as issues related to funding and the research needs of the partners. These rules include e.g. submitting a proposal whenever there is a suitable call, or following the rules of a specific call when writing a proposal for that

call. Preparing a project proposal could be sparked off e.g. by need for funding, or having previously conducted a pilot study in the field.

Funding decision rules (8) address the importance of the attributes of the proposal, knowing the "right people", or the importance of the country or organisational background of the partners in terms of the project getting funded. Having a sound and innovative proposal, and geographically balanced groups with an abundance of expertise are conducive of a successful application. Proposals in line with EU's policy goals were also likely to be funded, as well as applications by well known organisations or opinion leaders.

Task division rules (8) address the role of the coordinator or the work package leader. The rules pertaining to coordinators included e.g. that the partner coming up with the research idea would be coordinator, and that in a situation of having too many other duties, or already coordinating another project, the partner could not be a coordinator. Similarly, some other partner might take on a coordinating role if the EU rules or unexpected factors prevented the partner who originally came up with the idea from being the coordinator. The rules also include e.g. partners with specific expertise in relation to a specific research task being invited to be work package leaders for that task.

Collaboration rules (19) address issues related to the significance of the organisational, disciplinary and country backgrounds of the participants for the collaboration; rules related to knowledge production and communication within the project, success of the project, management and structures of the project and possible extension of the project. For instance different disciplinary or organisational backgrounds may either make communication slower and more cumbersome, or to be conducive of learning and positive dynamics within the project. Smaller projects facilitate collaboration, and larger projects require dividing the project into smaller subgroups. Communication takes place primarily within the work package.

Finally, **future rules** (9) pertain to the desired roles and expected collaboration opportunities in possible future projects, as well as continuing proposals and procedures in future projects. If the project at hand reached good results, many

interviewees wanted to continue with the same partners for a future proposal. Being a coordinator or a work package leader was respectively seen to facilitate further collaboration opportunities, or to have no consequences for them.

5.3 Implementation in the SKEIN model

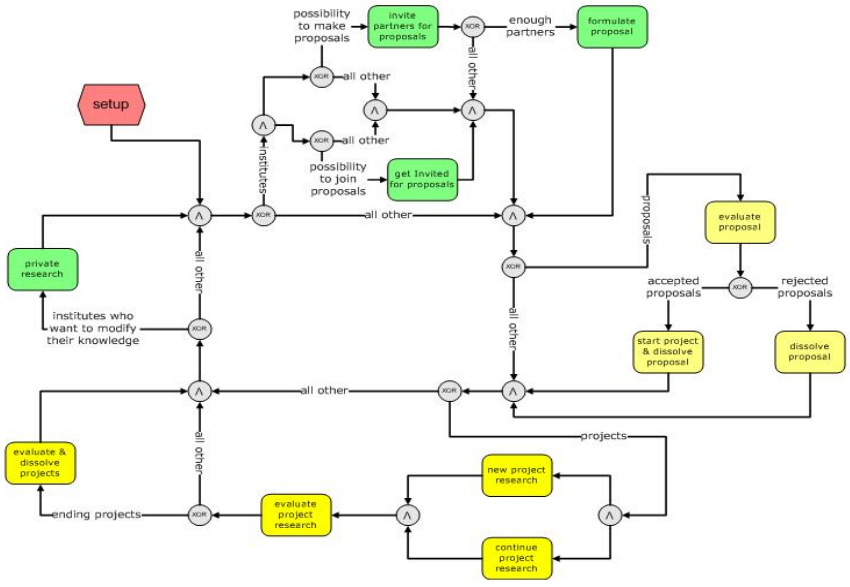
In order to implement the rules in the SKEIN model, the rules were scrutinised in the light of two other datasets, to see which rules might be supported either by the case studies of the Integrated Projects from FP6, or the survey of the participants of FP5 collaboration projects. (See Nokkala 2009 for further details). Of the aforementioned 67 rules, only those which were deemed feasible for the structure of the model, and could reasonably be expected to be supported either by the other empirical datasets, or by the EU governance rules, were implemented. The final 35 rules, fully or partly implemented in the model, are presented in the following table.

Rule Number	Rule	Cycle stage	Special theme
A1	If the agent gets invited to join a project and (it has had prior cooperation with the coordinator or other partners), or (the project is considered interesting/innovative) or (it fits the agent's research profile/priorities) or (the agent trusts the other partners) or (it is not overlapping with other projects) or (the agent is looking for funding) or (the proposal has a good chance of being funded) or (it's in a field the agent wants to expand to) or (if the agent wants to broaden its network and increase its visibility) or (if someone the agent considers a key partner) joins the project, the agent joins the project.	Consortium formation	Being invited
A5	If the agent is participating as coordinators in two proposals, and gets invited as a participant to a third one, the agent declines.	Consortium formation	Being invited
A7	If the agent has many other obligations at the same time, it does not joint the project.	Consortium formation	Being invited
A8	If the agent has more than one project being prepared at the same time, it can join all of them.	Consortium formation	Being invited
A10	If an agent moves away from the specific research are, it can no longer join projects in that particular research area.	Consortium formation	Being invited
A11	If there already is a partner who is an expert on a particular research task, no other partner will be invited with the same expertise.	Consortium formation	Inviting
A12	If agents (who have relevant expertise or needed equipment) have previous collaboration with existing partners of the consortium/are known to the coordinator, they will be invited to join.	Consortium Formation	Inviting
A15	If the agent does not know suitable partners for the project, it relies on the advice of a trusted agent who knows suitable partners.	Consortium formation	Inviting
A18	If the agent does not know suitable partners beforehand, it will (look for them in the internet/EU seminars/CORDIS and) invite them based on scientific expertise.	Consortium formation	Inviting
A20	If there are several possible partners for a particular task to choose from, the agent chooses the one known personally.	Consortium formation	Inviting
A22	If the agent is inviting partners to participate a project, the competencies of the organisation (research group) matter more than the competencies of an individual.	Consortium formation	Inviting
B2	If the agent is writing a proposal for a particular call, it has to follow all the rules related to that call.	Proposal submission	Procedure
C2	If the project proposal is in line with EU policy goals, it is more likely to get funding.	Funding decision	Proposal
C3	If the proposal is good quality and innovative, and the consortium consists of experts, (and management and economy is sound, (and it can't be funded on national basis) the project is likely to get funded.	Funding decision	Proposal
D1	If the agent has too many other obligations, it cannot be a coordinator.	Task division	Coordinator
D3	If the agent comes up with the research idea, it will be the coordinator of the project.	Task division	Coordinator
D7	If the agent is coordinating a project proposal, it cannot coordinate another project proposal.	Task division	Coordinator
D9	If a partner has needed expertise in relation a research task, it will be invited to be the work package leader of that task.	Task division	Work package leader

D11	If a partner doesn't have specific expertise in relation to a particular task, it is not involved in the work package relating to that task	Task division	Work package leader
E1	If partners represent different types of institutions, it has no consequences for collaboration.	Collaboration	Background
E2	If partners represent different disciplines/countries they learn from each other	Collaboration	Background
E4	If partners represent similar fields, their communication is easier.	Collaboration	Background
E7	If the agent writes articles/builds equipment, it collaborates with (at least) one other partner in producing them.	Collaboration	Knowledge production
E13	If the consortium achieves its deliverables and milestones, the project is successful.	Collaboration	Success
E14	If the agent does not have qualified personnel, it cannot fulfil its tasks well.	Collaboration	Success
E15	If the agent shares a research task/work package (works on a similar type of task) with another partner (another partner is important to the research task) the agent communicates more with that partner than with other partners.	Collaboration	Communication
E18	If the agent is a partner in a work package, it only communicates with the other partners in that work package.	Collaboration	Communication
E21	If there are more then 10-12 partners in a consortium/consortium is very large, the project needs to be divided into substructures.	Collaboration	Management and structures
E22	If the agent coordinates the project, it has to be able to trust the other partners to do fulfil their tasks.	Collaboration	Management and structures
F2	If the agent is invited to a further project/continue the project in a new proposal, (and it was a similar task) (if the expertise of the agent was only relevant to one limited part of the project) the agent continue on the same hierarchy level.	Future	Role
F4	If the agent will participate in a future EU project and the project is in its core expertise area (and the agent doesn't have too many other projects to coordinate) (and the agent have less other obligations), the agent continues on a higher hierarchy level. (WPL instead of ordinary participant, coordinator instead of WPL)	Future	Role
F5	If the agent is well-known/expert in its field/has participated in EU-projects before/has good networks, it is likely to be invited to future projects.	Future	Collaboration opportunity
F6	If the agent is a work package leader or a coordinator, it has no consequences for future collaboration opportunities.	Future	Collaboration opportunity
F7	If the agent does not perform well in one project, it is not invited to the next proposal.	Future	Collaboration opportunity
F8	If the agent is a coordinator/manager or a work package leader, and the collaboration is successful, the agent is more likely to be invited to future projects/ other agents are more likely to want to join its projects in the future.	Future	Collaboration opportunity

Table 1. Rules implemented in the SKEIN model

The rules were implemented as parameters in the SKEIN model. They pertain to all sections of the SKEIN model, the general structure of which is presented in the following picture.



Picture 1. Structure of the SKEIN model. Scholz et al 2009.

In the model each agent has a specific knowledge base, kene. This kene comprises four elements: research direction (basic or applied research), capabilities (knowledge area, e.g. discipline), abilities (specialisation of the knowledge area) and expertise (skill within the knowledge area). In addition to the knowledge base, the agents have capital stock, partnering strategy, research network and a stock of current research projects. In addition to the agents, the model incorporates several basic assumptions and operating procedures, e.g. a procedure for initiators of new proposals to select partners for the proposed projects, and a procedure for the Commission to select proposals to receive funding or fail. The model also assumes that the agents are only able to initiate one proposal per period, and only contribute to a maximum of two projects at the same time. The rules constructed based on the empirical data described above, were used to inform both the descriptions of the attributes and properties of the agents, such as their kene, partnering strategy or research network; and the other basic assumptions, decision conditions and procedures in the model. (See Scholz et al 2009 for further details on the model.) The following picture illustrates how a rule can be implemented in the different aspects of the model.

Rule Number	Rule	Cycle stage	Special theme
A1 Research network of the agent Basic assumption in the model Part of kene/partnering strategy Basic assumption in the model Part of kene/partnering strategy	If we get invited to join the project [AND (we have had prior cooperation with the coordinator or other partners) OR (we want to broaden our network and increase our visibility) OR (it fits our research profile/priorities) OR (we are looking for funding) OR (it's in a field we want to expand to)] we join the project.	Consortium formation	Being invited

Picture 2. Example of rule implementation in the SKEIN model.

6 Conclusions

This paper has presented two interlinked analytical exercises conducted on a qualitative dataset collected from the FP6/NEST Programme. The exercises have provided qualitative empirical data to analyse project formation and intra-project linkages in EU-funded collaborative R&D projects. The data have emphasised the importance of social capital (Coleman 1988) in the structuring of the collaborative

research projects. The networked relationships, based on prior acquaintance, friendship and trust, are essential for both partner selection and actual collaborative knowledge production in EU-funded research projects. The emergence and strengthening of social capital is facilitated by small communities (e.g. work packages), shared terminology and conscious communication. These results, based on the actions and perceptions of real-life actors, provide a starting point for modelling realistic sub-structures and processes in NEMO's Agent-based simulation. The internal collaboration rules, constructed based on the dataset, cover the entire life-cycle of the R&D collaborations, from issuing a funding call, to consortium formation, knowledge production and finally evaluation. The qualitative dataset provides a starting point for constructing the model which benefits from the insights of real-life agents, and is complemented by the more quantitative approaches to R&D collaborations. Building on various different empirical datasets, the agent-based SKEIN model provides a means for modeling the emergence of collaborations and development of knowledge production in collaborative R&D projects.

References

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

Barber, M., A. Krueger, T. Krueger and 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, Buckingham: 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.

Benner, Mats & Sandström, Ulf (2000). *Institutionalizing the triple helix: research funding and norms in the academic system.* Research Policy, Vol. 29, 291–301.

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.

Cohen, Wesley M. & Levinthal, Daniel A. (1990). *Absorptive Capacity: A New Perspective on Learning and Innovation.* Administrative science Quarterly. Vol. 35, 128-152).

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.

Etzkowitz, Henry & Leydesdorff, Loet (2000). *The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government relations*. Research Policy, Vol. 29, 109-123.

Geisler, Elizier (1995). *Industry-University technology Cooperation: A Theory of Inter-Organizationsal Relationships.* Technology Analysis& Strategic Management. Vol. 7 No 2 1995.

Georghiou, Luke (1999). *Socio-Economic Effects of Collaborative R&D – European Experiences.* Journal of technology Transfer 29: 69-79, 1999.

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.

Hagedoorn, J. and H. van Kranenburg (2003). *Growth patterns in R&D partnerships: an exploratory statistical Study.* International Journal of Industrial Organization, **21**, 517–31.

Kruckenberg, L.; Brandes, A. and Ahrweiler, P. (2008). *R&D Governance Rules of the EU Framework Programmes: The EURuled Archive.* NEMO working paper #6

Leydesdorff, Loet & Etzkowitz, Henry (1996). *Emergence of a Triple Helix of university-industry-government relations.* Science and Public Policy, Vol. 23, 279-286.

Luukkonen, (Terttu) (2002). *Technology and Market Orientation in Company Participation in the EU Framework Programme.* Research Policy Vol. 31, No 3, 437-455.

Nokkala, T.; Heller-Schuh, B.; Paier, M. and Wagner-Luptacik, P. (2008). *Internal integration and Collaboration in European R&D Projects*. Paper presented at the First ICC Conference on Network Modelling and Economic Systems. ISEG, Lisbon, Portugal, October 9-11 2008.

Nokkala, T. (2009). *Internal collaboration rules in international R&D collaboration projects - Analysis of seven NEST projects*. NEMO Working Paper #15

Nonaka, Ikujiro (1994). *A Dynamic Theory of organizational Knowledge Creation.* Organization Science, Vol. 5, No1.

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.

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

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.; 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.

Roediger-Schluga, Thomas & Barber, Michael, J. (2006). *The structure of R&D collaboration networks in the European Framework Programmes: Data processing, network construction and selected results.* UNU-MERIT Working Paper Series. #2007-032.

Ring, Peter Smith & van de Ven, Andrew H. (1994). *Developmental Processes of Cooperative Interorganizational Relationships.* The Academy of Management Review, Vol. 19, No. 1.

Scholz, R., Pyka, A., Ahrweiler, P. and Gilbert, N. (2009). *Simulating Knowledge Dynamics in EU-founded Innovation Networks (SKEIN)*, http://www.wiwi.uni-bremen.de/traub/index-Dateien/institut.htm