Working apart together: using ICTs in research collaboration
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2. Research collaboration

As stated in the introduction, changes in the context of scientific collaboration necessitate its study anew with a focus on the new elements: new technologies of collaboration, new types of social organization of research, increasingly interdisciplinary focus (Hackett, 2005a). How do these new elements interact? How can we understand research collaboration in the current context? Exemplary of all the changes in research collaborations (episodic character of research groups, interdisciplinarity, international collaborations, contractual agreements between organizations) are the Framework Programme (FP) collaborations funded by the European Commission. As mentioned in the introduction, funding for FP collaborations has increased in each consecutive programme, and they are also “an essential element in the national research policy of the member states” (Gusmão, 2001: 391). Finally, FP collaborations are becoming more and more important for the training and socialisation of young European researchers (Luukkonen, 2001). These are the reasons that the dissertation focuses on these specific types of collaborations.

Research collaboration has been studied within many disciplines and with many different methods (for extensive reviews Katz and Martin, 1997; Sonnenwald, 2007), but the focus of the current study is the working processes in research collaboration, which relates to the social organisation of research. The aim of the current chapter is first to provide the conceptual tools for thinking about collaboration. Why are working processes in collaboration important? How do communication and collaboration relate? This is elaborated in the first section, which ends with two typologies of collaborations in terms of the working processes. The second section deduces the working practices of research collaboration, and discusses empirical results from previous studies. The aim of that section is to understand how the working processes relate to each other, and what factors may influence them. It ends with a tentative model of the dynamics of research collaborations, on the basis of previous empirical studies. However, few studies so far have addressed the specificities of research collaborations within Framework Programmes. These specificities and relevant literature are presented in the following section of this chapter (section c). Finally, in section D I introduce the concept of a research team as a complex dynamic system, and discuss how that can guide the empirical work.
A. Research Collaboration

As noted in the introduction, there has been an increasing interest in the notion of collaboration, not only within various scientific fields but also in science policy circles (Beaver, 2001; Katz and Martin, 1997). In some ways it is now regarded as a value in itself (Duque et al., 2005). Even though there are many studies about collaboration in science and research, most of them examine different levels of analysis. In an attempt to categorise them, collaboration in science can be distinguished at three levels, following Rip (1990): collaboration at the researching level, involving cooperation in the search practices and everyday work of researchers at a specific location; collaboration at the scientizing level, entailing interactions through journals and conferences and involving co-authorship of publications, or use of knowledge claims of other scientists in the field, through citations; at the politicking level, collaboration may entail teaming up of scientists with policy-makers, or collaboration between universities and NGOs. As Laudel (2002) notes “While all scientific research is collaborative in certain respects because it makes use of the work of other scientists, collective knowledge production based on formal communication [scientizing level] differs from immediate collaboration in its social dynamics, especially in the way actions are coordinated”. The current dissertation focuses on research collaboration, that is, the first level discussed above.

At the researching level, collaboration entails working together in formulation of the research design, data gathering, data analysis, production of results, and/or writing up of reports, and can be understood as “solving problems together”. At this level, teamwork is necessary, either because no one scientist can possess the skills and knowledge to advance his or her work, or because groups are more capable of solving problems faster and more efficiently than individuals (Hagstrom, 1964). Partners in the collaboration may be a junior and a senior researcher, two or more peer researchers, or individuals with different skills, such as a researcher and a technician (Meadows, 1974: 195; see also Mullins, 1972). At this level, collaboration has three important functions, corresponding roughly to these three types of collaboration: the first is as a socialization mechanism, which relates more to the collaboration between a senior and a junior researcher. This apprenticeship relationship can be understood as “a rite of passage” for young researchers (Hara et al., 2003), through which a younger researcher learns how to conduct research, what the role entails, and how to commit to the research group (Crane, 1972: 35).

The second function of collaboration relates to its role as a quality-control mechanism. Beaver (2004) notes that ‘the chief epistemological advantage of collaboration is that it confers the benefits of ‘intersubjective verifiability’, which is the ability to establish that something holds true (or not) by different people (p. 401). In this sense, it is more difficult for two or more people to agree that something holds true, than it is for one individual researcher. Thus, collaboration is seen as a review mechanism: ‘Collaborative research in fact introduces the context of justification into the context of discovery at an early stage; it tends to merge the two contexts.’ (ibid. p. 402). As Rigby and Edler (2005) note “collaboration at the level of the research network acts upon research quality qua
peer review and ... this peer review effect is inherent throughout the research process” (p. 784) [italics in the original].

The third function of collaboration is to bridge different expertise and skills together. With the growing specialisation in science (Katz and Martin, 1997), and the progressive professionalisation (Cronin, 1995), it is becoming increasingly difficult for a researcher to possess the necessary skills and knowledge to solve problems alone. This is even more so, when the researching practice requires the use of instrumentation, tools and equipment. In this respect, collaboration in some fields (e.g. high energy physics) is inevitable.

But does collaboration in research differ from collaboration in any other line of work? The functions of apprenticeship and socialisation, quality-control mechanism, and bridging of different skills can also be seen in collaboration for software development, or the building of a house. Indeed, sciences can be seen as a distinctive type of work organization, with a focus on continuous novelty and at the same time a strong collective coordination of outcomes (Whitley, 2000). Both the elements of novel outcomes, as well as their collective coordination, make research collaboration (with the three aforementioned functions) inevitable and highly desirable. First, its quality-control function is vital in a work system which is based solely on the utility of one’s results for other colleagues’ research. Second, the combination of different skills and knowledge is a precondition of the production of continuously novel outcomes. Finally, the socialization mechanism is highly desirable in a system characterized by the continuous revision of procedures and methods (ibid., p. 33). In this sense collaboration is of special importance for science.

However, there are different ways in which research is organized in different fields of science, and therefore we would expect collaboration to have a different role and different dynamics as well. Whitley (2000) explains how scientific fields, as reputational systems of organizing and controlling research, are similar to other types of work organization. His main thesis is that there is a symbiotic relationship between the intellectual and social organisation of different sciences, and he provides an analytic framework against which we can understand the variations in the social organisation of different sciences. He claims that there are two distinctive variables on the basis of which we can distinguish the work organisation of scientific fields: their degree of mutual dependence and their degree of task uncertainty. ‘Mutual dependence’ refers to the degree to which scientists in a field depend on their colleagues for reputation and access to resources, as well as on their results, ideas and procedures as contributions to collective intellectual goals. When mutual dependence in a field is high, there tends to be a high degree of collective identity, competition between researchers is also higher, the

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2 In this respect, Beaver (2001) distinguishes between teamwork (pattern of collaboration in Big Science with many laboratories working together) and collaboration, which is distinctive of small science, suggesting that teamwork has spread from fields such as HEP and biomedicine to ever more fields.
degree of local and individual autonomy from collective goals and standards is low, and the communication system in the field is formalised.

‘Task uncertainty’ refers to the degree of uncertainty in terms of work techniques, intellectual priorities, and research topics in different scientific fields, and it results from the innovative character that scientific outcomes need to have. When task uncertainty in a field is high, research strategies and procedures are less standardised, and the results are less easily compared and coordinated. In those fields, centralised control over research strategies and performance standards is less feasible, and the overall coordination and integration of research is reduced (pp. 130-131).

Moreover, Whitley notes how mutual dependence and task uncertainty are influenced not only by the context within which each field operates, but also by the subject matter in each field, that is, the intellectual focus. For instance, in social sciences, because the subject matter has an affinity with audiences such as policy makers, journalists and NGOs, there is a wider potential audience, and hence the mutual dependence is lower than, let’s say high-energy-physics, whose subject matter would be incomprehensible and further from the everyday experiences of these audiences. Thus contextual factors and the cognitive focus condition the ways in which research is organized in each field.

We can understand how these differences between fields result in different ways of conducting research and thus organizing research collaboration. In a field of high mutual dependence, researchers would be much more inclined to collaborate, having a low degree of autonomy, and at the same time competitive tendencies would be an element of research collaboration. In a field of high task uncertainty, coordination of research collaboration would be more problematic, the combination of different results less easy and control over the collaborative process less feasible. Coordination and task allocation, competition and potential conflicts, integration of output, degree of autonomy in research decisions seem to be integral parts of solving problems together at the researching level.

Summarising the argument so far, research collaboration can be defined as “solving problems together” at the level of search practices and everyday work, and it has a vital role in science through its functions as a socialization mechanism, a quality control mechanism and through bridging different skills and knowledge. These functions are especially important in the distinctive type of work organizations that sciences are. At the same time, the organisation of research collaboration is different in different fields, and these differences relate to contextual factors, and to the cognitive focus of the fields.

But how do scientists collaborate in their everyday work? What do researchers do when they conduct research together? The most important element is indeed that they solve research problems together. The everyday research activity can be distinguished in different stages: formulation of research problem and strategy, gathering and analyzing data, interpreting results, writing up reports. At every stage, collaboration may consist of common problem solving: exchange of draft versions of the survey to be administered, analyzing data together, and brainstorming about the interpretation of results. More important is the end result, the production of research output, in the form of a journal
publication or conference announcement, or any other sort of formal communication. Even though a collaborative endeavour may aim at the development of equipment, or the establishment of a database, the formal communication of the output is the most crucial element for researchers who depend on this process for their reputation and, subsequently, material rewards.

Because of the different stages of the research activity, cooperation between two individuals usually entails an allocation of roles, tasks and routines: who is going to do what, and what is expected from each person. As discussed above, according to Whitley (2000) coordination and task allocation are important ways of organizing research work, and are different in different fields. Shinn (1982) also discusses how tasks are allocated in different fields as “cognitive patterning”. He distinguishes between different operations of research (conceptual/ theory formulation, data and information collation, experimentation or observation) and examines how these tasks are performed by individuals with different roles (research director, senior scientists, younger scientists, technicians) in different fields. In some fields, the cognitive patterning features a specialization, with each type of employee performing one, predetermined, type of operation, whereas in other fields almost everyone participates in these operations, without much specialization.

In other words, task allocation may entail a division of labour, where each partner has distinct and specialised activities, e.g. one gathering the data, another analysing them, another writing the reports. In this case, the work is divided in discrete units and each partner is responsible for one unit. This would lead to what Hara et al. (2003) call complementary collaboration, where each partner is responsible for their own stage in the research and it is not necessary to work close together with each other. In these types of collaboration, there is a need for awareness among the partners of their complementary skills and expertise, and conflicts over responsibilities and contributions are less likely to arise. On the other hand, task allocation can be non-specialised, with all partners involved in all stages of the research project: data gathering, data analysis, writing reports etc. This would lead to what Hara et al. (2003) call an integrative collaboration, with a need to work close to one another to develop shared ideas over the project and challenge each others’ assumptions, and thus a high degree of interdependence between the partners.

Hara et al. (2003) also note how this feature, namely the specialisation or not of task allocation, conditions the dynamics of research collaboration, and leads to essentially different types of collaborations: a continuum of collaborations ranging between the integrative and complementary forms. On the basis of these two forms, they suggest that there are four factors impacting collaboration in research: compatibility, work connections, incentives and socio-technical infrastructure. In complementary collaborations, it is important for the team members to have a compatible work and writing style, whereas in more integrative collaborations it is important for the partners to have a compatible approach to science, and often compatible personalities for trust to emerge. The more integrative a project, the more the compatibility of management styles becomes essential. Moreover, in complementary collaborations external motivations (prestige, funding, publications) influence research collaboration, whereas in more
integrative forms internal motivation, such as personal motivation of identifying an answer to a research question becomes more important.

Coordination of who does what during the research process and task allocation may be implicit or informal, such as during a brainstorming session, where the assumption is that each brings their own knowledge and skills, without any discussion of who should say what. In contrast, task allocation may be highly formalized, involving a contractual agreement between two partners (Wagner et al., 2002; Chompalov et al., 2002).

Decision-making processes in research collaboration are another integral part of everyday dynamics, and the ways they are organized are also specific in different fields. Shinn (1982) notes that in some fields, there exist strict lines of authority, with the director of the laboratory taking decisions about not only the intellectual focus, but also about the communication of results and the external relations of the lab. In contrast, in other fields, laboratories are typically organized in a more participatory way, and decisions are based on the principle of negotiation and persuasion, with the involvement of many lab employees. Similarly, Shrum et al. (2007) note that the way decisions are taken in a research team (formal or informal; bottom-up or top-down; by one or by many) influences the dynamics of research collaboration. They study different collaborations in fields related to physics and note that in some fields, and notably particle physics, there is a tradition of participatory decision-making (see also Knorr-Cetina, 1999), which however is not the case in other fields. They argue that, with the exception of particle physics, they did not find any field-specific ways of decision-making processes, even though that could be related to the fact that they studied multi-institutional collaborations, which tended to include more than one fields.

The issue of authority, of who decides over what, may lead to conflicts and tensions in a collaborative endeavour. Indeed Shinn (1982) notes that in physics research labs, contesting the power of decisions is a common phenomenon (p. 247) and relations between collaborators are often tense, with conflicts occurring either in formal planned meetings, or in informal settings such as chanced encounters in the corridors (p. 248). In this sense, decision-making processes may result in conflicts and tensions over authority and control of the collaborative process.

Tensions in research collaboration may also arise from competitive relationships between the partners, which is a more prominent feature in some fields than in others, as noted by Whitley (2000). In their ethnographic study of a medical discovery, Atkinson et al. (1998) provided a detailed account of the collaborative efforts of scientists at various stages of their work. They emphasise the dialectic relationship between cooperation and competition in research collaboration, in the context of a ‘hard’ science, where scientists want to be the first to make a claim. They describe their case study as going through different phases: when the possibilities of research are perceived as open, there is relatively free flow of communication between the collaborating groups, and there is exchange of research material. But, there are critical points when a discovery is considered imminent, and it is then that ‘the collective enterprise fragments into competitive relations’ and the different composing teams race for publication in order to
gain esteem, career advancement and renewed funding of their work. ‘The paradox – which reflects the significance of priority in research results – is that the more researchers converge on a solution, the less they collaborate; conversely, they can collaborate more freely the more their research paths are seen to diverge’ (ibid. p 280).

Maybe this result is specific for medical fields, where there are a lot of resources at stake, and where the time difference in the announcement of the results plays such a big role. The standardization of the research problems and often methods in these fields, result in a competitive environment which is not easily found in, say, sociology, where addressing the same research question with different methods and from various viewpoints is accepted and even promoted (Whitley, 2000). Therefore tensions and conflicts in research collaboration may relate to the decision-making processes, or the competitive environment of some fields. They may even relate to disagreements about the course of work, the interpretation of results, and the output of the collaboration (Shrum et al. 2001).

Even though the degree of coordination and the decision-making processes, both of which are related to tensions and conflicts in the collaboration, are different in different fields, tensions are not necessarily restricted to some fields. Instead, they can be understood as a general tendency in collaboration, related also to affective relations, that is, closer interpersonal relations (Hinds and Bailey, 2003). The development of closer, interpersonal relations among collaborators can be generally understood as an inherent characteristic of all human interactions: in the working place, pleasantries are often exchanged; informal lunches or dinners take place in a relaxed environment; details about one’s personal life are exchanged. The development of personal relations would be more encouraged in a working environment in which team-wide socialising activities, such as common lunches, or celebrations are promoted. Indeed, socialising activities in research collaboration are quite important as they may improve job satisfaction, creating a pleasant working environment for the collaborators, and providing a positive attitude towards work (Mante-Meijer and Haddon, 2005) and potentially contributing to identification and identity formation in a research team (Rasters, 2004). In this respect, socialising, the promotion and development of a friendly atmosphere and activities at work, is an important characteristic of everyday research collaboration, even though an essentially informal element.

In summary, research collaboration usually entails a number of formal and informal working processes, which influence its dynamics: output production, task allocation and coordination, decision-making processes, tensions and conflicts and socialising. We can understand these working processes as ways in which researchers communicate (interact) with each other in their everyday work: output production involves the communication of research content and research results; coordination involves the communication and exchange of roles, and tasks; decision-making processes involves the exchange and communication of decisions; tensions and conflicts involve the exchange of negative comments and attributes; socialising involves the exchange of pleasantries, personal non-work-related information, or emotional support. But how are media configurations related to research collaboration? How can we study the influence of different media in collaboration at the researching level?
Media configurations can influence research collaboration, by influencing the different communication processes in collaboration. Following Thompson (1995), communication is a “distinctive kind of social activity which involves the production, transmission and reception of symbolic forms”; thus we can understand different communication processes relating to the different kinds of symbolic form communicated. In this way, we can view working processes of research collaboration as distinct communication processes which entail the exchange of different types of symbolic content (research-related symbolic content, tasks and responsibilities, decisions, negative attributes, emotional support and pleasantries).

According to the previous chapter, media configuration of a research group can be understood as the characteristics of media used, the content or functions of media, and the frequency of media use. The content or functions of media, however, also refer to the symbolic forms communicated through media (Thompson, 1995), and the practices for which media are used (Nardi and O’Day). And working processes of research collaboration are understood as communication processes of different symbolic content. The research questions then become:

- How do differences among media influence working practices in research collaboration?
- How does the frequency of media use influence working practices of research collaboration?
- How do working practices in research collaboration influence the frequency of media use?

If the differences among media influence these working practices, that would result in different dynamics of research collaboration. Indeed some of these working practices, namely decision-making processes and type of task allocation and coordination, are so important in structuring the dynamics of research collaboration, that they have been the basis for classification of research collaborations in different types. In a detailed study of research collaboration in three fields (mineral chemistry, solid state physics and computerized vector analysis), Shinn (1982) elaborates how the cognitive organisation of a field conditions the social organisation of inquiry. He focuses on what he calls “laboratory morphology” and the everyday working routines of collaboration in a lab.

The social organisation of inquiry is examined in terms of authority and hierarchy, communication patterns, and task allocation. Hierarchy levels are identified on the basis of decision-making processes about intellectual activity and overall coordination and who participates in them. Communication patterns are identified in terms of frequency of contact between the different hierarchical levels, who initiates the communication, how codified and formalised the means of communication are (oral vs. written). Finally, the task allocation is studied in terms of which hierarchical levels participate at which stage of the research: data gathering, data/ information collation, conceptualisation and theory.

Shinn argues that these three dimensions are interrelated: for instance in rigid hierarchical laboratories, communication tends to be vertical and formalised, with a strict division of
labour between the hierarchical levels. He then offers a typology of the laboratories in organisational terms (p. 252):

1. the mechanistic model: which refers to ‘organisations characterized by a single powerful sources of command, complex and petrified hierarchy, circumscribed communication flow and a stringent division and precodification of all work activity’;

2. the organic model: which refers to organisations with limited pluralistic leadership based on negotiation; moderately constraining hierarchy; the polarization of communications around several distinct centres; and a dichotomy of task allocation, where certain tasks are allocated and some others are undertaken;

3. the permeable model: which refers to organisations with a participatory decision-making apparatus; with absence of assertive authority; an uncomplicated and minimal hierarchy; multi-directional and plentiful communication channels; and non-differentiation of tasks.

Even though Shinn shows how the type of decision-making processes and task allocation and coordination are important for the characterisation of the type of collaboration, and how they relate to the cognitive dimensions of different fields, he nevertheless studies different types of collaboration to the ones that are the focus here. Collaboration in a laboratory usually involves people from the same field. However, FP project collaborations involve two levels of analysis: between different local groups, and between different individuals from diverse fields (see also next section). Nevertheless, the question remains whether these three types of collaboration can also describe the cases under study in this dissertation.

Another classification of research collaborations, closer to the level of analysis of this study, also uses coordination and task allocation, as well as decision-making processes as its basis. Chompalov et al. (2002) collected data on 53 multi-institutional collaborations in physics and related sciences on the following four dimensions of bureaucracy: formalization, hierarchy, leadership and division of labour. Formalization referred to the presence of written contract in the collaboration, the presence of an administrative leader, division of authority, the self-evaluation of the project and outside formal evaluation. Hierarchy referred to levels of authority in the collaboration, the system of rules and regulations, and the style of decision-making processes. Leadership referred to whether there was a designated scientific leader in the collaboration. Finally the division of labour referred to whether there was a differentiated task allocation between the collaborating partners.

They found four organizational types of collaborations (pp. 756-9):

1. the bureaucratic: this type has a well-defined hierarchy of authority; written rules, formalised responsibilities and a specialised division of labour; extensive external evaluation; officially appointed project managers and clear lines of scientific and administrative authorities;

2. the leaderless collaborations (semi-bureaucratic): these collaborations are also formally organised and highly differentiated in terms of division of labour.
However, they lack a single scientific leader, and administrators seek the input of researchers with regards to the collaboration affairs.

3. the non-specialized collaboration: this type has a medium level of formalisation and hierarchy, with a scientific leader and unspecialised division of labour;
4. the participatory collaborations: these collaborations have participatory and consensual decision-making processes; general lack of formal contracts, and fewer levels of authority; there exists a scientific leader and also specialised division of labour.

One of their interesting findings is that the three first forms spanned all disciplines under study, whereas only the last one was discipline-specific, and particle physics was overrepresented there\(^3\). In this sense, they argue that disciplinary traditions, infrastructures and idiosyncrasies may not play such a big role to the organisation and management of multi-organizational collaborations. Thus, this typology may prove useful to understand different types of multi-institutional collaborations in other disciplines as well. It may provide a basis for the characterisation of the cases under study here.

In the next step, Chompalov et al. (2002) examined the relationship between these organizational types and the process of knowledge production: the acquisition of instrumentation, the data collection and the communication of results. They suggest that all collaborations, except from the non-specialised ones, usually design and build their own instrumentation. They relate this to the need of the non-specialised ones to create uniform standardised data, and thus they use already available instrumentation (p. 760). Furthermore, more bureaucratically run collaborations (types 1 and 2) tended to collect data in an autonomous, less collective ways and not to share them as much as non-bureaucratic projects (types 3 and 4).

Finally, there was a difference in the internal and external communication patterns between all types of bureaucratic collaborations, and the participatory one. The participatory ones exhibited a highly variable internal communication, depending on the stages of work, and a collective management of external communication of results; features which were very low in all other forms of collaborations. Their concluding argument is that overall the patterns of organisation of research collaborations were associated with particular ways of knowledge production, and what seemed to matter the most was the link between the leadership structure and the degree of formalization on one hand, and the interdependence of knowledge production practices on the other. In a way, this resembles the results of Shinn, adding furthermore the degree of formalization as an important element in the organisation of collaborative work.

These two studies are relevant for the current dissertation insofar as they attempt to characterise research collaborations in terms of organisational structures. Indeed, they show that the working practices of research collaborations (especially decision-making processes and task allocation and coordination) are distinct, but also show patterns of

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\(^{3}\) Indeed this is also the way Knorr-Cetina (1999) described the field of particle physics.
similarity. These patterns in turn are related to the processes of knowledge production and the intellectual output of the collaboration. So, the ways in which researchers take decisions or allocate tasks or argue with each other relate to the ways they produce research output.

In conclusion, research collaboration has a vital function for knowledge production: as a socialization mechanism for young researchers, as a mechanism for quality control, as well as a mechanism of bridging different skills, knowledge and expertise. It entails a series of working processes (some formal and some informal), which can be understood as communication processes, ways in which researchers communicate with each other: output production, task allocation and coordination, decision-making processes, conflicts and tensions and socialising. These processes, even though they seem to be specific for different disciplines, relate to each other in patterned ways, and thus create different types of research collaboration. Moreover, they relate to the ways research output is produced. The introduction of new communication media may influence research collaboration, by influencing these communication processes (the ways researchers take decisions with each other, create and solve their disagreements, allocate their tasks etc). Thus, if differences among communication media influence these communication processes, we would expect new types of research collaborations to emerge, as a result of new communication media being used for collaboration. Furthermore, these working processes in research collaboration may influence the frequency of media use. Of course, this will be tested empirically further on.

Before this, however, there is another logical step to be made. In order to examine the influence of different communication media on these working practices, we need to be able to identify other factors which may influence these processes. In other words, which factors influence decision-making processes or task allocation in research collaboration? If these are not distinguished, the influence of communication media can, at best, only be speculated, among the influence of a number of other possible factors. Thus, the following section discusses the results of empirical studies and presents factors which are expected to influence the working processes of research collaboration.
B. Working practices of research collaboration

The previous discussion about research collaboration identified the following communication processes: decision-making processes, tensions and conflicts, socialising, task allocation, output production. These are reviewed briefly below, with two aims: first to show their interrelations and importance in collaborations; second, to identify the main factors influencing them.

1. Decision-making processes.

As discussed in the previous pages, decision-making processes are an integral part of the everyday work in research collaborations. The extent of participation in these processes, their formality, and their result of these processes are all important parameters in the organisation of work. Decisions may be taken by one person (administrative or scientific leader or manager), or by many in processes of negotiations. They can be formal, with rules and regulations recorded, or spontaneous and informal. They can be public, entailing all members of a collaboration, or private. They can initiate bottom-up or be imposed top-down. Moreover, their result may be followed by the team members or ignored. Finally, decision-making processes may be different for different topics (scientific or administrative; communication or substantial) or may be consistent across all topics.

There are a number of factors therefore that may impact on decision-making processes. First, the existence of leadership, as indicated by Chompalov et al. (2002) and the style of leadership (Chawla and Singh, 1998; Melin, 2000) have an impact on decisions. The style of leadership can be conciliatory, participatory, informal or formal, authoritative, or non-imposing. Generally, participatory decision-making processes are considered to enhance research performance, as the amount of output produced (Chawla and Singh, 1998), but this is only one type among many for decision-making processes. Second, the levels of authority are also important. There may be one or different levels of authority in the collaboration, depending on the topic of the decision, each with its own style of leadership. For instance, Shrum et al. (2001) discuss how in some collaborative endeavours there are two levels of authority: a managerial and a scientific coordinator, or director. Decision-making processes are also related to the status of the participants in the collaboration. It could be the case that the collaboration consists of equal status researchers, without therefore clear or distinct levels of authority (Meadows, 1974: 195). It could also be the case, though that the members have different status e.g. professors, PhD students, junior and senior researchers.

Finally, the level of formalization, that is, the existence and degree of formal rules and regulations may also influence the ways in which decision-making processes are taken (Chompalov et al. 2002). In an informal collaboration between two peer researchers, some decisions (e.g. relating to data gathering) may be taken by either one, with just informing the other, whereas other decisions (e.g. where to publish a co-authored paper)
may include a discussion and negotiation between them. On the other hand, in a multi-institutional collaboration there may be regulations pertaining decision-making processes and that would mean that all decisions are taken in a specific way (e.g. through majority of votes).

In summary, previous empirical studies suggest that decision-making processes may be influenced by the following factors: the existence and style of leadership, the levels of authority in the collaboration, the status and discipline of the participants, and the degree of formalization of rules.

2. Tensions/Conflicts

Tensions and conflicts are quite common in research collaboration, especially in some fields, and could be related to the degree of competitiveness in the field (Shinn, 1982). Indeed Atkinson et al. (1998) - discussed in the previous section - suggest that in biomedicine competitive tendencies in research collaboration are related to the stage of the research. When the breakthrough of the results seems close, researchers tend to be more competitive with each other than when new research is initiated.

Apart from the stage of the work, there are more factors that could be influencing the existence of conflicts and tensions in collaboration. Shrum et al. (2001) analysing collaborations in physics and related sciences point to three different types of conflicts: 1) conflicts between members, 2) conflicts between groups 3) conflicts between researchers and project management; 4) conflicts between scientists and engineers. Conflicts between members, they claim, do not necessarily affect the collaboration as a whole and when they happen, they often result in mediation by other members, and possibly a redefinition of tasks so that the interaction between the disputants can be minimised. However, the other three types of conflicts can threaten the collaboration. Conflicts between groups tend to be due to resources, communication and credit and control over the project, while the size of the collaboration influences the between-teams conflicts (collaborations with fewer organizations are more prone to them).

Moreover, their study suggests that conflicts with project management are discipline-specific, and they are influenced by the existence of scientific leaders (more conflicts if there are leaders), by external evaluation (more conflicts when there is external evaluation) and by the decision-making process (more in hierarchical collaborations, less in mixed, even less in consensual collaborations) (ibid. p. 692-8). Here we see again the interdependence between the working processes also noted before, with decision-making processes being related to tensions and conflicts in a team. In general, the tension between professional autonomy (scientists) and managerial control (managers) in collaboration is considered one of the most common problems in research (see also Cohen et al. 1999). Finally, conflicts between scientists and engineers tend to occur when there is little autonomy in use of instruments and shared data analysis, so when there is greater interdependence (Shrum et al., 2001: 699). That means that different types of conflicts in research collaboration tend to have different factors influencing them.
Hackett (2005b) also focuses on the tensions in research, and more specifically research groups, and notes that they are inherent in science. He identifies five sources of tension: 1) the tension between control of decisions vs. autonomy and democratic participation; 2) the tension between conducting innovative research (which could be risky) or conducting traditional research topics (which could result in mundane results); 3) the tension between the different roles of each participant (as the same individual may be the director of a research group, and a PhD supervisor at the same time); 4) the tension of openness and sharing of information and results vs. secrecy and protection 5) the tension between craftwork and articulation work (daily research obligations vs. reading, reflecting and writing). Some of these tensions are at the level of the individual researcher (2, 3, and 5) whereas the tension between control vs. democratic participation and the tension between openness vs. secrecy can be experienced at the level of the collaboration as well.

In summary there are several factors that may influence the occurrence of conflicts in research collaboration: the stage of the research, the size of the collaboration, the existence of leaders, the existence of external evaluation, the type of decision-making processes, the degree of interdependence between the partners. As possible sources of conflict the following are identified: communication of results and credit, resources, and control over the collaborative process.

3. Socialising and personal relations

As discussed in the previous section, socialising, the promotion and development of a friendly atmosphere and activities at work, is important in research collaboration, possibly influencing job satisfaction, and identity formation, even though studies on it are scarce. This could be related to the limited traceability of socialising: it tends to take place during informal lunches and dinners between collaborators; during personal visits or telephone calls; in short, outside the laboratory, which has been traditionally the locality for studying research collaboration. “Yet when people work together they also learn from each other, socialize, provide social and emotional support, and sometimes play together, exchanges that each enhance the ability to get work done” (Haythornthwaite, 2001).

Therefore, the importance of social relationships between researchers should not be underestimated. Lievrouw et al. (1987) used a number of different methods to compare the social network, the cognitive structure, and the grant structure in a scientific specialty, and concluded that, even though there is a distinction between the communication structure, or social network among scientists and the intellectual network, they are symbiotic, and “to neglect examining one in favour of the other in the search for a comprehensive description of social networks in science tells only half the story” (ibid. p 246). Thus socialising may be distinct from the knowledge production activities in a team, but it is important to understand the social dynamics in collaboration (see also Schulze, 1990).
Even though there is lack of empirical studies on socialising in research collaboration and what could influence it, it is reasonable to expect that affinity between the collaborators may increase socialising activity. This could be either affinity in terms of prior existing relations, or prior working experiences, or affinity in terms of nationality. When two members have worked together before, or knew each other before in a personal or working-related environment, we would expect that they tend to socialise more with each other, than members who did not know each other before, and are the newcomers in a collaborative endeavour. Similarly, we would also expect members from the same country to ‘clique’ together more than people from different countries. We would expect, thus, nationality to play a role in social relations, especially in international collaboration, because this becomes what the members have in common. Indeed Bozeman and Corley (2004) studying personal motivations for collaboration, suggest that there are researchers who choose their collaborators on the basis of whether they have the same nationality and speak the same language. Other researchers choose their collaborators on the basis of whether they know them personally, they have worked previously together, and to what extent the previous collaboration was fun (ibid. p. 609).

What should also be noted in terms of socialising, as the development of personal relations in collaboration, is that it might create tensions and conflicts in a team. Indeed, Hinds and Bailey (2003) reviewing a vast number of studies on conflicts suggest that affective conflict, that is, disagreements “characterized by anger or hostility among group members”, is more likely when team members are friends (p. 616-618), as different expectations of behaviour and interaction arise. Furthermore, we may also expect that in disagreements between members, socializing activity may play a role in resolving the tension and helping calm things down. Therefore, we would expect socializing activities to be related to disagreements and tensions in research collaboration, both as a potential source of tension, as well as a conflict resolution mechanism.

In short, even though there few empirical studies on the factors which may influence socialising activities in research collaboration, we may expect that affinity between the collaborators, as some sort of common ground (e.g. prior relations and working experience, same nationality) may play a role. Further, the development of personal relations may influence conflicts and conflict-resolution mechanisms.

4. Task allocation

The type of task allocation or distribution of work is generally considered to be an important element of research collaboration (see also Wagner et al. 2002; Melin 2000), and as Shinn (1982) and Whitley (2000) argue it varies between different fields.

Among the factors influencing task allocation and coordination is the type of work, or intended output. Indeed Shinn (1982) discusses how different elements of the intended output, such as the role of theory, the place of scientific equipment in the work, and the type of data collection influence the way tasks are allocated between partners in a
laboratory (ibid. 255-257). This is one of the reasons that task allocation and coordination are structured in a different way in different disciplines.

Moreover, the *distribution of expertise and skills* between partners may influence task allocation as well. Hara et al. (2003) distinguish between complementary collaboration, which refers to collaboration where the participants have different and complementary skills and knowledge, in which case tasks are allocated according to these different skills and collaboration is thus more specialized (ibid. p. 959). In contrast, integrative collaboration consists of collaborators with similar knowledge and expertise, where all partners are involved in all stages of the research. Hara et al. (ibid.) also discuss *status* differences between the collaborators as an element which may influence task allocation. They suggest that different types of coordination are necessary when the collaboration involves a young researcher (PhD or postdoctoral) and the supervisor, on one hand, and collaboration between two scientists through a common PhD student, on the other (ibid. p. 958). Finally, task allocation may be different at different *stages* of the work: it could be the case that whereas only one partner would be involved in data collection activities, data analysis and writing reports would be more integrative process, or the other way around, as noted by Shinn (1982) for different fields. So, each stage of the collaborative work may also entail different types of task allocation between the partners.

As noted above, task allocation may influence tensions and conflicts: the higher interdependence between the partners, the higher the likelihood that tensions and disagreements over control and responsibilities may emerge (Shrum et al., 2001).

5. Output production

Output production in this study refers first to the ways in which participants in a collaborative endeavour produce research output: does it ‘emerge’, or is it a pre-determined decision? Second, it refers to the type of intended output of the collaboration. The intended output may for example be a large database, a digitization of a single text, or three published articles. Finally, it also refers to the quantity of the output produced by the collaboration. There are collaborations which aim at the development of a scientific instrument, or the co-authorship of a paper; on the other hand there are collaborations aimed to produce many papers. We would expect the dynamics of collaboration to be different in the former and the latter cases.

The quantity of research output is by far the most studied aspect of collaborations, for obvious reasons. The number of collaborative output, sometimes referred to as research performance, is reported to be dependent upon a number of individual traits: *personal motivation, creative ability, skills and expertise, career stage* among others (see also Lee and Bozeman, 2005). At the same time, there are a number of contingency variables, that may influence it, such as *resources* (material, human and information), and *team size* (Carayol and Matt, 2004; Martin Sempere et al. 2002).
However, of special interest to the current thesis are the elements of the social organisation (working processes) that may influence the collaborative output. At the team level, research has shown that the following elements are related to the amount of output produced: frequency of communication (Pelz, 1956), leadership style and degree of control (Pelz, 1956; Omta and de Leeuw, 1997), good climate of the research group, formal and informal reward system.

With regards to the frequency of communication and contact, even though some research indicates a positive relationship between communication processes and research performance (Saxberg and Newell, 1983), Pelz (1956) reported slightly different results. He studied a large medical-research organisation and found that the similarity of participants (in terms of scientific and institutional orientation) acted as an intervening variable: the more frequently researchers communicated with colleagues with similar orientation, the lower their performance. The more frequently they communicated with dissimilar colleagues, the higher their performance was. Thus, we may expect that in a relatively homogeneous collaboration, frequent communication would be associated with lower performance, whereas in a relatively heterogeneous environment, frequent communication would be associated with higher performance.

The influence of the variety of the participants in collaboration on its performance was also emphasised by Guimera et al. (2005). Using a network approach they studied creative teams (artistic teams and scientific fields) and established that the way a team is formed, influences the structure of the team, as well as its performance. Of special interest here is the distinction they made between ‘newcomers’ and ‘incumbents’, that is, newcomers in a team, versus people who collaborated and knew each other before. This distinction, they show, plays a role in the diversity of the team and its ability to come up with innovative solutions from diverse perspectives.

With regards to the informal reward system, research indicates that immaterial rewards such as e.g. honourable mentions, public recognition, non-financial prizes have a positive impact on productivity since they can motivate researchers to perform better (Chawla and Singh, 1998). With regards to leadership style and degree of control, Pelz (1956) found that researchers in tightly coordinated and controlled situations did not perform well, and this could be related to the high degree of autonomy of work as an intrinsic characteristic of (especially academic) researchers (Hagstrom, 1964).

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4 This is an issue with a long history in the sociology of science. The main question related to whether forms of recognition (immaterial rewards) are positively correlated to productivity (amount of output produced) or quality of publications (measured by citations). Relevant studies include Cole and Cole (1967) and Gaston (1970). Blume and Sinclair (1973) studying chemists in British universities found a positive relationship between both quantity of research on the one hand and quality of research on the other with recognition received (what is here termed as immaterial rewards). They recognize, however, that this relationship may depend on the structure of the discipline.
It is interesting to note that good management, understood as including participatory decision-making, frequent communication and limited tensions and conflicts was reported by Chawla and Singh (1998) to alleviate the negative results that the lack of resources have on performance of research units. They note that, resources and facilities are “a necessary but not sufficient condition of performance”, and that good management and social organisation of research can counter-balance a shortage of resources.

The study of Bergen (1983) suggests a more elaborate relationship between research performance and what he calls scientific activities (task allocation, decision-making processes, conflict resolution mechanisms and leadership style among others). His results from 85 academic research projects showed that each type of output (book, patents, articles, technical reports) is differently influenced by scientific activity variables: for example good leader-member relations facilitate book production but inhibits patent activity, whereas participation in the decision making process facilitates technical report production. This suggests that the type of output may act as an intervening variable between working processes in research collaboration.

In conclusion, research output production relates to a number of factors, among which the resources, the social organization, decision-making processes, conflicts and tensions, communication, control and leadership style all seem to be important.

From this brief review on the working processes of collaborative research we can identify the interrelations between the five processes under study, and pinpoint some factors that may affect them. The following model (figure 1) is deduced from the empirical studies described already.

The arrows in the model indicate an influence: of one working process on another e.g. task allocation is influencing conflicts and tasks (the more integration between collaboration activities, the higher the chances for conflicts and tensions, according to Shrum et al. 2001 as noted above). The arrows also indicate the factors influencing the working processes (e.g. the intended output, the distribution of expertise, the status differences between collaborators and the stage of the research influencing the ways tasks are allocated between collaborators). The question marks indicate that there is no empirical evidence of the influence. So, in the case of socialising, it is my expectation that prior (working or personal) relations and common nationality may positively influence socialising, but it is not based on any empirical study. Moreover, the frequency of communication and the style of leadership are related to output production, according to studies mentioned before, but the direction of the influence is unclear. It should also be noted that the model indicates an influence, but does not indicate whether there is a positive or negative relationship. This would have made the model far too complicated to read. The type of relationship in each case has been described in this section.
Central in the model are the five working processes under study, and their interdependencies. For instance, the style of decision-making processes is reported to influence output production (Bergen, 1983; Chawla and Singh 1998), and can also cause conflicts and tensions (Shrum et al. 2001). The model results from the presentation of the empirical studies so far, but we should keep in mind two things: first, that the types of collaborations in these studies are quite different from the ones the current dissertation focuses on; second, that these empirical studies examine different disciplines and fields, which is fundamental in the ways in which research collaboration is structured (Whitley, 2000; Shinn, 1982). Let me elaborate these two points.
First, the studies discussed so far did not examine FP collaborations in particular. Some examined collaboration patterns in a laboratory (e.g. Shinn, 1982); others examined multi-institutional collaboration between dispersed laboratories (e.g. Chompalov et al. 2002); others collaboration in the context of a research institute, or university (e.g. Chawla and Singh, 1998; Pelz, 1956); and others collaboration within the context of a specific scientific field (Whitley, 2000). Thus, they study research collaboration at different levels, than the current dissertation intends to. Second, most of these studies focus on one discipline, whereas few others studied more than one disciplines in a comparative way. The current dissertation focuses on collaborations that are interdisciplinary. Further, it is noteworthy that most of the aforementioned studies focused on collaboration patterns in natural or medical sciences. Collaboration patterns in social sciences are rarely studied. Therefore, it remains to be investigated whether the results of the studies mentioned so far apply in these types of collaborations.

In short, this model can serve as a guideline for the empirical part, and it remains to be tested for the cases of FP project collaborations.

I now turn to discuss the specifics of FP5 research collaborations. Since both of the cases studied were EU-funded collaborations under FP5, there are a number of variables which they have in common. The following section examines them.
C. Working processes in FP5 collaborations

Both case studies reported here were collaborations involved with the completion of projects funded by the 5th Framework Programme of the European Commission, in the Information Society Technologies thematic programme. The distinctive character of research collaborations under FP is noted by Gusmão (2001), who studied collaborations within FP1 through FP4. He emphasized the wide geographic dispersion of the collaborations, and the different institutional background of the partners, and suggested that most of the collaborative links created by these projects are quite stable (ibid. p. 391). Another distinctive characteristic of these collaborations is their interdisciplinary or multidisciplinary character, as they usually link researchers from different fields (Bruce et al., 2004). Moreover, the temporary nature of the projects (around three years) may create a different organization than a collaborative endeavour without any time limit (Arranz and Fernández de Arroyabe, 2006). In what follows, I explain the rules that FP projects follow, in order to show what type of collaborative working processes can be expected.

The process of project funding under FP5 involves the following steps: the European Commission opens a call for projects on a pre-specified topic of interest (e.g. knowledge society, or e-government) and interested individuals (either on the basis of previous working relationships or advice; see also Guy et al., 2005) coordinate and decide to formulate a proposal for this call. The proposals are evaluated on a variety of criteria by scientific committees appointed by the Commission (Sharp, 1998). The proposals with the highest scores are selected for funding, depending on the resources available, and this selection sets off a negotiation process. During this process, the project partners meet the Commission representatives and discuss, and sometimes negotiate points of the proposal: e.g. the budget, the task allocation, the composition of the consortium, the focus of the project (Siune et al., 2005).

A way in which the Commission’s regulations influences the intended output of the project is in the form of non-technical, administrative output: part of the collaboration output needs to be related to users’ requirements, plans of dissemination and exploitation of the results, as well as evaluation (internal or most often external) of the project. Especially the integration of research with exploitation activities is a characteristic of FP5 (Bruce et al. 2004). Moreover, at this stage the consortium is also judged as to whether it

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5 It is indicative that in a survey of FP5 participants Guy et al. (2005) found 62% of participants having prior experience with FP collaborations.

6 Information for this section was obtained by a study of the administration documents of the teams as well as information available at cordis.europa.eu/fp5

7 This is established on a number of scientific, technological, economic, social criteria such as scientific quality, innovativeness, promotion of EU policies, user-relevance etc (Georghiou, 2001). For the different aims of FP see also Luukkonen (2001).
has a diversity of participants, in terms of participating countries, and disciplinary background of the members (Bruce et al. 2004; Gusmão, 2001).

The negotiation process then results in the revision of the proposal by the consortium, and the proposal is signed as a contract by the parties involved: the institutes where the interested individuals belong, and the European Commission. Here we also see that these collaborations operate in two contexts: the local context of the institute, which is formally responsible for the project (by signing the contract) and the context of the European Commission, which is funding the project. It also means that these collaborations are different to the studies reviewed so far: they operate at the level of distributed individuals, as well as at the level of distributed research institutes.

The contract of the consortium specifies not only the intellectual content of work, but also the social organisation, or management of the project. Frequency and means of communication between the collaborators, hierarchy levels in decision-making processes, leadership of scientific tasks, coordination activities are also laid down in the contract. One of the participating institutes acts as the coordinating institute, with the responsibility to oversee the scientific work, to distribute the funds, to manage overall the consortium, and to be the intermediary between the Commission and the consortium. In this sense, the Commission rules prescribe two roles: a managerial and a scientific coordinator who may or may not be the same person. Moreover, each separate work task (or work package) needs to be assigned a scientific leader.

The projects are assigned project officers, representatives of the European Commission, who oversee the functioning of the project, both from a scientific and a managerial aspect. Written scientific reports as well as managerial documents (e.g. progress reports, cost statements etc) are sent for approval to the project officers on predetermined deadlines. At specific points in time (usually once a year) there is a review meeting, between the project officers and the team members, where the progress of the work is reviewed. In these meetings, external evaluators hired by the Commission are also present to assess the scientific work. If a team is performing poorly, and the evaluation of the project is negative, the Commission may decide to stop funding the project.

In short, FP5 collaborations are characterised by a rather high degree of formalisation, an existence of a scientific and managerial leader, different levels of authority, with a scientific leader, as well as work-package leaders, internationalisation and interdisciplinarity, existence of external evaluation (usually two-fold, assigned by the project officers, and by the consortium itself), as well as non-scientific output. What does this imply for the working processes within the collaborations?

If the results from previous empirical studies on collaboration apply in the context of FP collaboration, we would expect decision-making processes to be formalised, and also complex, given the two levels of authority established (work-package leader and scientific leader). The existence of different national research cultures, which have different attitudes towards hierarchical levels, is also expected to make decision-making processes more complicated. Moreover, these collaborations would be prone to conflicts.
between research and management, given the existence of scientific leaders, and external evaluation processes, and conflicts between teams, given their relative small size. We may also expect tensions arising from different disciplinary backgrounds. Finally, the existence of external evaluation and the variety of disciplines in a consortium are expected to lead to high productivity.

But what type of communication patterns are expected in these collaborations? As indicated in most studies of social organisation, communication patterns constitute a distinct and important dimension of working practices, and relate to the process of output production (Pelz, 1956; Shinn, 1982). The geographical distribution of FP5 collaborations necessitates the use of a multitude of technical communication media, apart from face-to-face meetings. Their possible influence on the working practices of research collaboration is explored in the following chapter. But first, I turn to a set of concepts which can help us understand the research teams under study.
D. Research groups as complex systems

A fruitful way of conceptualising the research teams under study is to view them as complex, dynamic systems, whose dynamics are driven by interactions between their members and elements of their contexts (Arrow et al., 2000). This viewpoint suggests that a collaborative team exhibits dynamics that are more than the sum of its parts: the communications of the team and its decisions are expected to be distinct from the aggregation of local communications or the aggregation of decisions in each local group. In other words, group dynamics can be considered an emergent phenomenon that cannot be fully reduced to the properties (behaviour) of its local elements. Consequently, the way the team coordinates its activities is expected to be different from the sum of coordination activities in each local site. Following the discussion in the previous section, EU-funded research teams can be understood as complex systems, consisting of individual researchers in different countries, who interact with each other to organise the activities around their common tasks. At the same time, these teams are embedded in a wider environment, consisting for instance of the funding agency (Commission) with its rules and dynamics, but also the local environments, such as the individual universities or research centres with their own regulations and dynamics. The concept of a complex dynamic system indicates that the research team is more than just the collection of the individual members and their characteristics (discipline, experience, age etc), and at the same time distinct from its embedding context.

This conceptualisation of the research teams draws on the theory of complex adaptive systems (Arrow et al., 2000; Monge and Contractor, 2003; Miller and Page, 2007). The concept of complexity has attracted attention from different fields, something that has resulted in different definitions. Even though the scope of the theory is very wide, there are a number of ideas that can be fruitfully applied in the types of research teams under study here. I follow Arrow et al. (2000) who define system complexity as “the number and variety of identifiable regularities in the structure and behaviour of the group, given the description of that group at a fixed level of detail” (p. 38). In other words, complexity is low in a team whose behaviour is a collection of random events; but it is also low if the behaviour of the team is highly ordered and adheres to a single rule. The structure and behaviour of teams, therefore, includes both regularities and random elements. Also, teams with few types of members, few different tasks and rules, and few types of relations between the members are expected to be less complex than those with more of those elements. Further, research teams with high complexity have many kinds of regularities (e.g. in their communication dynamics, in the ways output is produced) generated by multiple rules, including contingencies and exceptions. In the empirical part I use these conceptualisations to suggest that the DELTA case exhibits lower complexity than ERICOM.

Research teams are dynamic systems in the sense that their structure and behaviour is expected to change over time, exhibiting temporal patterns of development. This suggests that studying research teams requires longitudinal designs, which can capture the beginning of its team, its development through time, and its end. Especially EU-funded
collaborative teams exist for a specific period of time (usually 2-3 years), and therefore have a natural end. The way the team coordinates its activities, takes decisions, and resolves conflicts is therefore expected to change in a dynamic system.

As suggested above, there are three levels of dynamics that shape the research team: the local, the global and the contextual dynamics. Local dynamics refer to the activities of the individual researchers, and local institutes. Local dynamics give rise to global (team-level) dynamics that are shaped by them. Global dynamics refer to team-level variables (e.g. team communications). Contextual dynamics refer to the impact of features in the contexts in which the team belongs to, which shape and constrain the local and global dynamics (Arrow et al., 2000; p. 40). For instance, a change in the Commission’s funding mechanism may influence the dynamics of the research teams under study.

Following the concept of a research team as a complex dynamic system requires that we allow for nonlinearity in the relationship between different elements of the system. Linearity suggests that two variables are linked in a proportional way: the more the research team communicates, the better it can coordinate its activities. In complex systems, there are nonlinear relationships between variables as well as nonlinear effects. This means that a small change in a local variable (e.g. a new member in the team) may trigger a positive feedback loop which ultimately results in a big change in a global variable (e.g. communication frequency). In the ARIMA modelling, in the analysis, this positive feedback loop can be seen in the positive influence of the disturbance in the following week. Further, there may be also negative feedback loops, as, for instance the more a team communicates, the less time the members spent working, which may result in a reminder to work, which may result in less communication. In this way, actions may be offset by other actions. In the ARIMA modelling, in the analysis, this negative feedback loop can be seen in the negative influence of the disturbance in the following week. In the empirical part I do not focus on non-linear relationship between dependent and independent variables. However, I do examine whether random shocks have nonlinear effects (with positive feedback loops).

Since many elements in a complex dynamic system mutually influence each other (in a negative or positive feedback loop) causality may be more difficult (if at all possible) to discern. Since we expect local dynamics and attributes to give rise to global dynamics, and we know that all local elements interact with each other in a dynamic way, the extent to which a local variable would be independent loses importance, up to an extent. Rather than trying to predict the exact values of particular variables, the focus is on discovering the rules of interaction among variables at the global level. For this reason, the relationship between dependent and independent variables at the global level was investigated in the analysis. Further, as suggested by Arrow et al. (2000), what is of interest is “the evolution over time of the group as a system, as evidenced in the trajectory over time of a given set of global variables for a given group as a system” (p. 46). The current dissertation also focuses on this trajectory over time, as well as uncovering the rules of interaction between the variables of interest.
A final note on causality relates to the traditional assumption that a cause precedes an effect in time. In complex systems we may expect anticipatory behaviour (Rosen, 1985): a “cause” causing a specific behaviour beforehand, such as e.g. a meeting in time $t$ leading to an increase in email communication before the meeting, to exchange the work in progress, request information about the meeting logistics etc.

In conclusion, this dissertation explores the viewpoint of complex systems. To what extent does the theory of complex systems help us understand the dynamics of research teams? What can we learn by conceptualising EU-funded research teams as complex systems? And what type of methodological tools can we use to explore them as complex systems? I explore these questions in the following chapters.