Inter-Organizational Collaboration in Multi-Actor Projects: the Interplay between Structure and Knowledge Creation

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Abstract

Over the last decades, research and innovation have become more open, more collaborative, and more project-organized. Inter-organizational multi-actor research and innovation projects have a broad knowledge base and high knowledge combination potential. But do different project structures stimulate knowledge generation in different ways? Using a comparative multiple case study of collaborative projects funded by the EU Research and Innovation Framework Programmes, the paper provides empirical evidence on how project structures favor knowledge creation over the project lifetime. Contradicting the management literature, we found that deep knowledge creation in inter-organizational projects does not depend on the size of the knowledge base or on the knowledge combination potential per se: the modular structure, despite its limited size of the knowledge base and reduced variety of combinations, may be the most efficient structure for deep knowledge creation, while the interconnected modular and network project structures particularly favor lateral and broad knowledge creation.

Key words: inter-organizational collaboration, structure, knowledge creation, multi-actor project, research and innovation

Introduction

Over the last decades, research and innovation have become more open, more collaborative (Chesbrough, 2005), and more project-organized. Collaboration increases the potential for knowledge creation, thanks to the variety of the knowledge base and the combination possibilities (Nahapiet and Ghoshal, 1998), but it also experiences complexity challenges (Swink, 2006). Inter-organizational projects cumulate challenges in an amplified way (vom Brocke and Lippe, 2015), but we know little about *how* inter-organizational collaboration with the goal of knowledge creation works within the project boundaries. Calamel et al. (2012, p.1) pointed out that "*a literature review highlights the need to open up the 'black box' of collaboration within projects*".

Collaboration and thus creation of knowledge are intrinsically linked to the project structure (Wood and Gray, 1991). Scholars found that the amount of structure affects the sharing of knowledge and collaboration (e.g. Davis et al., 2009) and that there is no optimum structure (Ahuja, 2000). However, it is not well known *how* to structure multi-actor projects to favour knowledge creation through inter-organizational collaboration.

Therefore we pose the research question "How do different types of project structures influence knowledge creation over the lifetime of multi-actor collaborative projects", and put in place an empirical multi-case study in the context of collaborative projects funded by the European Union's Research and Innovation Framework Programmes. Specific features of these projects are a *large number of partners, autonomy and equality* of partners (Bor, 2014), *bottom up self-organization* in response to competitive calls, *requirement for complementarity of partners, collective responsibilities, significant public funding, lack of structural project flexibility* (vom Brocke and Lippe, 2015), as well as *uncertainty* and *communication complexity* (Kapsali, 2011).

The research design is a comparative inductive multiple case study method (Eisenhardt, 1989). In the first part of the study, we selected 15 projects, studied their configuration using the project documentation, and identified three main types of project structures. In the second part, we narrowed the selection to 6 projects with different types of structure, organized 40 semi-structured interviews, coded them and analyzed the interplay between structure and knowledge creation.

Our research provides theoretical contributions to the management of collaborative projects, by shedding light on the impact of different project structures on knowledge creation through inter-organizational collaboration. Some of the findings are not in line with the management literature: we found that deep scientific/technical knowledge creation does not depend on the size of knowledge base and on the variety of collaboration opportunities. We also found that the modular structure in a multi-actor project may be the most efficient one to favor deep knowledge creation, despite its reduced variety of knowledge combinations and the limited size of the knowledge base. From the practical point of view, our research provides suggestions to the project managers on how to structure inter-organizational collaborative projects in order to foster knowledge creation.

Theoretical framework

Collaborative research and innovation projects

Collaborative research and innovation projects are specific settings in which actors, often both from academia and from industry, work together and contribute towards creating knowledge (vom Brocke and Lippe, 2015). This collaborative setting helps to enhance the innovation potential, thanks to the variety of the knowledge base and the possibilities for the combination of knowledge (Nahapiet and Ghoshal, 1998). Knowledge is created using the mechanisms of *exchange and combination* (Nahapiet and Ghoshal, 1998); the size and the structure of the knowledge base affects the organizational ability and the potential to create new knowledge (Ahuja, 2000, Yayavaram and Ahuja, 2008). However, the combinatory mechanisms are activated only when certain preconditions exist: for instance, the cognitive technological distance between partners shall not be too large (Nooteboom et al., 2007) and the knowledge base shall be irrigated by social relations, influencing the creation of social capital (Nahapiet and Ghoshal, 1998).

To achieve innovation outputs, quality and depth of collaboration within the project are required (e.g. Kotlarsky and Oshri, 2005). Collaboration does not come by itself and is difficult to manage (Swink, 2006), especially taking into account the coopetitive dimension in multi-actor R&D projects (Schiavone and Simoni, 2011). Universal collaboration antecedents include *mutual trust, commitment, good personal relationships* (Littler et al., 1995), *strong research and innovation capabilities, complementary competences and technologies* (Ahuja, 2000), and *collaboration capabilities* (Blomqvist and Levy, 2006). Scholars also concur that the *project structure* significantly affects the success of the collaboration (Dietrich et al, 2010, Calamel et al., 2012). However, the existing body of literature does not provide answers on *how* collaborative projects shall be structured to favor knowledge creation in the context of uncertainty, complexity and involvement of multiple autonomous actors. There is a call for research to measure the impact of specific influencing factors, such as team structuring, on collaboration for knowledge creation (Calamel et al., 2012), and a call for research to understand the underlying processes and explain the settings and processes of collaborative research and innovation projects (vom Brocke and Lippe, 2015).

Role of structure in multi-actor projects

Management scholars almost synonymously use the terms 'structure', 'design', or 'architecture' (Aubry and Lavoie-Tremblay, 2018) to define the division and the coordination of activities. The role and the effect of the structure have been extensively studied: it is known that it 'hosts' the knowledge base of the organizations, guides integration efforts (Ahuja, 2000) and influences knowledge creation (Schilling and Phelps, 2007). Specifically within the project context, scholars studied structures in product development projects or contractor-supplier projects (e.g. Baldwin and Clark, 2000), but these findings are not directly applicable to multi-actor collaborative research and innovation projects, where "*people (are) coming together to solve a problem, this is different from the relationship between a principal contractor and a number of subcontractors*', as reflected in a statement of a project manager quoted by Calamel et al. (2012).

A multi-actor project is a temporary organization (Lundin & Söderholm, 1995, Bakker et al., 2016) and an organization of organizations (Bor, 2014), thus a meta-organization. This brings two layers of additional dynamics to the organizational setting. High temporality of the projects requires structure in order to divide and coordinate the activities, stabilize patterns of social interaction, and achieve better collaboration (Raab et al., 2009). Too much structure impedes the performance of the organization (Davis et al., 2009), but too little structure may prevent the realization of the project according to the plan. The hierarchical way of coordination is not applicable to the multi-actor project setting because it includes multiple autonomous organizations (Bor, 2014): like in other meta-organizations, coordination in the projects is partly informal, collaborative, and empowers participants (Berkovitz and Dumez, 2016), knowing that the project boundaries are closed and partners are bounded by an agreement to collaborate. Although it is known that there is no optimal structure (Ahuja, 2000), projects shall be structured. There is a call for further research to investigate the project structures for the success of collaboration strategies in specific settings (Fernandez et al., 2018). In the meta-organizational stream of literature, scholars call for future research about the diversity of the structures of meta-organizations (Berkovitz and Dumez, 2016).

Modularity and connectedness for organizing projects

Structure is deeply rooted in the concepts of modularity (division) and connectedness (integration, coordination). Simon's (1969) seminal theory of complex system and near decomposability puts in evidence that complex systems with nearly decomposable structure adapt themselves to the demands of their environment more easily than non-decomposable systems; decomposition level depends on the necessity of interactions between components that is necessary to achieve results. However, too high modularity has additional downside effects: it does not take advantage of synergies between modules (Schilling, 2000) and limits the discovery of interconnections that span modules (Yayavaram and Ahuja, 2008).

Collaborative projects provide a high potential to achieve innovation outputs; the capacity to realize this potential depends, among other factors, on the combination of ties among participants (Tiwana, 2008). Michelfelder and Kratzer (2013) studied large a R&D inter-organizational network with 27 projects and found that the combination of strong and weak ties happening at an individual level may lead to superior innovation outputs under the condition that the right structure and processes are put in place (Michelfelder and Kratzer, 2013). This again points to the importance of "structure", but it is not clear how to set up the right structure: Michelfelder and Kratzer (2013) called for research to increase the knowledge about how strong and weak ties interact in the creation of innovation outputs.

The structure of multi-actor research and innovation projects which aim for knowledge creation thanks to inter-organizational collaboration experiences two paradoxes. First, the *division* paradox: large groups of partners require decomposition, or modularity, but too much modularity limits knowledge creation (Yayavaram and Ahuja, 2008). Second, the *connectedness* paradox: too many links are difficult to manage, but too few links limit knowledge creation (Nahapiet and Ghoshal, 1998). In addition, this happens in the paradoxical context of research and innovation projects: research requires freedom and it operates in an uncertain environment, which suggests a minimum structure (Lawrence and Lorsch, 1967), but research projects have high temporality and have to produce the promised results in a fixed timeframe, therefore they require a significant amount of structure (vom Brocke and Lippe, 2015, Raab et al., 2009).

To sum up, knowledge creation benefits from inter-organizational collaboration that mostly happens in the projects (Tiwana, 2008). Projects require structure, which defines the division of the activities among the partners by means of modularity and also defines the coordination and integration of activities through connectedness. Management scholars demonstrated the importance of structure for knowledge creation, however there is not enough understanding what are the most promising structures in a collaborative project setting, and paradoxical structure is even less studied in the setting of collaborative research and innovation projects with many partners.

The present study has been designed to address this research gap. We pose the research question "How do different types of project structures influence knowledge creation over the lifetime of multi-actor collaborative projects". Scholars concur that a dynamic layer of processes is required in addition to the structure (Lundin & Söderholm, 1995, Aubry and Lavoie-Tremblay, 2018); while we included the process element in our research, this paper focuses on the element of 'structure'.

Research setting and research design

The research setting is defined as multi-actor collaborative projects funded through competitive open calls by the European Commission through its Framework Programmes of Research and Innovation. The calls define the topic, the challenge and the scope of the project; the goal of the projects is pre-competitive R&D, the output is the creation of knowledge which results into innovation outputs, such as new materials, devices, algorithms, software, services. During the proposal preparation phase, the applicants agree on the way to organize their collaboration, and they must demonstrate in the proposal why the work requires a joint effort.

There are two main reasons that make this setting important for management research. First, multi-actor projects have become nowadays an important way of research funding, and their number is growing: the on-going Horizon 2020 Research and Innovation Framework Programme has already provided 21,8 billion Euros in 2014-2019 to fund over 6300 multi-actor projects (European Commission, 2019). Second, the number of partners in such projects is high, over 11 in average (European Commission, 2019), which amplifies the challenges for project management.

We have adopted an exploratory inductive multiple case study method (Eisenhardt, 1989). A case study protocol has been developed with two phases, including specifications about the quantity and variety of data collection (Avenier and Thomas, 2015). The objective of the first phase was to identify types of project structures. For this phase, we selected 15 projects, using three selection criteria: *homogeneity, variety and availability of data*. The projects lasted or last 3 to 4 years, have between 8 and 21 partners, budgets between 1 M€ and 6 M€ and are at different stages of advancement. We gave the names of celestial constellations to the projects for their anonymization, and studied characteristics and structure of the projects, using content analysis of over 2100 pages of project documentation. Based on the literature, we used three criteria to identify project structures: the *decomposition* of activities (how many modules are in the project, parallel or sequential), the *coordination* (connectiveness between partners), and the *finality* (project outputs).

The second part of the study had the objective to understand the relationships between project structure and knowledge creation. Following Eisenhardt (1989), we selected the projects that are *comparable* and applied three additional criteria to narrow down the knowledge base from 15 to 6 cases that represent *all types and sub-type of structures*, respect *antecedents* of collaborative research and innovation, and are at an advanced project stage or already *completed*. For this phase, we performed 40 semi-structured interviews which resulted into 40.3 hours of recording and over 700 pages of materials transcribed verbatim. The interviews involved 31 informants, mostly of senior level. Several informants could compare several projects, adding to this research a comparative multiple-case element that so far is underrepresented in the literature (Bakker et al., 2016). The interviews included questions related to the motivation of the partners, the project structure, the inter-organizational collaboration and its evolution, knowledge creation, innovation outputs, and leadership. The interviews were coded and analyzed (Strauss and Corbin, 1990). During the research process, general relations to the theory have been regularly done; the process was iterative. Additionally, we integrated participatory observations for some projects.

Summary of results

The empirical results of the first phase, based on the study of 15 projects, put in evidence three main types and several sub-types of project structures: *linear* (3 projects, including 2 projects of *converging* sub-type), *modular* (9 projects, including 2 projects of modular 1.0 sub-type, 2 projects of waterfall sub-type, and 5 projects of grid sub-type of structure) *and network* (3 projects). They are conceptually presented on Figure 1.

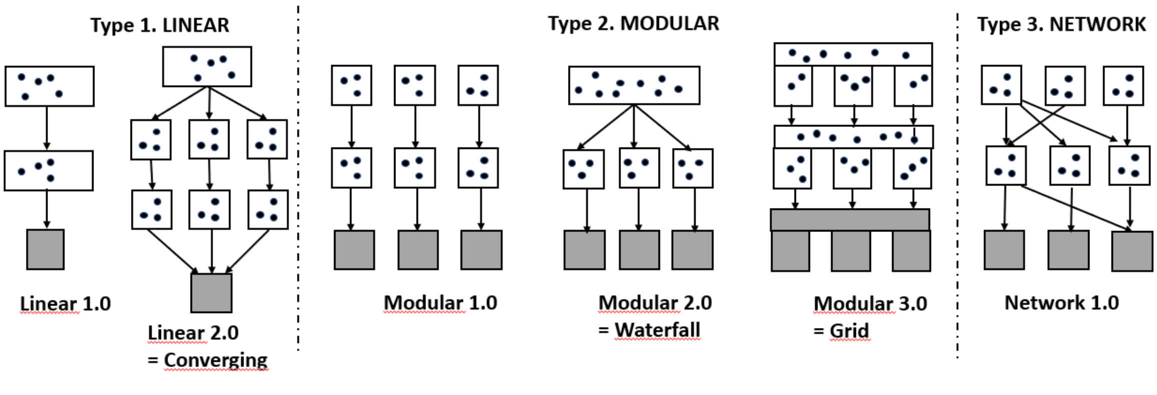

Fig. 1. Abstract representation of the types of project structures. The dots represent partners, the grey box(es) at the end of the process represent project output(s). Modules involve groups of partners working together.

We observed that the structure of the projects does not simply depend on the project characteristics (Annex 1), such as the number of partners or the maturity of the technology. One element that may logically lead to a linear structure, is the ‘platform development’ type of project. We also observed an overrepresentation of the modular structure in our sample.

During the second phase, we performed a deeper analysis of the inter-relationships between project structures and knowledge creation. The selected projects are highlighted by grey color in the Annex 1: GEMINI (linear 1.0), SCORPIUS (linear 2.0, converging), PERSEUS (modular 1.0), HERCULES (modular 2.0, waterfall), PEGASUS (modular 3.0, grid), ORION (network).

Linear structure: efficient but limited knowledge creation with focus on finality

Projects with linear structures (GEMINI and SCORPIUS) are structured in a way where outputs from one stage are a prerequisite for the work on the next stage. In the *converging* sub-type of structure, the main work is organized into several linear modules and the final project output integrates results from these modules. The knowledge base of the partners is relatively narrow. The linear structure is efficient in achieving a well-defined finality that requires input from different partners, thus it enforces collaboration. However, it is difficult to structure large groups of partners linearly during the whole project: as a result, partners often intervene for specific tasks, collaboration opportunities are limited, knowledge creation happens within small sets of partners working together either in the same modules or within interconnected modules. The interfaces between the modules create a challenge for project management, as the results of one stage must fit to the needs of the next stage. The linear structure does not allow much flexibility: problems at one stage will impede activities at the following phases, and if there is a defaulting partner in a module, the whole project output is in question. To reduce risks and to achieve planned knowledge creation, projects shall be very well prepared with detailed discussions during the proposal phase.

Partners in linearly structured projects work mostly separately, bringing their “bricks” to the process. However, to some extent also *deep scientific/technical knowledge* may be created by the interaction of partners, e.g. deepening knowledge in a partner’s main specialization topic: “*Our work, it’s not depending on the others. But the way we want to do it, it depends on the others. It would give different shape, lead to specific directions, we didn't step there before. When we discuss, we come up to some agreements on the way we should work, which technologies to use, which methods... We learn some directions to continue*” (*GEMINI_large*). The mechanism of deep knowledge creation in the context of multi-actor projects is regular joint work: it requires strong ties between partners, regular discussions, and it results in scientific and technical outcomes, towards at the main planned outcome. In some cases, linearly structured projects may provide opportunities of the broadening of the horizons: *lateral technical/scientific knowledge* is created, resulting in initial insight into other methods, which can lead to taking up ideas, improved own work or productive combinations. Linear projects may also allow limited b*road knowledge* creation: it comes from the whole project as the result of observation and happens during regular exchanges and socializing activities, thus it for the most part happens in physical meetings. It may result in better understanding about how firms work, what they consider confidential, and other broad knowledge, such as the identification of talents for future hiring or better understanding of cultural differences.

Modular structure: a mix of modules and connectedness for deep, lateral and broad knowledge creation

Projects with different sub-types of the *modular* structure (PERSEUS, HERCULES, and PEGASUS) are all composed of several linear modules with limited numbers of partners within each module. There are several finalities in the project, at least one per module. The knowledge base of the partners is broad and partially overlaps. Cognitive technological distance is small within the modules but not necessarily at the project level: modules can be very specialized, especially when aiming at solving pressing problems in industrial settings. In many cases, the collaborating partners within the modules had already worked together: this facilitates the alignment of interests and reduced the effort needed for creating a mutual understanding. However, sometimes partners also search for opportunities to work with new teams: "*I prefer to follow something like a 70/30 strategy, so taking 70% partners you have worked with already or whom you know reasonably well to be relatively sure, and you add 30% you want*" (*PEGASUS_coord*).

The sub-types of modular structure differ in terms of connectedness. The modular 1.0 sub-type has low connectedness and thus a low variety of potential knowledge combination between the modules: "*We did not have scientific partners who could exchange over the boundaries of the modules because the modules were very specialized" (PERSEUS_acad*). This limits the collaboration potential and hardly provides reconfiguration possibilities. The advanced versions of the modular structure (2.0 waterfall, 3.0 grid) increase the potential collaboration opportunities thanks to the weak or strong connections between modules. However, this is often mostly beneficial for limited groups of experienced partners. The *waterfall* sub-type has an integrative module at the beginning of the project where all or most partners contribute to create a common foundation or framework, and then the outcomes of this module are used in the "waterfall" of parallel modules. *"There was from the very beginning a common theme and a common idea that that we wanted to pursue. That helped a lot to draw the different ideas together. Some things have to brew for a while, and then all of a sudden the ideas are there and you can implement the ideas" (HERCULES_large).* The potential collaboration opportunities and the knowledge combination potential are high at the beginning of the project within the integrative module. The *grid* sub-type includes more horizontal "grid" elements which creates regular needs and opportunities for inter-organizational collaboration and knowledge combination between modules.

Similarly to linear projects, modular projects enable the creation of both deep and lateral technical knowledge. However, the modular structure 1.0 limits the potential for collaboration and knowledge creation between the modules. Modular projects also enable the creation of broad knowledge, which is broader than in linear projects thanks to the regular connectedness with many heterogeneous partners. In addition, modular structures provide opportunities of the broadening of the business horizons, and may lead to the creation of *lateral business knowledge*, which results into strategic knowledge from business point of view: understanding the priorities, bottlenecks, constraints of organizations of different type, and thus generation of knowledge on how and with whom to cooperate. In addition, *lateral meta-knowledge* in modular projects may be generated thanks to the applications of different approaches in different modules and understanding of their successes or failures. Collaboration in modular projects is likely to be successful and results in innovation outputs and thus creation of knowledge: "*It's a very convenient way to run projects because then each industrial partner, each end-user, each technology developer can do what they want and that's basically it." (PERSEUS_acad).*

Network structure: allowing partners to grasp a variety of collaboration opportunities for different types of knowledge creation … that however are not necessarily realized

The network structure (ORION project) appears when a large group of partners collaborate, often with some partners joining at the last stage of the proposal preparation with unclear collaboration links. This leads to the situation when it is almost impossible to clarify the roles for all partners in details in the proposal: as a result, some collaborative ties are left open. Several partners contribute to different modules, which lead to a stronger connectedness between these modules. Modularization happens inevitably in such network projects with many partners: "*In one project with so many people working, you know, they would never get synchronized. So almost automatically inevitably, you form* *subgroups …*" (*ORION_sme*). Also, it is difficult to avoid overlap of knowledge and coopetition between partners in the network project setting.

The network structure provides a large variety of collaboration opportunities; however, it does not mean that these opportunities will all be seized. At the beginning of the project, time and efforts are required to define missing collaboration links. As the capacities of partners are limited, including in terms of project budget and time, at a later stage of the project it is too late to exploit the opportunities that are offered by network structure: *Our collaboration is not specified in the proposal, and we very quickly decided that … it would be better to focus on one two or three and do something really good there rather than try to … you know spread too wide." (ORION_sme); "If you have to collaborate with a large number of partners in a project of three years, and the partners illustrate different type of problems, then it is impossible to do serious work*" (*ORION_acad*).

The network structure favors all types of knowledge creation described previously: deep knowledge in the modules, different types of lateral knowledge within and between the modules, and broad knowledge. The knowledge created is significantly richer than in linear projects but, in terms of amount, is comparable with the modular 2.0 (waterfall) and 3.0 (grid) projects. The network structure helps in creating a collaborating community with a complementary knowledge base, working toward the same goal. It combines the advantages of modular structure but adds complexity and a variety of combination opportunities. However the structure 'pushes' for collaboration only within the planned links, it depends on the partners how to benefit from other opportunities. The project processes can help in this direction.

Table 1 lists the types of project structures together with their main distinguishing features, and with the empirically found types of knowledge that was created in the studied projects. The *continuity* factor, both in terms of technical discussions and in terms of socializing activities, appears as being very important for all types of projects: "*At the meetings, I think, "how could we make use of this? Some of the work changed our views or we looked at least from a slightly different perspective. It's more effective than a conference because there is continuity*" (*ORION_sme).*

We observed that the modular and network structures may evolve over time: the processes within the project play an important role. Integrative activities, even spontaneous, may 'advance' the structure from one version to another (for instance, from modular 1.0 to 3.0), counteracting the initial deficiencies of the structure. On the contrary, the more there are integrative and inter-module activities present in the project, and the more difficult it is to keep the planned structure 'on track': network or modular grid projects may rapidly disassemble into modular 1.0 projects, which limits collaboration and thus knowledge creation. The interests of the partners and the degree of alignment of them play an important role too: especially, industrial use cases help in project structuring and facilitate the collaboration process.

Discussion and conclusion

Our research makes two contributions to the management literature. First, we identified the types of structures in multi-actor inter-organizational projects and provided insights into the interplay between the types of structure and knowledge creation (Nahapiet and Ghoshal, 1998, Yayavaram and Ahuja, 2008). Structures, except linear ones, do not depend on the project characteristics. All structures identified in the study allow deep, lateral and broad knowledge creation, the question is "how much": the linear structures provide considerably less opportunities for collaboration and less opportunities for knowledge creation than other types of structures. Modular and network structures favor the creation of lateral knowledge; advanced versions of the modular structure, as well as the network structure, favor meta-knowledge. Some structures offer a high variety of additional knowledge combination opportunities (Nahapiet and Ghoshal, 1998) that may be facilitated by the

Table 1. Types of project structures with their distinguished features and empirically found types of knowledge creations

Type of structure	Specificity	Size of knowledge base	Presence of strong collaborative ties	Difficulties in terms of potential combinations via strong links	Variety of potential knowledge combination	Types of jointly created knowledge				
						Deep	Lateral			Broad
							Technical	Business	Meta-	
Linear 1.0	Sequential workflow for one main project finality	Relatively narrow	Only in the modules and at the interfaces between connected modules	Easy within modules, difficult between modules	Low	+ Occasionally	+	+		+ Limited
Linear 2.0 (converging)	Converging modules for one main project finality	Same as above	Same as linear 1.0	Same as linear 1.0, but more difficult integration	Medium	+ Occasionally	+	+		+
Modular 1.0	Largely disconnected modules, each module has its finality	Broad, do not necessarily overlap	In the modules	Easy	Low	+ + +	+	+		+ +
Modular 2.0 (waterfall)	First module is integrative and has its own finality, each module has its finality	Medium to broad, with partial overlap	In the modules and in the first integrative phase	First integrative phase is more difficult but overall as in modular 1.0	Medium	+ + +	+ +	+ +	+	+ +
Modular 3.0 (grid)	At least one module is "horizontal" and interact with other modules regularly; each module has its finality	Medium to broad, with partial overlap	In the modules and in the intersections of the grid	Easy within modules, difficult at the intersections if partners come from different background	High	+ + +	+ +	+ +	+ +	+ + +
Network	Modules connected irregularly, open ties; each module has its finality	Can be broad, with partial overlap	In the modules and in - between connected modules	Difficult	High, and higher than in modular	+ + +	+ + +	+ +	+ +	+ + +

project processes, however, these opportunities are not necessarily seized and thus do not necessarily lead to knowledge creation. Therefore, having a large variety of potential collaborations and knowledge combination opportunities at the beginning of the project, like in waterfall project, has advantages: the recombination potential may more easily meet the conditions that are needed to realize this potential. Such integrative elements also help in creating common a base of understanding (Calamel, 2012) and a project identity which catalyzes informal exchanges and lateral and broad knowledge creation. Modular or network structures consist of parallel tracks, enabling the project consortium to invest in those which are promising and to abandon others, tacitly or explicitly: such collaborative settings enable a more dynamic project execution, favoring knowledge creation.

Our second contribution are findings about the role which the size of the project knowledge base (Ahuja, 2000, Yayavaram and Ahuja, 2008) and the variety of knowledge combination opportunities (Nahapiet and Ghoshal, 1998) play for deep knowledge creation in multi-actor research and innovation projects. In contrast to these scholars, we empirically found that the size of the knowledge base and the variety of knowledge combination opportunities do not necessarily favor deep knowledge creation in the multi-actor project setting. Despite a limited size of the knowledge base and a low variety of combination opportunities in the modules, the modular structure may be the most efficient for deep knowledge creation: it focuses the efforts from the beginning of the project and gives more resources to the partners to create deep knowledge. This is related to the three elements: first, lack of structural flexibility of the projects (vom Brocke and Lippe, 2015) and thus difficulty of recombination, second, limited processing capacities, and third, large cognitive technological distance (Nooteboom et al., 2007) which is difficult to avoid in a setting of multi-actor projects. These elements make the development of new collaborations during the project lifetime difficult. Modular structure is well adapted to solve the project paradoxes (Yayavaram and Ahuja, 2008; Nahapiet and Ghoshal, 1998, vom Brocke and Lippe, 2015). On the other side, the size of the knowledge base and the interconnections between the modules help to generate lateral and broad knowledge, echoing Michelfelder and Kratzer (2013). Structuring processes may have positive or negative effects on knowledge creation during the project lifetime (Lundin & Söderholm, 1995); we empirically found that structuring depends on the alignment of the partners' interests, on the presence of industrial use cases, on the presence of integrative activities in the project and on the motivation of the key project persons, especially the coordinator.

The research presented here is limited to multi-actor collaborative projects funded by the European Union Research and Innovation Programmes, which have specificities such as a large number of autonomous organizations working together. We studied a certain set of themes and projects; thus, it is possible that there are additional types of project structures that have not been found in this study. Also, we did not focus in this paper on the processes that operate within the project and influence inter-organizational collaboration and thus knowledge creation.

Our findings improve the understanding about the type of structures in multi-actor research and innovation projects and about the interplay between structure and knowledge creation, on the theoretical level. On the practical level, they provide guidance to the project managers about how different types of project structures favor different type of knowledge creation.

References

Ahuja, G. (2000). Collaboration Networks, Structural Holes, and Innovation: A Longitudinal Study (2000). *Administrative Science Quarterly*, 45(3), pp. 425-455.

Aubry, M., and Lavoie-*Tremblay*, M. (2018). Rethinking organizational design for managing multiple projects. *International Journal of Project Management*, 36, pp. 12–26.

Avenier, M.J. and Thomas, C. (2015). Finding one's way around various methodological guidelines for doing rigorous case studies: a comparison of four epistemological frameworks. *ESKA. Systèmes d'information et management*, 1(20), pp. 61-98.

Baldwin, C. and Clark, K. (2000). *Design rules: The power of modularity*. The MIT Press.

Bakker, R. M., De Fillippi, R. J., Schwab, A., and Sydow, J. (2016). Temporary organising: Promises, processes, problems. *Organisation Studies*, 37(12), pp. 1703-1719.

Berkowitz, H., & Dumez, H. (2016). The Concept of Meta-Organization: Issues for Management Studies. *European Management Review*, 13(2), pp. 149–156.

Blomqvist, K. and Levy, J. (2006). Collaboration capability – a focal concept in knowledge creation and collaborative innovation in networks. *International Journal of Management Concepts and Philosophy*, 2(1), pp. 31–48.

Bor, S. (2014). *A Theory of Meta-Organisation: An Analysis of Steering Processes in European Commission-Funded R&D 'Network of Excellence' Consortia*. Publications of the Hanken School of Economics Nr 285, 448 p.

Calamel, L., Defelix, C., Picq, T., and Retour, D. (2012). Inter-organisational projects in French innovation clusters: the construction of collaboration. *International Journal of Project Management*, 30, pp. 48-59.

Chesbrough HW (2005). *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Harvard Business School Press, First Trade Paper edition.

Davis, J., Eisenhardt, K.M., and Bingham, C. B. (2009). Optimal Structure, Market Dynamism, and the Strategy of Simple Rules. *Administrative Science Quarterly*, 54(3), pp. 413–452.

Dietrich, P., Eskerod, P., Dalcher, D., and Sandhawalia, B. (2010). The dynamics of collaboration in Multipartner Projects. *Project Management Journal*, 41(4), pp. 59–78.

Eisenhardt, K. (1989). Building Theories from Case Study Research. *Academy of Management Review*, 14(4), pp. 532 – 550.

European Commission (2019), Horizon 2020 Interactive Dashboard. Retrieved from: https://webgate.ec.europa.eu/dashboard/hub/ , accessed on May 18, 2019.

Fernandez, A.-S., Le Roy, F. and Chiambaretto, P. (2018). Implementing the right project structure to achieve coopetitive innovation projects. *Long Range Planning*, 51, pp. 384-405.

Kapsali, M. (2011): Systems thinking in innovation project management: a match that works. *International Journal of Project Management*, 29, pp. 396 – 407.

Kotlarsky, J. and Oshri, I. (2005). Social ties, knowledge sharing and successful collaboration in globally distributed system development projects, *European Journal of Information Systems*, 14(1), pp. 37-48.

Lawrence, P. and Lorsch, J. (1967). Differentiation and Integration in Complex Organizations *Administrative Science Quarterly*, 12, pp. 1-30.

Littler, D., Leverick, F., and Bruce, M. (1995). Factors affecting the process of collaborative product development: A study of UK manufacturers of information and communications technology products. *Journal of Product Innovation Management*, 12(1), pp. 16-32.

Lundin, R. and Söderholm, A. (1995). A theory of the temporary organization. *Scandinavian Journal of Management*, 11(4), pp. 437-455.

Michelfelder, I. and Kratzer, J. (2013). Why and How Combining Strong and Weak Ties within a Single Interorganizational R&D Collaboration Outperforms Other Collaboration Structures. *Journal of Product Innovation Management*, 30(6), pp. 1159–1177.

Nahapiet, J. and Ghoshal, S. (1998). Social capital, intellectual capital, and the organisational advantage. *Academy of Management Review*, 23(2), pp. 242-266.

Nooteboom, B., Vanhaverbeke, W., Duysters , G., Gilsing, V., van den Oord, A. (2007). Optimal cognitive distance and absorptive capacity. *Research Policy*, 36 (2007), pp. 1016–1034.

Raab, J., Soeters, J., van Fenema P., and de Waard, E. (2009). Structure in temporary organisations. In P. Kenis, M. Janowicz-Panjaitan, B. Cambré, (Eds.). *Temporary organisations: prevalence, logic and effectiveness* (pp. 171-200), London: Edward Elgar Pub.

Schiavone, F. and Simoni, M. (2011). An experience-based view of co-opetition in R&D networks. *European Journal of Innovation Management*, 14 (2), pp. 136-154.

Schilling, M. (2000). Toward a General Modular Systems Theory and Its Application to Interfirm Product Modularity. *Academy of Management Review*, 25(2), pp. 312 – 334.

Schilling, M. and Phelps, C. (2007). Interfirm Collaboration Networks: The Impact of Large-Scale Network Structure on Firm Innovation. *Management Science*, 53(7), pp. 1113-1126.

Simon, H. (1962). The Architecture of Complexity. *Proceedings of the American Philosophical Society,* 106(6), pp. 467-482.

Swink M. (2006). Building Collaborative Innovation Capability. *Research Technology Management*, 49(2), pp. 37-47.

Tiwana, A. (2008). Do bridging ties complement strong ties? An empirical examination of alliance ambidexterity. *Strategic Management Journal*, 29 (3), pp. 251–72.

vom Brocke, J. and Lippe, S. (2015). Managing collaborative research projects: A synthesis of project management literature and directives for future research. *International Journal of Project Management*, 33, pp. 1022–1039.

Yayavaram, S. and Ahuja, G. (2008). Decomposability in Knowledge Structures and Its Impact on the Usefulness of Inventions and Knowledge-base Malleability. *Administrative Science Quarterly*, 53, pp. 333–362.

Wood, D. and Gray, B. (1991). Toward a Comprehensive Theory of Collaboration. *The Journal of Applied Behavioral Science,* 27(2), pp. 139–162.

Annex 1. Projects' overview. The grey lines show the projects selected for the 2nd phase of the study.

	Name	*Project activity*	*Technol. Maturity*	*Project thematics*	*Project stage*	*Number of partners*	*Type of structure in the proposal*
1	**PEGASUS**	R&D	Low	ICT	Ended	12	Modular 3.0, grid
2	**HERCULES**	R&D	Medium	Production	Ended	10	Modular 2.0, waterfall
3	**PERSEUS**	R&D	Medium	Production	Ended	15	Modular 1.0
4	**ORION**	R&D	Medium	Production	On-going	17	Network
5	**SCORPIUS**	R&D	Medium	ICT (platform)	Ended	14	Linear 2.0, converging
6	**ANDROMEDA**	R&D	Medium	Environment/ multi-disciplinary	On-going	21	Modular 3.0, grid
7	**LIBRA**	R&D	Medium	ICT (platform)	Ended	19	Linear 2.0, converging
8	**GEMINI**	Innovation	High	ICT (platform)	On-going	13	Linear 1.0
9	**CAPRICORNUS**	Innovation	High	Production	On-going	12	Modular 1.0
10	**TAURUS**	Service innovation	N/A	Support to R&D teams	On-going	9	Modular 2.0, waterfall
11	**CASSIOPEIA**	Support	N/A	ICT	Ended	10	Network
12	**SAGITTARIUS**	Support	N/A	ICT	On-going	8	Modular 3.0, grid
13	**VIRGO**	Support	N/A	ICT	Ended	13	Network
14	**CENTAURUS**	Support	N/A	ICT	Ended	10	Modular 3.0, grid
15	**URSA**	Service innovation	N/A	Support to R&D teams	On-going	9	Modular 3.0, grid