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Collaboration dynamics among institutions in the European research space

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Abstract

This paper examines the collaboration dynamics of institutions in the context of project collaboration in European Framework programmes. Its goal is to identify the key factors that promote the formation of collaborative ties among institutions as well as factors that influence the maintenance of collaborative ties when they are already formed. The paper broadly presents the theoretical starting points for the study of scientific networks within the EU, and it is in its empirical part organised around five hypotheses shaped on characteristics of analysed institutions and their positions within the dynamic network. Using valued blockmodeling, the study analyzes data from EU FP projects in the "Food, Agriculture, and Fisheries" theme between 2008 and 2014. The analysis reveals a complex hierarchical structure, characterized by a core–semi-periphery–periphery global structure. The findings confirm the significant role of coordinating institutions in driving European scientific collaboration and highlight the persistent challenges faced by organizations from new member states in securing influential positions. The study also identifies a distinct pattern of lasting collaboration dominated by established European research institutions, with non-European organizations playing limited role in the network.

Keywords: scientific collaboration, institutions, EU Framework Programe, longitudinal network analysis, blockmodeling

1. Theoretical starting points

Collaboration in science takes place in different ways and involves increasingly heterogeneous actors. It may be observed on the level of individual researchers, it may include different scientific disciplines, research sectors or countries. Given the increasing scientific differentiation, increasing spread of resources and policy framework, the relationships embedded in scientific networks are under constant change. Relationships among actors

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are formed, maintained and dissolved, and these processes are driven by individual characteristics of the actors or the environment they operate in. Another indispensable process of modern science is internationalisation. The growth of international collaboration in the research and development fields (henceforth R&D), alongside the application of performance indicators (e.g., institutional or country-wide recommendations regarding the production of scientific publications in indexed international, peer-reviewed journals) is changing the global scientific arena. It is no longer realistic to consider contemporary science without the significant influence of the internationalisation of scientific networks. For example, international projects account for at least 20% of national government spending on scientific research. Some countries spend as much as 50% of these funds on international collaboration (Wagner & Jonkers, 2017). A large number of published works have already addressed project-driven collaboration, which is rapidly increasing with contemporary globalisation and internationalisation of higher education processes. Scientific collaboration shows specific characteristics depending on whether it takes place within the framework of international, national or local contexts (Gibbons et al., 1994; Katz & Hicks, 1998; Ziman, 1994). International collaboration includes several elements of *self-regulation* (Scharnhorst et al., 2012); on the other hand, collaboration in national and local environments inherits more elements of *external regulations*, driven by various measures of political decision-makers (Kramberger & Mali, 2010; Mali, 2010). Arguably, European Union (EU) R&D collaboration tends to rest more on an *external* then on *self*-regulative environment. For example, the distribution of funds is governed not only by the process of academic peer review (i.e, self-regulation) but also by the political prioritisation of research themes, as well as by organisational requirements of how an EU-funded research project should be conducted. The bureaucracy of EU agencies, and sometimes also of the national funding agencies, actively intervenes in research practices, scientific discourses and organisational forms of scientific research. This means that researchers working in a trans-European context are faced with a complex and changing environment that is affected by various policy- and economic-driven interests. International R&D collaboration has attracted a great deal of interest from R&D policy decision makers because it is assumed to increase research productivity by reducing the costs for expensive facilities and by leading to new ideas, new discoveries, and higher scientific quality (more in Melin, 2000).

From the viewpoint of planning and implementation of (public and private) research strategies and policies, the geopolitical space of the EU is of our particular interest. The collaboration among scientists from different European countries in the scope of the EU Framework Programmes (EU FP) is a very important factor in determining *the rules of the game* (i.e., external regulation), set by the European Commission. Scientific collaboration that results from transnationally (European) dictated policy measures and mechanisms is particularly interesting. We could say that the EU FP is a representative example of how an increasing number of funding agencies have begun to promote research collaboration by specifying collaboration among researchers, with an emphasis on mixing researchers from different disciplines, organisations, and countries, as a funding condition. The initial idea of the concept of the European Research Area (ERA) is the stabilisation of collaboration across Europe to capitalize on synergies in knowledge networks (see more: Kim & Bak, 2017).

The story of the EU FP is already quite long. Back in the '80s, the most developed EU countries introduced new mechanisms to establish and productively develop various forms of scientific collaboration. They also carried out a lot of systematic strategies and policies with the goal of mutual interconnectedness. With EU enlargement, new countries have entered the joint R&D and innovation space. The core of this space was inter-institutionally strongly supported project collaboration within the EU FP. In practice, many performing aspects of the EU FP have been more or less stable across different editions of FPs. Attempts by the EU to create and adapt the integrated space for R&D through FPs were implemented through a series of policy initiatives that have changed over time in relation to the instruments adopted and their goals and budget) (EPEC, E.P.E.C., 2012).

If we look at the entire ideological platform underlying the EU FP, then the first phase of their operation (1984–1987) was dominated by atomic energy research and research on information and communication technologies. Projects dealing with societal goods (health, infrastructure, the environment and other factors that are associated with societal functioning) did not receive as much attention. The 4-th EU FP (1994–1998) established four new action programmes which re-established the disciplines belonging to the social sciences and organised their own sub-program, which financially accounted for less than 1% of the funds dedicated to European science (Maggioni et al., 2017). The 7-th EU FP (2008–2013) had five action programmes (Cooperation, Ideas, People, Capacities, Euratom). The importance of research in the fields of the social sciences has increased significantly, and the funds invested in social sciences have begun approaching 10% of the whole budget (European Commission, 2015). A significant change in funding can also be observed in the change of structure of participating institutions. The trend is continuing in the current Horizon 2020 programme. On the whole, the EU institutions made significant investments to create a common institutional framework of European science. In that sense, we can talk about a transformation of scientific collaboration in Europe from the traditional cosmopolitan individualism into transnational scientific collectivism. In the last decade, European Commission has attempted to mobilise science for European integration and provided a specific space for transnational research for this purpose. The Lisbon Treaty (2009) included the promotion of *scientific and technological advance* among the basic objectives of the EU. The treaty declared research, technology and space as areas of shared competence between the EU and its member states. It also formulated the goal of creating a common European Research Area (e.g. Pfister, 2015) which should lead to the elimination of the scientific and technological gap in regard to the EU's global competitors (USA, Japan, etc.). The Horizon 2020 strategy of the joint research programmes even more strongly emphasizes the creation of some sort of pan-European network of scientists and other stakeholders (Makkonen & Mitze, 2016).

The conditions of R&D work in the European context set new requirements for researchers coming from various EU countries to design and execute their own research goals and particular research agendas. Let us consider only changes in the funding environment of science which lead to so-called pan-European funding of science. When these processes have turned they provoked a lot of new challenges. With the development of the EU FP, the evaluations became increasingly complex and also increasingly supported by various types of bibliometric analyses. The European Commission carried out various types of ex post evaluations in different time periods (e.g. European Commission, 2010a, 2010b, 2015). Within these widespread types of meta-evaluations, a number of indicators were developed (Georghiou & Laredo, 2006). Other types of analyses were also conducted, normally constrained to the time period of five years (the duration of the individual EU FP) or to specific thematically selected project areas.

Regarding the formation of structural characteristics of scientific networks in the context of the EU FP, various levels of analysis are usually considered: (i) The first is EU level. This framework is dictated by the European Commission with various public policy measures which have different effects on the functioning of national, regional and local R&D policies.

Encouraging the spread of pan-European principles, including the most general principles, such as “Integrated European Science”, “European Added Value of Science” or “Principle of Subsidarity,”[1] is at the core of all the instruments of the R&D policies of the European Commission. The European R&D policies are formed by a series of objectives. (ii) The second level refers to the national context. It relates to the operating conditions in the national contexts from which the partners involved in European research projects originate. In the contemporary processes of globalisation, national space represents more than just a closed geographical area where individual researchers, research groups or institutions operate. It is often the first and most important factor in establishing scientific collaborations that are directed outward beyond national borders. (iii) The third level addresses the characteristics of the institutions that are involved in European research projects. They are characterized by extreme heterogeneity in terms of sectoral (e.g., R&D institutions, small and medium-sized enterprises, NGOs) and disciplinary affiliation.

In the scope of these types of studies, quantitative analyses were conducted, which, inter alia, undertook to (1) discover various thematic and geographic substructures within the network of European research projects (Barber et al., 2011), (2) study the effects of EU FP on the formation of various types of scientific networks (Gusmão, 2001; Hazir & Autant-Bernard, 2014), (3) study the impact of the EU FP on scientific excellence and productivity of the participating scientific institutions (Arnold et al., 2005), (4) investigate funding models within the EU FP and their impact on the hierarchy of relations in the partnership structure of the project (Luukkonen, 2014), (5) analyse changed models of interaction within the EU FP as a result of the contemporary advent of trans-disciplinary types of scientific knowledge (Protogerou et al., 2013), (6) analyse the positioning indicator (Lepori, 2006), etc. A review of the research already conducted on co-authorship networks as well as transnational institutional forms of scientific collaborations proves that much has already been accomplished in this area. However, the complexity and dynamics of scientific collaboration in the contemporary processes of globalisation open up a range of new problems that require new theoretical and methodological approaches.

While existing literature has explored co-authorship networks and transnational forms of scientific collaboration, there remains a gap in understanding the intricate dynamics and long-term stability of institutional collaborations, especially in the context of externally regulated frameworks like the EU FPs. Previous studies have often overlooked the specific mechanisms that drive the formation and maintenance of collaborative ties within such regulated environments.

In our current paper, we address organisation-driven dynamics and structural characteristics of the EU FP founded, project-based collaboration network. We are interested in the key factors leading to establishment, as well as in factors that foster maintenance of collaborative ties over longer period.

The selected theme of “Food, Agriculture, and Fisheries” for the period 2008–2014 represents only minor segment of all interorganisational collaboration but is particularly significant due to its alignment with European policy objectives during this timeframe. This theme was a focal point in the EU Framework Programme, reflecting broader trends in sustainability and food security, which were critical areas of investment and policy action in

[1]EU R&D policy should follow through the implementation of EU FPs the principle of subsidiarity. It does mean that only consortia of partners from different EU-Member States could apply for EU funds. R&D activities that can better be carried out at national or regional level, that is, without cooperation across borders will not being eligible under the FPs.

the European Research Area (ERA). By choosing this period and theme, the study captures a pivotal moment in the evolution of European research collaboration, providing insights that may be indicative of larger patterns within the EU FP landscape.

In the following section, we present research hypotheses. The third section is dedicated to the description of analysed data, the fourth to the description of the model, and the last one to presentations of results and discussion of findings.

2. Research questions

The former studies of EU FPs have shown that the structures of scientific collaboration networks have formed around organisations which embrace the role of coordinators or principal investigators (e.g., Graf & Kalthaus, 2018; Hoekman et al., 2013; Maggioni et al., 2017; Protogerou et al., 2013). Due to their central position, the coordinator can importantly dictate the type of relationships within the whole scientific network for the duration of an EU FP project and the potential follow-up collaborations after the project expires.

The *first research question* stresses the role of coordinator in EU FP colaboration: are coordinators with established consortia of partners generators of network dynamics? How inclusive are they in respect to turnover of their collaborators?

Taking into account the rising importance of the common European Research Area, EU-Member States strive to be integrated into EU R&D networks to access external knowledge and thereby secure their scientific and technological progress. Unfortunately, it is not easy to achieve this goal. A lot of previous empirical studies pointed out that there existed uneven distributions of coordinating institutions in EU FP projects among the old and the new EU-Member States (e.g., Maggioni et al., 2017; Makkonen & Mitze, 2016; Must, 2010).

At the same time, we notice a lack of support by national R&D policy actors in new EU-Member States to internationalise R&D in their countries. For example, in our former analyses performed on the case of Slovenia (it belongs to the group of new EU-Member States), we found out that research groups and organisations have (i) not enough active national R&D policy support for their international activities (Ferligoj et al., 2015), (ii) inadequate institutional and organisational structure to achieve the networking behaviours at the international level (i.e., inability to reach the adequate human resource concentration to be competitive at international level) (Kramberger & Mali, 2010), (iii) inadequate R&D evaluation systems (Mali et al., 2017), etc. The *second research question* is: Are there any differences in the collaborationg environment of organisations from new member states compared to those from well established countries? What is the role of non-European organisations in the network?

In recent years, the number of non-research and non-academic participants in the EU FP has been increasing. One of the consequences is that partner institutions which take over the role of coordinators are becoming aware of the “hybrid” character of the European research programme (e.g., Pohoryles, 2014). Various participating institutions with their interests may cause more dynamics and long-range instability in EU research networks.

It is common that partners coming from the business-enterprise sector are expecting applicative results and create more innovations in the industrial and service sectors. On the other side, academic research institutions still expect research results which will improve the knowledge base in disciplines in which they are engaged. In that sense, some previous studies showed that there existed all the time the tensions between two different framings of science, i.e., the view that science has self-contained value in its own right and the view that science has an instrumental role as producer of innovations for development of industrial sector (e.g., Arnold, 2012; Avedas, 2009; Breschi & Malerba, 2011). In the dynamic non-academic context and the less-dynamic academic context we can formulate the *third research question* as: Do research institutions as representatives of academic sector form a backbone of network with relatively stable list of partners with whom they collaborate, and are there any typical roles played by other types of institutions.

If the organisations which are involved in international projects by building new ties do not maintain their collaboration for longer periods, we can assume, that they are *creators* of ongoing dynamics (e.g., Hallonsten, 2012). During the whole operational history of all EU FP, there have been established a lot of collaborations, with objectives of building new R&D competences.

Is there a core of organisations that we can describe as highly influential and in the spirit of preferential attachment described as central?

Structure of scientific collaboration networks on individual level reveals high level of clustering and the multicore–semi-periphery–periphery structure. A high level of clustering as one of the components of small world was thoroughly observed by several authors in collaboration networks measured on the level of individual researchers (e.g., Ferligoj et al., 2015). The idea of transitivity in scientific collaboration on individual level is expected due to organisation of scientific work in research groups. This pattern was already questioned and confirmed on the level of institutions in a relatively small research community (Cugmas et al., 2020).The association between clustering (transitivity) and various types of blockmodeling structures (e.g., cohesive and symetric core periphery) was already showed by (Cugmas et al., 2018).

Some form of core-periphery structure is expected to be found in the data. In the analysis we will explore the embeddedness of prolonged ties in its context of core-periphery structure.

3. Data and operationalisation of variables

Collaboration on level of institutions is operationalised as valued social network. The network is based on the research collaboration in all 7-th EU Framework Programme founded research projects on the *Food, Agriculture and Fisheries, and Biotechnology* theme in the period spanning from year 2008 to 2014.[2]

The focus on the theme was selected due to its significant representation of research collaboration trends in the EU. This theme encompasses a critical sector in European research, known for its diverse network of participants and strategic importance to EU policy. Analyzing this subset allows for a nuanced understanding of collaboration dynamics that may be reflective of broader patterns in the EU research space. While it could be considered a convenience sample, its representativeness is rooted in its policy relevance and the diversity of institutions involved.

The overall data contains information on 226 projects, with 1530 different participating institutions from one hundred different countries. Duration of the projects is presented in Figure 1. The projects lasted from 18 to 69 months. As such, the analysed network can be treated as a description of the whole collaboration population on the selected theme.

Collaboration between two institutions is measured as common involvement in a project. If institutions collaborated at only one project the tie among them has weight 1, if they collaborated at two or more project the tie has value 2. We presume, that prolonged collaboration between institutions may be interpreted as consequence of positive experience of previous collaborations and other accompanying factors that shape the environment and

[2]List of all projects with basic information is available in the CORDIS repository at https://cordis.europa.eu/projects/home_en.html.

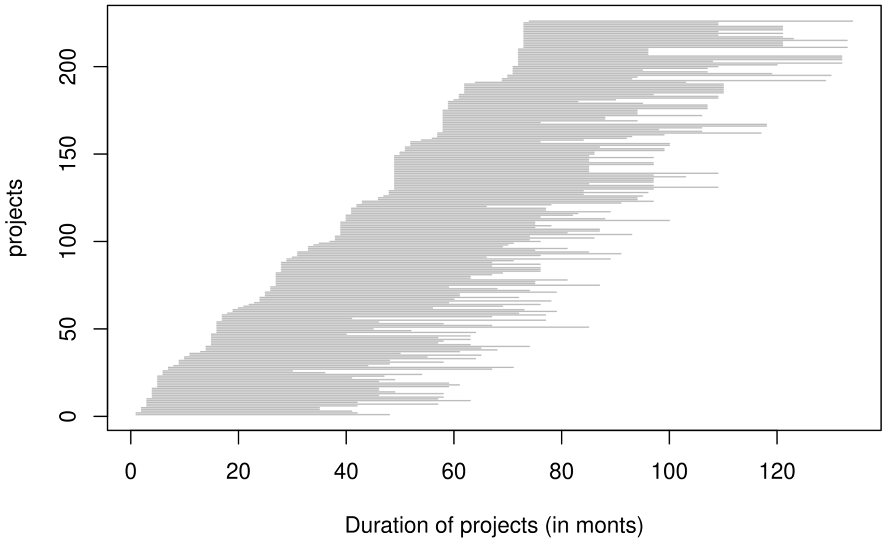

Figure 1. Distribution and duration of projects through analysed period

relations in which institutions operate.

To reduce computational burden of the applied method the dataset was split by institutions involved in only one project and those participating in two or more projects. Latter were clustered and after the obtained clustering results re-merged. On one hand, the excluded institutions had no ability to form prolonged ties, on the other, we can detect those that were involved in more than one project and did not prolong their existing collaborations (were connected with ties weighting 1). After the split size of the clustered part of network decreased to 482 institutions. Number of ties with value 1 in this symmetric network is 14 326, number of prolonged ties with value 2 is 5652—therefore density is 0.086. Degree distribution in network ranges from 5 to 359, its high level of skewness will be discussed later in the analysis.

The 1048 units excluded from the clustering procedure is later analysed as part of the network and in final results presented as separated cluster. For the purpose of interpretation and evaluation of hypotheses several additional variables were included in the analysis:

1. *Type of organisation*: Organisations are categorised into 3 categories (see Table 1): research institute (REI) also containing academic institutions summing up to 797 units, industry (IND) containing small, medium and large enterprises (666 units), and non-governmental organisation (NGO) with 67 representing organisations. In the separately analysed cluster there were 53% of REI, 76% of NGOs and 85% of all IND classified organisations. This variable was added to the original database by means of manually checking organisations that could not be automatically classified according to their legal name.
2. *Coordinatorship*: If in the analysed time-span the organisation was coordinator of at least one project, the value of the variable is 1, else the value is 0. From 1530 organisations there are 122 coordinators, 26 (21%) of them were excluded from the clustering procedure.
3. *EU membership*: Given the numerous complaints of new member states' roles in the European scientific environment, this variable classifies the organisations according to the year of EU membership accession of the country of residence. For the analysis, three categories are used: accession in the year 1995 or earlier (old members), accession after 1995 (new members) and non-European countries. Organisations from non-European countries origin in 71 different countries from allover the world. The largest

number of participating institutions come from the Swiss Confederation (53), Norway (32), Turkey (22) and China (22).

Table 1. Descriptive variables and split of the data

		Clustered (%)	Excluded (%)	All (%)
Type of organisation	IND	95 (14)	571 (86)	666 (100)
	NGO	16 (24)	51 (76)	67 (100)
	REI	371 (47)	426 (53)	797 (100)
Accession to the EU	Old members (≤ 1995)	306 (31)	678 (69)	984 (100)
	New members (> 1995)	81 (38)	134 (62)	215 (100)
	Other countries	95 (29)	236 (71)	331 (100)
The organisation is coordinator	No	386 (27)	1022 (73)	1408 (100)
	Yes	96 (79)	26 (21)	122 (100)

Table 2 presents a strong (significant) association between three types of country-origin data and the coordinatorship. This results from the fact that out of 215 organisations originating from the new member states, only 7 held coordinating roles.

Table 2. Number of coordinating organisations by country of origin accession to EU

The organisation is coordinator	Old members (≤ 1995)	New members (> 1995)	Other countries
No	879	208	321
Yes	105	7	10

This problem of uneven distribution of coordinatorsihp was previously exposed by Maggioni et al. (2017), who studied the spatial pattern of the contracts financed under the FP6. The results of their analysis showed that from a total number of contracts related to the whole group of EU countries, only 4.2% were managed by institutions located in the group of new EU-Member States. The data show that the spatial distribution (old and new EU-Member States) of coordinators of 6 EU FP projects was extremely skewed.

Partners from new EU-Member States seem therefore to be much more limited to take over the position of principal investigators compared to the partners from old EU-Member States.

4. Method

Data analysis in this paper is performed with application of blockmodeling approach for valued networks. This exploratory method can give useful insights into the global structure of the data and enables researchers to address variety of research questions.

More specifically, in a blockmodel, groups of equivalent (according to the structure of their links) nodes from the empirical network are reduced to transform large, complex, and potentially incoherent networks into smaller and more comprehensible networks (Doreian et al., 2005). The relationships between the clusters so obtained can serve to operationalize social roles (Borgatti & Everett, 1992). Of several available approaches for blockmodeling valued networks the homogeinity blockmodeling was applied (Žiberna, 2007). The approach emphasizes the similarity of link (tie) strengths within the blocks over the pattern of links (Matjašič et al., 2020). The tie (link) values (or statistical data computed on them) are assumed to be equal (homogeneous) within blocks (Žiberna, 2007).

In the case of analysed network with tie weights valued 1 or 2, the method respectively searches for ideal homogeneous blocks with majority of ties valued 1, 2 or empty blocks among non-connected organisations. The best solution is chosen according to the minimum value of criterion function—sum of deviations from ideal block values.

Alternatively we could use *k*-means blockmodeling approach which we tested but resulted in higher (worse) value of objective function.

5. Results

Clustering of ties in the reduced part of the network with use of the blockmodeling procedure resulted in 6 clusters of organisations. Number of clusters was set arbitrary according to distribution of possible combinations of tie types—prolonged ties with value 2, ties with value 1, non-connected organisations and organisations that were exempt from clustering. The error value of the final result after 1000 repetitions of the blockmodeling procedure, obtained with criterion function was 24 240.25.

The overview of the global structure (see Figure 2) reveals complex core–periphery like structure of the network with two small clusters (1 and 2) containing two and five organisations, and four clusters (3 to 6) with varying sizes ranging from 29 to 239. Additionally, in Figure 3, the re-merged part of the network is included and marked as cluster 7 which is the largest cluster containing 1048 organisations.

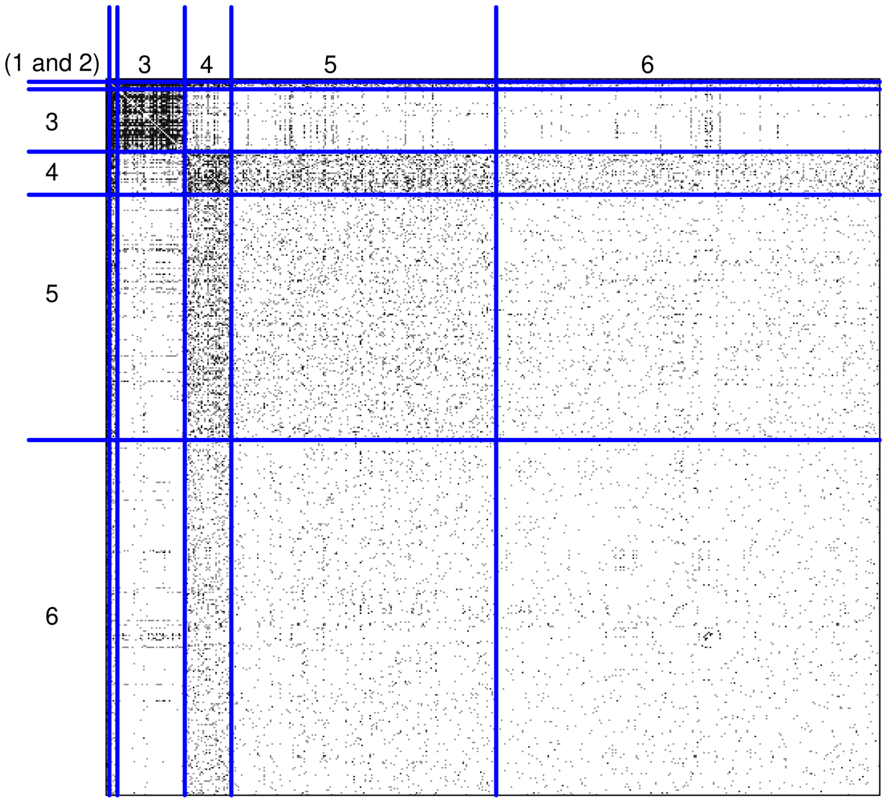

Figure 2. Matrix representation of the network reordered according to result of blockmodeling procedure

	1	2	3	4	5	6	7
1 (n=2)	%1= 0 %2= 100 %0= 0	%1= 0 %2= 100 %0= 0	%1= 13 %2= 79 %0= 8	%1= 2 %2= 98 %0= 0	%1= 23 %2= 71 %0= 6	%1= 38 %2= 16 %0= 46	%1= 39 %2= 0 %0= 61
2 (n=5)	%1= 0 %2= 100 %0= 0	%1= 0 %2= 100 %0= 0	%1= 10 %2= 77 %0= 13	%1= 26 %2= 57 %0= 17	%1= 29 %2= 15 %0= 56	%1= 14 %2= 2 %0= 84	%1= 11 %2= 0 %0= 89
3 (n=42)	%1= 13 %2= 79 %0= 8	%1= 10 %2= 77 %0= 13	%1= 19 %2= 58 %0= 23	%1= 17 %2= 4 %0= 79	%1= 5 %2= 1 %0= 94	%1= 2 %2= 0 %0= 97	%1= 2 %2= 0 %0= 98
4 (n=29)	%1= 2 %2= 98 %0= 0	%1= 26 %2= 57 %0= 17	%1= 17 %2= 4 %0= 79	%1= 26 %2= 40 %0= 34	%1= 22 %2= 10 %0= 68	%1= 13 %2= 3 %0= 85	%1= 8 %2= 0 %0= 92
5 (n=165)	%1= 23 %2= 71 %0= 6	%1= 29 %2= 15 %0= 56	%1= 5 %2= 1 %0= 94	%1= 22 %2= 10 %0= 68	%1= 9 %2= 2 %0= 89	%1= 4 %2= 1 %0= 96	%1= 2 %2= 0 %0= 98
6 (n=239)	%1= 38 %2= 16 %0= 46	%1= 14 %2= 2 %0= 84	%1= 2 %2= 0 %0= 97	%1= 13 %2= 3 %0= 85	%1= 4 %2= 1 %0= 96	%1= 2 %2= 1 %0= 97	%1= 1 %2= 0 %0= 99
7 (n=1048)	%1= 39 %2= 0 %0= 61	%1= 11 %2= 0 %0= 89	%1= 2 %2= 0 %0= 98	%1= 8 %2= 0 %0= 92	%1= 2 %2= 0 %0= 98	%1= 1 %2= 0 %0= 99	%1= 1 %2= 0 %0= 99

Figure 3. Image matrix of the network with distribution of tie values in each of the obtained blocks. Cluster no. 7 is added after the blockmodleing procedure. %1 presents percentage of present ties with value 1 among all possible ties, %2 percentage of continued ties (with weight 2 or more) among all present ties and %0 percentage of unconected pairs of institutions.

The first two clusters consist of highly collaborating set of organisations and would be in terms of terminology proposed by Kronegger et al. (2011) described as dominant bridging cores. Cluster no. 3 is as all other clusters strongly conected to the first two but practically isolated from the rest of the network. Clusters 4 to 7 resemble typical core–semi-periphery–periphery structure (Kronegger et al., 2011), with cluster 4 as a core, cluster 5 as active semi-periphery, cluster 6 as passive semi-periphery and cluster 7 as the periphery of the network. Latter was arbitrary defined as set of organisations that only participated in a single project.

5.1. Description of clusters

Cluster no. 1 is compound of two organisations (*Stichting Dienst Landbouwkundig Onderzoek* from the Netherlands and *Institut National De La Recherche Agronomique* from France). The first one was involved in 94 and the second one in 83 out of 122 project included in the analysis, so they can be described as outliers in the data. For the reference, the third among the most active organisations participated in 34 projects. In total this two organisations are collaborating with more than 23% of all organisations included in the analysis.

From the institutional background point of view, the organisations are experienced coordinators, one NGO and other research organisation, both originating from old member states.

In terms of collaboration with other clusters, the first one is through complete blocks strongly connected to all other clusters in the network, except to cluster 7 in which it has 39% non-absent ties. The complete blocks are those with more than half non-absent ties. In non-diagonal blocks connecting it to clusters 2 to 5 there is less that 5% of absent ties, while the percentage of prolonged ties excels 70%. Prolonged collaboration is present in 16% of all possible ties in block connecting it to cluster 6.

Cluster no. 2 is the second bridging cluster, that is slightly less dominant compared to the first one. To the first four clusters it is connected with complete blocks. In the block connecting it to cluster 5 there is slightly less than half non-null ties which technically classifies it as empty block, this non-diagonal block is still dense compared to the connection to passive semi-periphery (cluster no. 6) and periphery (cluster no. 7) with 84 and 89 percent of null ties.

Connections to clusters 1 to 4 are in majority of instances prolonged, while this percentage drops to only 15% in connection to cluster 5.

All five organisations from cluster two are research organisations, four or them are from old member states and one from outside EU. Three of five coordinated at least one of projects included in the analysis.

Cluster no. 3 could be from its position towards the first two *core* clusters treated as part of the network core. Since it has practically no connections to any other clusters within the network it could be described as completely dominated by the first two.

Percentage of prolonged ties within the diagonal block and in blocks connecting this cluster to the first two ranges from 60 to 80%.

Practically all (95%) of organisations clustered into the third cluster are research organisations. Among all clusters this one has the highest proportion of organisations coming from new member states and, if treated as part of the network core, very low proportion of coordinating institutions (12%). The presence of non-EU organizations is significantly lower than expected.

Cluster no. 4 could be described as the healthy core in terms of its dense, but not determining inner collaboration and its collaboration with organisations from the rest of the network. The density of the block connecting it to *active semi-periphery* (cluster no. 5) technically classifies as an empty block but has more that 30% of non-null ties. In non-diagonal blocks connecting it to clusters 6 and 7 the number of non-empty ties drops to 15% and 7% which indicates low, incoherent, but still present level of collaboration.

As expected, the prolonged collaboration is dominant with organisations from clusters 1 and 2, within cluster, percentage of prolonged ties is higher than of those that are present and not prolonged. Prolonged collaboration was (in 10% of ties) still present in collaboration with organisations from cluster 5, but dropped to 3% of ties in collaboration with cluster 6.

Cluster no. 4 tends to be an expected typical core, also when looking at it from a characteristics perspective. The majority of organizations clustered into it were research organizations from old member states with extensive experience as coordinators. Similar to cluster 3, non-EU organizations have a lower-than-expected presence in this cluster, suggesting that while the cluster remains open to diverse collaboration, it primarily consists of well-established European institutions.

Cluster no. 5, described as the active semi-periphery is typical peripheral cluster, strongly tied to the core (clusters 1, 2 and 4) in combination with relatively low level of connectedness on inside between members of the cluster. This is already large cluster containing 165 organisations. The prolonged ties of this cluster are tied to clusters 2 and 4 with tie 2 block proportions of 10% to 15%. The main upholder of the cluster 5 members are the two organisations clustered to the cluster 1.

Regarding the composition, as other presented clusters, also this one consists mostly of research organisations, with even distribution among organisations from new, old member states or from outside the EU. For peripheral cluster this one has relative high proportion of organisations that were project coordinators (22%).

Cluster no. 6 is the last cluster obtained by blockmodeling procedure. It can be described as the passive semi-periphery. Connections between organisations of this cluster presented in the diagonal block are rare—there are only 3% of possible ties that are present, 1% of ties is prolonged. In terms of collaboration with other clusters visible from non-diagonal blocks statistics the proportion of prolonged ties is above 0% but very sparse.

From the perspective of descriptive variables this cluster remains relatively strongly represented by research institutions, who by relatively high proportion originate from the new member states and have relatively low (similarly as cluster 4) proportion of coordinators (12%).

Cluster no. 7. The large periphery consists of 1048 organisations that (by our definition) can not have prolonged ties. This are organisations that participated at certain projects but are not significant actors within the network. This is the only cluster in which proportion of research institutions excels the marginal proportion of industry classified institutions. These organisations practically never coordinated the project in which they participated.

5.2. Research questions

Coordinators, "new" member states and non-EU organisations:. The role of coordinators strongly correlates with organisations clustered to clusters 1, 2, and 4 that were within the analysis recognised as the core clusters. According to descriptions available in Table 3, the coordinatorship tends to be a very good indicator weather the organisation is part of one of the network cores or not.

Table 3. Descriptive variables according to obtained clusters

Cluster	Organisation type			Accession to the EU			Coordinator	
	IND	NGO	REI	Old	New	Other	No	Yes
1	0 (0%)	1 (50%)	1 (50%)	2 (100%)	0 (0%)	0 (0%)	0 (0%)	2 (100%)
2	0 (0%)	0 (0%)	5 (100%)	4 (80%)	0 (0%)	1 (20%)	2 (40%)	3 (60%)
3	2 (5%)	0 (0%)	40 (95%)	29 (69%)	10 (24%)	3 (7%)	37 (88%)	5 (12%)
4	1 (3%)	0 (0%)	28 (97%)	27 (93%)	0 (0%)	2 (7%)	8 (28%)	21 (72%)
5	29 (18%)	4 (2%)	132 (80%)	109 (66%)	23 (14%)	33 (20%)	129 (78%)	36 (22%)
6	63 (26%)	11 (5%)	165 (69%)	135 (56%)	48 (20%)	56 (23%)	210 (88%)	29 (12%)
7	571 (54%)	51 (5%)	426 (41%)	678 (65%)	134 (13%)	236 (23%)	1022 (98%)	26 (2%)
All	666 (44%)	67 (4%)	797 (52%)	984 (64%)	215 (14%)	331 (22%)	1408 (92%)	122 (8%)

Connection between the property of organisations of being coordinators and also prolonging their collaborating ties is present, but not necessary sufficient property. The example of opposite are organisations clustered into cluster 3, with low coordinatorship level, which are completely dominated by the core organisations from clusters 1 and 2, but still strongly connected on inside. Member organisations from this cluster prolong their ties only within the cluster and with organisations from two dominant clusters.

The subordinate role of organisations originating from new member states was shown immediately within the data description section. As shown in Table 2, only 3% of organisations originating from new member states coordinated a project with this percentage being more that 10% among old member states.

Regarding the presence of prolonged ties, the relative proportion of organisations from new member states is the highest in already mentioned and described cluster 3, and followed by cluster 6, the passive periphery with insignificant amount of prolonged ties.

Non-European organizations occupy a distinct role, filling specific (non-binding) needs within the consortiums. As a result, they are underrepresented in all core clusters.

Research institutions. Research institutes and academic institutions are as expected the most active type of organisations participating within the EU FP calls. Therefore they can be found in practically any role identified by applied blockmodeling procedure. What strikes is the peripheral role of non-academic institutions (IND) which were in 86% classified into peripheral cluster 7 as organisations that only participated at single project.

Preferential attachment and global structure of the network. The two highly connected organisations clustered into the first cluster, five in the second, and all the other organisations clustered into the following clusters tend to resemble a pattern that can be fitted into power-law distribution as one of the indicators of preferential attachment. Another indicator, the stability of the network after removing the most connected units confirms the same story as the network falls apart if we remove clusters 1 and 2 out of it.

Using the blockmodeling results, this same pattern can be observed twice: first observing presence of ties or distribution of full vs. null blocks in image matrix, and the second within the presence of blocks within high proportion of prolonged ties, with value 2, which indicates that the prolonging ties with collaborators follows the same general pattern driven by preferential attachment mechanism.

6. Discussion

Is the position and role of coordinating institutions in accordance with ideas of a balanced European research environment?

The strongest effects in the models indicate low turnover of collaborative ties of coordinating organisations. It is hard to say this is a striking finding for researchers who operate in the environment of the EU FP. As mentioned in the introduction, coordinators built the networks around themselves in early rounds of the EU FP. Today these networks seem to be the stable core of a grand European R&D framework. Such structure can be interpreted as an evident tendency in EU science to collaborate with established partners, with long traditions of collaboration, in which trust plays a significant role in the process of selecting partners. On the other hand, such structure of networks can be interpreted as a barrier to creating new contacts with the new partners. Namely, it seems that coordinators are more committed to “exploitation of old certainties” than “exploration of new possibilities” (March, 1991) which potentially leads to limited knowledge flow and loss of development opportunities.

Hard life of organisations operating in new member states

Although the organisations originating from new EU-Member States have a strong interest in joining excellent EU research projects and keeping their place in these networks, they are still encountering many barriers at the national as well as the EU level. It is reasonable to think that the differences between the new and old EU member states would converge as time passes by; however, no empirical evidence conclusively confirms this expectation (e.g., Maggioni et al., 2017).

Sometimes serious doubts are raised whether the current EU R&D policy instruments are efficient enough to create cohesive research collaboration with equal possibilities for research groups and institutions in all EU-Member States. Do they not reinforce the "centralization of knowledge flows" among the core group of West-European countries which have already been well connected with excellent scientific research? Although some authors (e.g., Scherngell & Barber, 2009) try to prove the opposite, the evidence is quite striking.

Research organisations against industry and other sectors

For coordinators of the EU FP and Horizon 2020 projects, it was sometimes difficult to combine the two ways of framing the science: science with self-contained value and science as instrumental producer of innovations for development of the industrial sector. The 7-th EU FP and the Horizon 2020 projects represent an especially complex process in regard to various participating institutions, interests of involved partners, their expectations concerning the impact of obtained results, etc. This situation is leading to many coincidences and uncertainties which probably cause more dynamics and long-range instability in EU research networks. Namely, for coordinators of EU R&D projects, it is difficult to predict further collaborations with some partners beyond the lifespan of the specific project. Despite adoption of different measures to make it even, the European Commission (2015, 2018) acknowledges that the European scientific space did not change and there is still a tendency that Horizon 2020 will end up in a concentration of institutions closer to scientific and technological progress.

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