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Co-funding Networks as a New Tool in Research Evaluation: A Linked Open Data-Based Study of the Seventh Framework Programme Projects

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Abstract

There is a growing interest in studying the influence of funding on scientific progress. Through exploration of the connections between funding acknowledgements (FAs), which link research results to funding sources, science communication processes can be understood and their influence in the international context can be evaluated. Such analyses become more complex when the projects involved have two or more funding sources. This study examines FAs that mention the Seventh Framework Programme (FP7) and tries to achieve a broader, fuller, more singular view than previous studies of FP7 by visualising co-funding networks and conducting a structural analysis of inter-agency relationships. This is done using open sources that have been linked after exhaustive data cleansing and harmonisation and the assignment of unique identifiers. Compliance with the objectives of the three most visible, most productive programmes is also examined, and the geographical distribution of the agencies participating in co-funding networks is evaluated. One intriguing result shows that the number of projects with associated publications has risen 21% thanks to FAs. Considerable differences between programmes are also revealed: IDEAS-ERC is the programme with the highest number of co-funders, and PEOPLE is the programme with the densest, most cohesive network. Lastly, it is found that a stronger commitment is required from all the actors involved in the course of co-funding and publication to ensure that the funding data provided is of the right quality to facilitate accurate, transparent, useful, full evaluations.

Introduction

Funding acknowledgements (FAs) generally occupy a section of their own in scientific articles, listing all the people and organisations that have funded, supported or contributed to the paper (Wang & Shapira, 2011). FA information is essential for understanding the research context, its communication processes and the essential role played by funding in scientific advancement. Information of this sort lends itself to various types of analysis, including the creation of co-funding maps, as a subset of scientific collaboration networks, with distinctive information that is useful for tracing other kinds of intellectual influences (Costas & van Leeuwen, 2012).

The quality of co-funding analysis is affected by the availability, integrity and quality of the metadata used and by the workableness of linking funding with published results for an accurate evaluation of the most efficient, effective funding systems, programmes and policies. FAs are crucial to such studies, because they name funding agencies and identify projects, and these are the basic components for building networks and establishing links between agents to connect funding with scholarly output. As the section on methodology will explain, the funding metadata used in this study were obtained from open sources that were combined to expand upon the

quantitative analysis perspective by adding the structural facet furnished by network analysis.

Furthermore, science policies in the European Union (EU) call for the transcension of traditional barriers to research. In that effort, they support transnational, multisector and multi, inter- and transdisciplinary research. Funding opportunities themselves, whether individual or collective, promote diverse, heterogeneous funding and funding co-use (Aagaard et al., 2021).

The Framework Programmes are a good example. The Framework Programmes are the main funding instrument for consolidating the European Research Area. The seventh programme (FP7) in particular made project co-funding one of its basic principles (European Commission, 2007). Funding plans for 2007-2013 were divided into collaborative projects, networks of excellence and coordination and support actions, with the objective of enhancing the competitiveness and excellence of science in Europe.

The main objectives of the Seventh Framework Programme are not limited to producing co-funding, but also include the following: to promote excellence in research, to foster competitiveness and economic growth, to help address social challenges, to strengthen human potential, to foster researcher mobility and to promote transnational cooperation in research. FP7's budget was 66% higher than FP6's. Eighty-one percent of the budget (44,600 million euros) was assigned to four preferred programmes, FP7-COOPERATION, FP7-IDEAS, FP7-PEOPLE and FP7-CAPACITIES (European Commission, 2018).

The main benefits of European funding as opposed to national funding are the following: access to international research, networking with leading scientists, better reputation, greater possibilities of obtaining additional funding and the formation of international consortia. The end result of all these efforts was greater participation by actors and stakeholders, helping to cast a more solid foundation for cooperation, at the national level as well.

FP7 is one of the few research funding programmes that maintained its budget, thus placing it in a better light in the eyes of the international research community. Global economic development no longer depends on the "triad" of North America, Japan and Europe. New actors are arising, including China, Korea and Latin-American countries, generating multipolar competition and creating the need to establish fresh partnerships (European Commission, 2018).

Lastly, prior studies of co-funding networks (Boyack, 2009; Wang & Shapira, 2011; Grassano et al., 2017; Aagaard et al., 2021; Mugabushaka, 2022 and Perianes-Rodríguez et al., 2024a) agree that the general processes involved in conducting these kinds of analyses are data gathering, data cleansing and data harmonisation. These processes vary depending on the underlying funding, its influence on the research and the way the funding is recorded. However, few studies run detailed analyses of the resulting networks and visualisations.

This study, then, examines the Seventh Framework Programme's co-funding network, bringing fresh perspectives that complement those described in other papers on FP7 funding (Mugabushaka, 2020; Ardanuy et al., 2023; 2024). Co-funding can help redefine traditional scientific collaboration practices, widen the

scope covered by the scarce economic resources available and underwrite projects that can make disruptive breakthroughs. In addition, because co-funding links diverse open data sources together, it enriches and expands the scope of accountability, helping to make the evaluation of science, technology and innovation policies more open and easily reproduced and fostering more efficient, more inclusive, more transparent evaluation ecosystems.

Objectives

The main objective is to run an open-source structural analysis of the effects of co-funding on FP7-funded projects and its role in scientific development, based on a study of research results published in scientific journals. A thorough empirical study explores the usefulness of the funding information reported in publication acknowledgements and the influence of co-funding, focusing especially on analysis of the resulting co-funding networks. For these purposes, the following secondary objectives are defined:

- To find the proportion of projects correctly labelled with their identifier in the FAs of papers published in scientific journals.
- To extract open-source funding metadata to determine their quality and the synergies that could result if they are appropriately combined.
- To determine the geographic composition of co-funding networks and to identify the main participating agencies.
- To analyse the relational indicators of the European funding programmes that have the highest number of projects with reported publications, to determine compliance with the funding programmes' main objectives.
- To identify the problems with co-funding data and the action needed to improve the quality of results based on metadata of this sort.
- To measure compliance with FP7's strategies and objectives on the basis of structural analysis of the published results of funded projects.

This study is structured as follows: "Data and methodology" describes how data were downloaded and processed and what methodology was used to create the co-funding maps; "Results" presents the base map of FP7 project co-funding and the leading bibliometric and structural data of the four target networks; "Discussion and conclusions" sums up the main findings on performance differences between the analysed programmes; lastly, "Limitations and future work" contains recommendations for improving the quality of data for co-funding analysis, proposes practical steps for the various agents involved and maps out future lines of research aimed at ascertaining the visibility and influence of co-funded papers.

Data and Methodology

The ties between research funding and the scientific results of funded research are hard to track and often require access to separate reports from researchers or funders (Wang & Shapira, 2011). Although FP7 project funding ended in 2014, the last funded projects were not complete until 2019, and papers reporting work funded by

FP7 projects are still being published today (Ardanuy et al., 2023). These are the results of research that needs to be analysed from a holistic perspective, making use of open data to gain a clearer picture of the synergies between funders and to determine the influence of the publications that funders sponsor.

From the start FP7 was split into four programmes, Cooperation, Ideas, People and Capacities, as a means of better achieving its European research support objectives. The main anticipated results included stronger industrial competitiveness for Europe, job growth and the identification of new ways to improve research and innovation infrastructure to ensure the quality of science and effective complementarity among Community institutions (European Commission, 2016).

Analysis of funding programmes based on the data available from open bibliographic sources can be used to evaluate the operation, scope and impact of these programmes and determine their efficacy and transformative ability. One source used in this study is CORDIS[1], which is the source of official FP7 data on projects and publications reported by beneficiaries (Ardanuy, 2023). Another data source is Crossref[2], the leading international registration agency of Digital Object Identifiers (DOIs), through its Open Funder Registry (OFR) initiative. Crossref is a complementary source that provides data on publication funding based on the information released by authors and editors in publication acknowledgements (Álvarez-Bornstein & Montesi, 2020). Authors and editors must furnish information on the funding agency involved, its unique identifier and the project's number (Kramer & de Jonge, 2022). To reach its objectives, this study uses the methodology described in Perianes-Rodríguez et al. (2024a), which employs linked open metadata from various data sources to analyse funding agencies' performance. Account is also taken of co-funding network studies described in Boyack (2009), Wang & Shapira (2011), Grassano et al. (2017) and Mugabushaka (2022), which are the theoretical and visual forefathers of this paper. The analytical processes are described below.

Data gathering and processing

Data cleansing and harmonisation require an immense amount of manual work to locate and enter information related with the target funding sources (Wang & Shapira, 2011). The first step in this project was to download data on projects and publications from CORDIS and data on the various FP7 programmes mentioned in acknowledgements in OFR, in July 2023. Next, the data were disambiguated and standardised. Of the 320,448 rows downloaded, 318,322 (99.33%) were disambiguated, and the funder's ISO 3166-1 alpha-3 country codes were added. In the case of funders with headquarters in more than one country, the country of the official headquarters was used. Of the 119,284 lines of European Commission funders, the 99,621 rows that included project numbers were reviewed. After harmonisation 91,887 rows (92.23%) were left. This intense cleansing process considerably boosted the quality and accuracy of the original data used in the structural analysis of the co-funding networks.

[1] https://cordis.europa.eu/

[2] https://www.crossref.org/services/funder-registry/

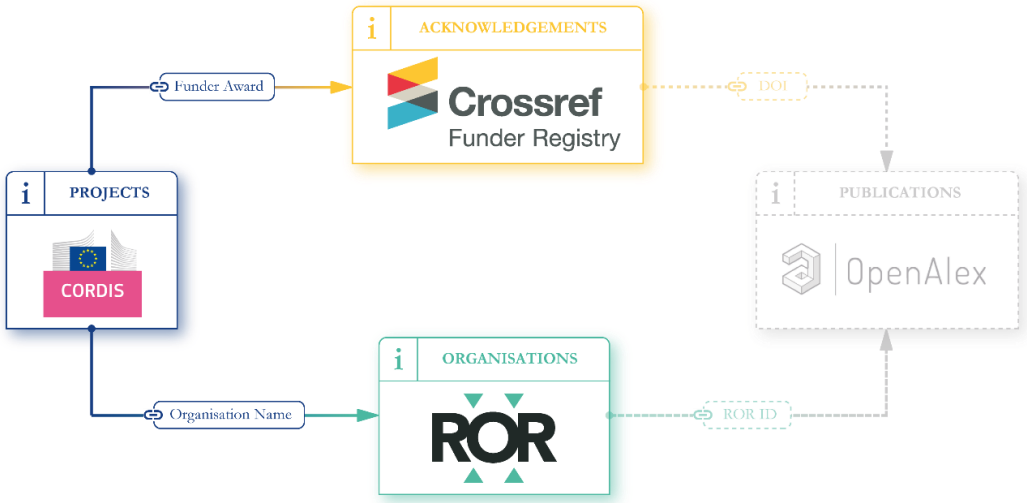

Figure 1. Linked open data. Schema of sources and normalised identifiers.

The Research Organization Registry (ROR) was also used to complete or correct institutional identifiers. This source provides standardised information about institutions and enables research organisations to be linked to their researchers and their research results (ROR, 2024). Figure 1 illustrates the linking procedure and the standardised identifiers used to connect the three data sources. OpenAlex is shown in grey, because it will be used in future research work.
The metadata extracted from each source are shown in Table 1.

Table 1. Sources and list of downloaded metadata.

Source	*Metadata*
CORDIS	Project identifier, title, publication DOI, total funding, year, grantee organisation, country, FP7 funding scheme.
OFR	Publication DOI, title, funder DOI, funder name, project identifier.

The main problems found in the information downloaded from OFR were disparities in funder names, gaps in the identification of project codes and an absence of essential data, like the funder's country. For example, the Dutch Research Council (NWO) appears under 150 variants of its name, and the Karolinska Institutet has 35 name variants listed.

Table 2. Basic indicators of projects and publications by source.

Sources	*Projects*
CORDIS	25,785
CORDIS with publications	14,297
CORDIS and OFR	9,250
CORDIS with publications and OFR	6,230
OFR only	3,020

Sources	*Publications*
CORDIS	216,004
OFR	47,493
CORDIS and OFR	7,333

Finally, 7,333 publications that matched in CORDIS and OFR could be connected. They referred to 9,250 projects, 6,230 of which had publications reported in CORDIS. Surprisingly, 3,020 projects were located without publications reported in CORDIS but with explicit acknowledgements in OFR, which is to say that one out of every five projects with publications was not included in CORDIS.

Structural indicators

The following structural indicators were analysed:

a) Nodes: Total number of funding agencies.
b) Edges: Number of connections between nodes.
c) Density: Proportion of real links relative to the maximum number of possible edges.
d) Average degree: The average number of edges per node.
e) Degree and betweenness centralisation: Centralisation of a network is a measure of how central its most central node is in relation to how central all the other nodes are. So, the measures analyse centralisation of degree (number of edges with adjacent nodes) and betweenness (frequency of a node on the shortest paths between other actors).
f) Average distance: Average shortest path length between nodes. It is a measure of the efficiency of communication in a network.
g) Diameter: The shortest distance between the two most distant nodes, that is, the longest of all the path lengths in the network.

Visualisation of co-funding networks

The networks were visualised using Pajek[3] (Batagelj & Mrvar, 2004). To create the networks, multiplicative counting (Perianes-Rodríguez & Ruiz-Castillo, 2015) and fractional counting (Perianes-Rodríguez et al., 2016) were employed. It was decided to use fractional counting because that is the method recommended in bibliometric studies of countries and research organisations (Waltman & van Eck, 2015). Analyses based on fractional counting show that scientific collaboration preferably takes place with national partners, and this circumstance helped in labelling the resulting clusters.

For the creation of the co-funder network base map, the methodology described by Leydesdorff & Rafols (2009) was used. Communities were extracted using the Louvain algorithm (Blondel et al., 2008). For spatial representation, the Kamada-Kawai algorithm (1989) was employed. Of the initial 4,459 funders, the analysis was restricted to the 947 that participated in the co-funding of at least 10 publications (not including EU funders). The national and regional ministries of each European country were grouped under a single government funder.

The aggregated data set is available as supplementary material at https://doi.org/10.5281/zenodo.14502483 (Perianes-Rodríguez et al., 2024b).

Results

The base map shows the general co-funding patterns of the set of projects and publications. Each of the nodes represents a funding agency. Node size depends on the number of papers co-funded. Links become thicker and darker as the number of co-funded publications increases. The base map contains 947 nodes linked by 29,521 edges (the IDEAS-ERC, PEOPLE and HEALTH co-funding maps are available in annexes 1 to 3).

[3] http://mrvar.fdv.uni-lj.si/pajek/

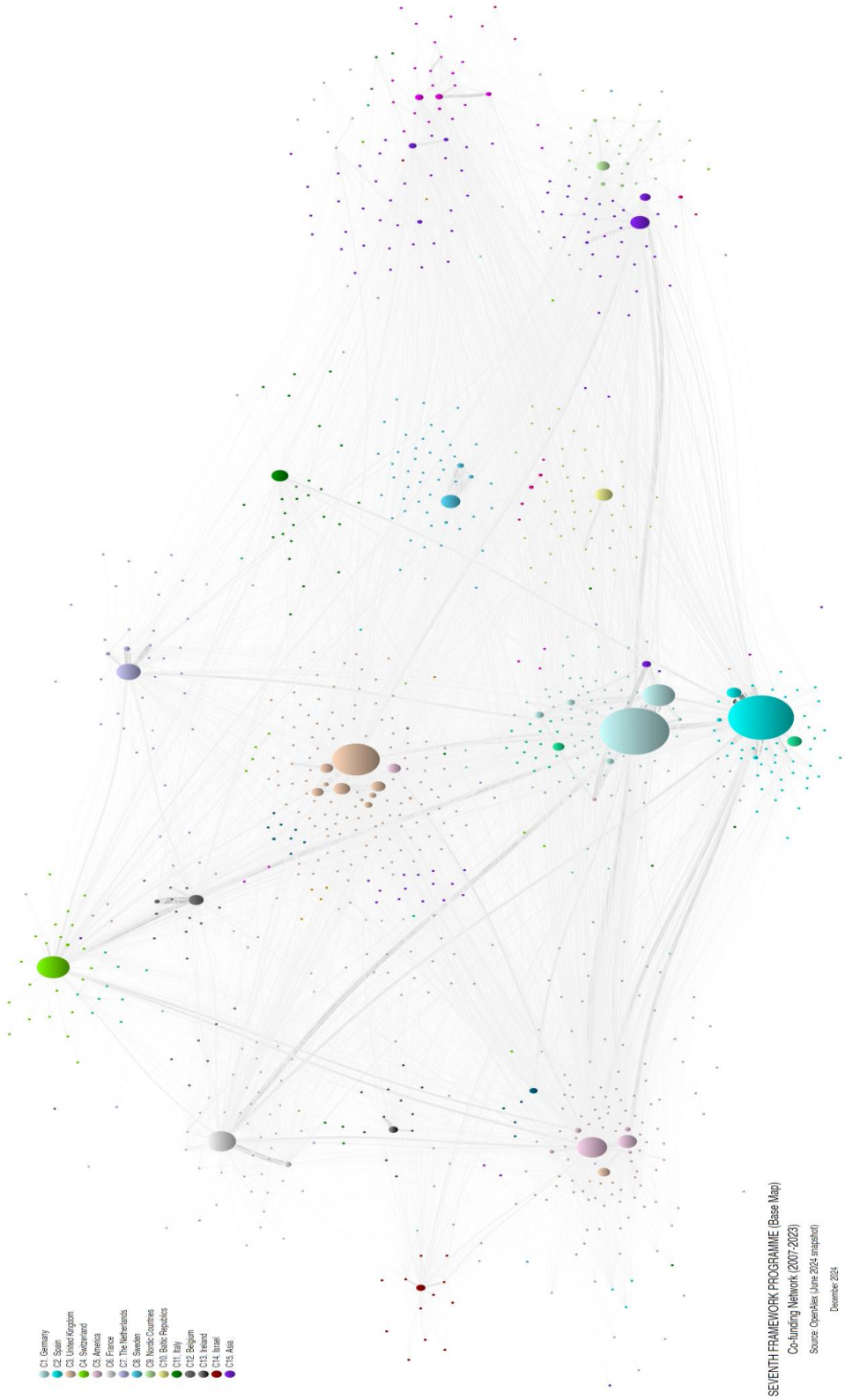

Figure 2. Co-funding base map. Sources: CORDIS and OFR (2007-2023).

Table 3 presents the ten most productive co-funding organisations in FP7. German and Spanish national research foundations have by far the highest number of co-funded projects.

Table 3. Ten most productive international funding agencies in FP7.

Funder	*Country*	*Publications*	*Projects*
German Research Foundation (DFG)	Germany	1,840	1,625
Agencia Estatal de Investigación (AEI)	Spain	1,739	1,899
Engineering and Phys. Sci. Res. Council (EPSRC)	United Kingdom	1,254	988
Government of Germany	Germany	865	619
Schweizerische Nationalfonds (SNSF)	Switzerland	864	765
National Science Foundation (NSF)	United States	803	855
Agence Nationale de la Recherche (ANR)	France	794	684
Dutch Research Council (NWO)	The Netherlands	641	490
FORMAS	Sweden	514	400
National Natural Science Foundation (NSFC)	China	510	776

The data from Table 4 have been used to label clusters based on homogeneity; homogeneity in this case is shown primarily on the basis of geographical links. Each cluster's label indicates the cluster's predominant country or geographical area. There are clusters that are more heterogeneous, like C5, made up of funders from the United States, Canada, Brazil and Chile, C10, which contains funders from Finland and Baltic republics, and C15, which consists of funders from southeast Asia.

Other groups are much more homogeneous. For example, 83.9% of the funders in C11 are Italian. Co-funders from the Netherlands make up 93.9% of C7. Only C9 has a homogeneity of under 50%; Norwegian and Danish agencies account for only 36.4% of the group.

The country proportions in Table 5 reveal that all the funders from the Baltic countries and Ireland fall into C10 and C13, respectively. Other countries, like Sweden (96%), Israel (92.9%) and Spain (91.3%), have practically all their funders in C8, C14 and C2. Asia is an exception: only 39.8% of its funding agencies are members of C15. The proportions of non-European funders are shown in blue. Interestingly, four out of 10 funders are Asian, British or American.

Table 4. Proportion of funders by cluster (nationality).

Country/Region	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*	*C9*	*C10*	*C11*	*C12*	*C13*	*C14*	*C15*	*Total*
DEU	61.7	0.0	1.1	2.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	1.1	6.8
ESP	0.0	71.2	0.5	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8
GBR	1.1	1.7	42.1	7.5	9.0	0.0	0.0	0.0	1.3	0.0	3.2	0.0	0.0	0.0	1.1	10.4
CHE	2.1	0.0	2.1	57.5	0.8	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	1.1	3.4
America	9.6	10.2	33.7	2.5	76.7	1.8	3.0	2.0	5.2	6.7	3.2	20.8	29.4	15.0	9.1	22.4
FRA	1.1	1.7	2.6	2.5	1.5	78.2	3.0	0.0	0.0	0.0	3.2	4.2	0.0	0.0	1.1	6.0
NLD	2.1	0.0	1.1	2.5	0.8	1.8	93.9	0.0	1.3	0.0	0.0	8.3	0.0	0.0	0.0	4.3
SWE	0.0	0.0	0.0	0.0	0.8	0.0	0.0	94.1	1.3	0.0	0.0	0.0	0.0	0.0	0.0	5.2
Scandinavia	0.0	0.0	0.5	0.0	0.0	1.8	0.0	0.0	36.4	4.4	3.2	0.0	0.0	0.0	1.1	3.6
Baltic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	82.2	0.0	0.0	0.0	0.0	0.0	3.9
ITA	1.1	1.7	0.5	0.0	0.8	5.5	0.0	0.0	0.0	2.2	83.9	0.0	0.0	0.0	2.3	3.8
BEL	0.0	0.0	0.5	2.5	0.0	10.9	0.0	0.0	0.0	0.0	0.0	58.3	0.0	0.0	1.1	2.4
IRL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.6	0.0	0.0	1.3
ISL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.0	1.1	1.5
Asia	2.1	1.7	7.4	2.5	2.3	0.0	0.0	0.0	42.9	4.4	0.0	0.0	0.0	0.0	42.0	9.7
EU-14	16.0	10.2	0.5	20.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	4.2	0.0	0.0	1.1	3.4
EU-13	3.2	1.7	0.5	0.0	0.0	0.0	0.0	0.0	2.6	0.0	0.0	4.2	0.0	0.0	25.0	3.1
Oceania	0.0	0.0	4.2	0.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4
Africa	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.6
Rest of Europe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	6.5	0.0	0.0	0.0	0.0	15.0	11.4	2.1

Table 5. Proportion of funders by country.

Country/Regio	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*	*C9*	*C10*	*C11*	*C12*	*C13*	*C14*	*C15*
DEU	89.	0.0	3.1	1.5	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.5
ESP	0.0	91.	2.2	0.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GBR	1.0	1.0	80.	3.0	12.	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0
CHE	6.1	0.0	12.	69.	3.0	0.0	0.0	0.0	6.1	0.0	0.0	0.0	0.0	0.0	3.0
America	4.2	2.8	29.	0.5	47.	0.5	0.5	0.5	1.9	1.4	0.5	2.3	2.3	1.4	3.7
FRA	1.8	1.8	8.8	1.8	3.5	75.	1.8	0.0	0.0	0.0	1.8	1.8	0.0	0.0	1.8
NLD	4.9	0.0	4.9	2.4	2.4	2.4	75.	0.0	2.4	0.0	0.0	4.9	0.0	0.0	0.0
SWE	0.0	0.0	0.0	0.0	2.0	0.0	0.0	96.	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Scandinavia	0.0	0.0	2.9	0.0	0.0	2.9	0.0	0.0	82.	5.9	2.9	0.0	0.0	0.0	2.9
Baltic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.	0.0	0.0	0.0	0.0	0.0
ITA	2.8	2.8	2.8	0.0	2.8	8.3	0.0	0.0	0.0	2.8	72.	0.0	0.0	0.0	5.6
BEL	0.0	0.0	4.3	4.3	0.0	26.	0.0	0.0	0.0	0.0	0.0	60.	0.0	0.0	4.3
IRL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.	0.0	0.0
ISL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92.	7.1
Asia	2.2	1.1	15.	1.1	3.2	0.0	0.0	0.0	35.	2.2	0.0	0.0	0.0	0.0	39.
EU-14	45.	18.	3.0	24.	0.0	0.0	0.0	0.0	0.0	0.0	3.0	3.0	0.0	0.0	3.0
EU-13	10.	3.3	3.3	0.0	0.0	0.0	0.0	0.0	6.7	0.0	0.0	3.3	0.0	0.0	73.
Oceania	0.0	0.0	61.	0.0	38.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Africa	0.0	0.0	83.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.
Rest of Europe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.	25.	0.0	0.0	0.0	0.0	15.	50.
TOTAL	9.8	6.2	19.	4.2	13.	5.7	3.4	5.3	8.0	4.7	3.2	2.5	1.8	2.1	9.2

C8 is a special cluster. It contains 96% of the Swedish funding agencies, which in their turn make up 94.1% of the agencies in this cluster. This means the agencies are extremely autonomous or extremely isolated (averse to co-funding with institutions from other countries or regions). On the other hand, 40% of Asian institutions only make up 42% of cluster C15. C15 is the most heterogenous, most dependent cluster, as might be expected of a cluster of non-European funders. The same may be said, although to a lesser degree, about agencies from America and the United Kingdom. In this sense, it should be noted that this study maintained the current EU-27 group, even though the United Kingdom was an EU member country during FP7.

In C1 61.7% are German agencies, accounting for 89.2% of all German funders. EU-14 countries, like Austria (45.5%), have significant weight in this cluster. Something similar happens in C2, where 71.2% of funders are Spanish, accounting in their turn for 91.3% of all Spanish funders. In C3 80% of funders are British, but they account for less than half (42.1%) of the British agencies in the network. Important co-funding with American countries and with practically all the African countries and Oceania can be seen.

Consequently, the most heterogeneous clusters are C5, C9 and C15. In cluster C5 76.6% are American funders, but they make up only 47.7% of the region's funders; this indicates wide scattering. The scattering is even greater in C15, where less than 40% of the funding agencies are from Asia. These anomalies can be explained by the fact that the regions in question are not directly involved in FP7 funding and their collaboration takes place in different clusters obeying diverse interests, where the national or regional effects are less intense.

The base map of FP7 co-funders includes those agencies that are mentioned in the acknowledgements of at least 10 publications. Using this threshold can help augment the effects of regionalisation. In terms of structural indicators (Table 6), it is a large network, with more than 900 nodes. The total number of edges (29,521) is only 6.6% of the possible connections; this indicates low density, although the network is much more dense than other, larger technological networks (Ji et al., 2024).

The average degree (62.35) and degree centralisation (0.56) of the base map are considerably higher than those of the other programmes. This suggests a greater ability to attract funding partners, although the network's centralised structure has few funding agencies in a leading role. The average distance (2.07) is very low, as is the diameter (4), revealing that this is an efficient network with abundant inter-cluster node edges.

Table 6. Structural indicators. Base map, Ideas, People and Health.

Indicators	*Base Map*	*Ideas-ERC*	*People*	*Health*
Nodes	947	431	121	223
Edges	29,521	7,894	2,480	3,314
Density	6.59	8.52	34.16	13.39
Average degree	62.35	36.63	40.99	29.72
Degree centralisation	0.56	0.43	0.49	0.40
Betweenness centralisation	0.085	0.077	0.057	0.080
Average distance	2.07	2.16	1.70	2.06
Diameter	4	4	3	5

In addition to the characterisation of the base map, Table 6 contains the structural indicators of FP7's top three funding programmes by number of publications and projects. FP7-IDEAS-ERC is the programme with the most publications (3,174) and the most projects mentioned in OFR acknowledgements (1,185). FP7-PEOPLE is acknowledged in 564 publications mentioning 360 projects. Lastly, FP7-HEALTH (part of FP7-COOPERATION) is named in 1,055 publications mentioning 308 projects.

The subprogramme with the most funding agencies is IDEAS-ERC (431), and, although it is also the network with the most edges, its density (8.52) is less than that of the other two subprogrammes. This is to be expected, since IDEAS-ERC provides funding for individual researchers. What is noteworthy is the high number of co-funders its grantees attract.

PEOPLE has an extremely high density (34.16) and great compactness, with the lowest betweenness centralisation (0.06), the highest average degree (40.99), the highest degree centralisation (0.43) and the lowest average distance (1.7) of the three subprogrammes.

HEALTH does not stand out in terms of any of its indicators. It is not the most numerous network (223 nodes) or the densest (13.39%). Its diameter is the greatest (5), its betweenness centralisation is the highest of the subprogrammes (0.080), and its degree centralisation is the lowest (0.40). The picture is one of an incohesive, less efficient, more centralised network with a few important nodes to which most of the edges are connected.

Discussion and Conclusions

Structural analysis of the projects and publications of the main programmes of FP7 reveals high co-funding in this macro-programme. Contributions from the funding agencies of European countries and different regions give the programme an extra boost; it is estimated that, for each euro invested, FP7 generated 11 euros of direct and indirect economic effects in the form of innovations, new technologies and products that help meet social challenges and improve the quality of European science systems (European Commission, 2018).

Surprisingly, the publication acknowledgements downloaded from OFR are found to mention 3,020 projects that do not have associated publications reported in CORDIS. This increases the number of FP7-funded projects with scholarly output by 21%. This discovery highlights the great usefulness of analysis based on multiple sources in this and other kinds of studies. In addition, it emphasises the urgent need for the actors involved in all funding flow processes to be responsible and to report and publish accurate, reliable funding acknowledgements in their research results. Research strategies and policies that facilitate access to such data must continue to be implemented, so the data can be analysed properly and the quality and transparency of research can be improved.

It is found that 40% of co-funding agencies are from non-European countries, thus revealing a high level of international cooperation. Asia and America are especially active. This finding is in line with FP7's strategic objectives, which seek to

strengthen competitive international participation in projects as well as in training and mobility actions.

The comparison of co-funding data on the three main FP7 subprogrammes reveals big differences. The IDEAS-ERC co-funder network is the most numerous, has the most publications and includes acknowledgements of more projects. For a programme aimed at individual grantees, it is surprisingly successful at attracting co-funders, doubly so because IDEAS-ERC does not require cross-border associations. This programme bases a good deal of its work on European associations, which enable effective collaboration, thus helping to comply with the scientific strategies mapped out for the programme, focusing on cutting-edge research. Future studies on the visibility of its research results will help arrive at a clear understanding of the excellence it has attained.

The PEOPLE network is the densest, most compact and most decentralised (least influenced by major nodes). Its intense connections speak to the programme's success in reaching its main objective, which is to connect European researchers and institutions through mobility to foster scientific collaboration. PEOPLE's high degree of co-funding activity is aligned with its actions aimed at coordinating scientific collaboration relationships between institutions on the basis of mobility and other instruments oriented toward the lifelong development of researchers' skills and competences. These results agree with those of the ex-post evaluation of the Framework Programme, which states that FP7 helped establish research networks (European Commission, 2018). The degree of excellence the report also mentions has yet to be corroborated by future analyses of published results' visibility.

The results of IDEAS and PEOPLE contrast with those of HEALTH. HEALTH is one of the main thematic areas of COOPERATION, the programme that manages two thirds of FP7's total budget. The objectives of conducting cooperative research in Europe and with other countries through transnational consortiums partnering industry and academia have been partially met from the structural perspective. Although HEALTH has a considerable number of collaborators and moderate density, it has a small number of nodes centralising relationships, and those nodes play too strong a role.

Results by regions show that some clusters are highly independent, while others are dependent. Among the independent clusters, the Swedish funding agencies are extremely isolated from other co-funders. Ninety-four percent of the nodes in cluster C8 are Swedish, and they in their turn account for 96% of all the Swedish funders in the entire network, leaving little margin for international co-funding for the work they sponsor.

Among the dependent clusters, there are two kinds of dependence. First, the dependence of small European countries that establish geography-based ties with larger neighbours, as in the case of Austria (tightly linked to German agencies) and Portugal (tightly linked to Spanish agencies). This sort of dependence reveals collaborations based on social, cultural or linguistic affinities. Another, sharper kind of dependence is found in the agencies of non-European countries, like America and Asia. They appear scattered in diverse clusters, denoting associations that seem to be based more on thematic affinities than on regional or social ties.

Lastly, as stated before, the quantity and quality of the data furnished by FAs are decisive and make a difference in the evaluability of research funding performance. Agencies must set specific mandates for researchers to include clear, precise statements of the funding they have received (which means designing unique project numbers). Researchers have the obligation to acknowledge the support behind their research. Editors must make it easy to report this information, for example, by establishing separate sections where authors must identify their funder and give an unambiguous project number.

Limitations and Future Work

Although this work does not have the disadvantages associated with sample analysis, because it analyses all the publications in Crossref that give an FA and all the projects in CORDIS with FP7 funding, it is not free of limitations. The main drawbacks that limit the scope of the results include poor access to quality funder data, problems in detection and availability of funder award metadata in databases, and errors and omissions in funding information on the part of authors and/or editors.

Furthermore, FA-based evaluation examines only one facet of research work. It fails to explore other aspects of scientific activity, like the number of patents registered, the number of cooperation agreements signed, the number of contracts concluded, young researcher training, conference organisation or scientific equipment procurement or construction.

Also, while the methods, techniques and results presented in this study are extremely helpful for evaluating funding systems, they cannot replace expert judgement in decision making. As editors demand the inclusion of accurate, reliable funding data, readers will trust the results more fully, funders will be able to conduct more accurate analyses of compliance with their objectives and specialists in quantitative studies of science will be able to consolidate this area of study.

Future work to flesh out this analysis should look into the role of funding agencies in highly cited publications, evaluate the influence of co-authorship and co-funding on productivity and publication influence, and analyse the productivity and visibility of the research published in each of the FP7 programmes. Then, quantitative and structural analyses will offer a significant, singular view of compliance with the general objectives of the framework programme and all its subprogrammes.

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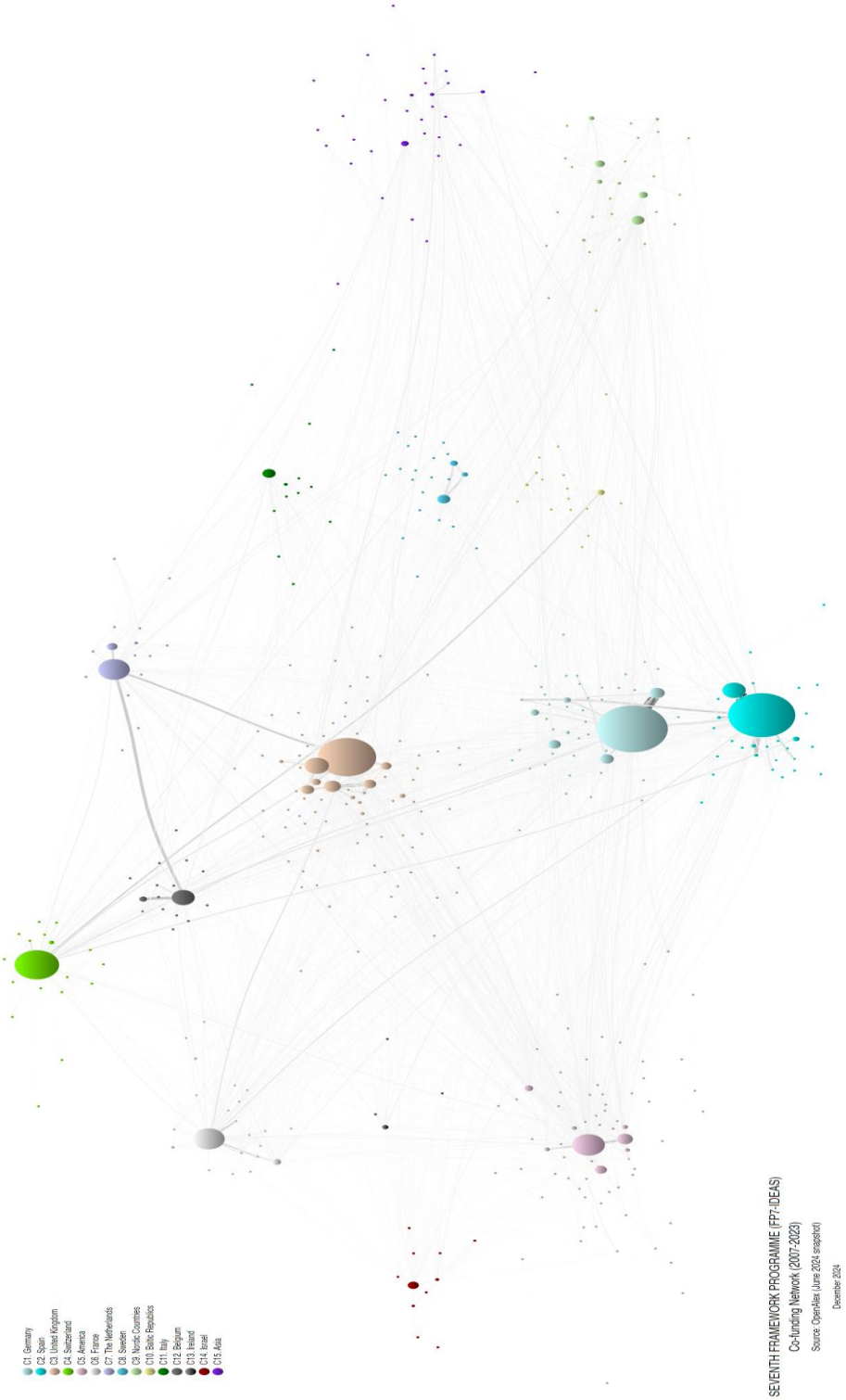
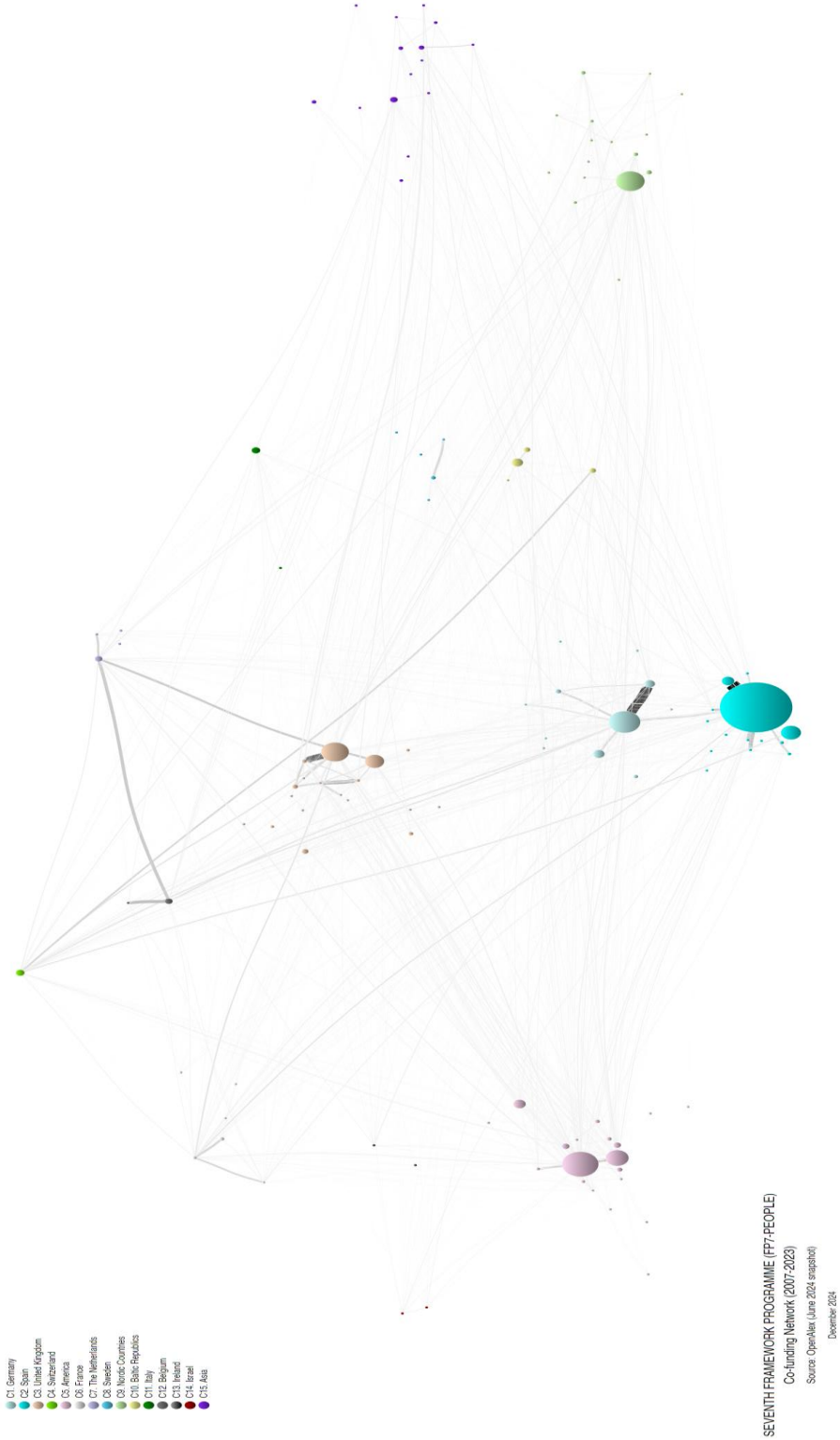
Annex 1. Co-funding Map. FP7-IDEAS-ERC. Sources: CORDIS and OFR (2007-2023).



Annex 2. Co-funding Map. FP7-PEOPLE. Sources: CORDIS and OFR (2007-2023).



Annex 3. Co-funding Map. FP7-HEALTH. Sources: CORDIS and OFR (2007-2023).