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Network collaboration in the 6th Framework Programmes: country participation in the health thematic area

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Abstract This paper aims to explore the role of each country in the health thematic area of the 6th Framework Programme (6FP) of the EU. We try to explain how the collaborative research processes are generated in a research programme using social network analysis (SNA) tools. We have modelled a one-mode network set up by 2,132 organizations which participate in 601 research projects. This network was shrunk at the country level, obtaining a network of 31 countries. Results show that there is a strong relationship between R&D indicators and the structural position of each country in the network. The paper concludes that the SNA techniques are a suitable tool to assess the country performance in the EU research programmes.

Keywords Scientometrics · EU research programmes · Network analyses · Country collaboration

Introduction

The progress made in data analysis and computing has allowed to study in depth the structural relationships in complex environments such as the Web (Barabasi and Albert 1999), disease spreading (Pastor-Satorras and Vespignani 2001) and trophic dynamics (Polis and Strong 1996). However, the scientific activity could be also described as a complex system in which several agents (industry, university, government, etc.) interact in an environment subject to multiple variables. The use of structural analyses in R&D has made possible to understand collaboration phenomena in scientific journals (Newman 2001; Barabasi et al. 2002; Wagner and Leydesdorff 2005), citation network among papers

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(Small 1999) and journals (Leydesdorff 2004) or relationships between patents (Valverde et al. 2007).

The European R&D system is strongly supported by the EU Framework Programmes, as relevant tools for the building and strengthening of the European Research Area (ERA). These programmes assume the collaborative research as a principal feature of the ERA system in which the projects must to be carried out by several organizations from different countries and sectors. This networked environment provides a great opportunity to understand how these relationships are made; which are the main actors and their role into the system; and how the network operates in order to improve the EU R&D system.

Previous works have already analysed the collaborative networks of the European programmes. Breschi and Cusmano (2004) studied the R&D joint ventures of the 3rd and 4th Framework Programmes. They found that there was a preferential attachment phenomenon (Barabasi and Albert 1999) between both calls. Barber et al. (2006) studied from the second to the fifth Framework Programmes, confirming that these networks had scale-free properties such as power law degree distributions, small diameters and high clustering. Roediger-Schulga and Dachs (2006) found significant differences in two EU programmes. They detected that while the telecommunication programme had more industrial partners and required greater funding; the agricultural one was dominated by public research institutions and attracted less income. These differences between research programmes was analysed by Cabo (1999) as well. Roediger-Schulga and Barber (2007), using the same data set, visualized the first five EU Framework Programmes, showing that the backbone of the network is shaped by large scientific organizations. Ortega and Aguillo (2008) presented a network analysis of the health thematic area of the 6FP. Kuitunen et al. (2008) also presented several network graphs which showed the collaboration of the Finn institutions with the rest of participants. Recently, several EU reports have studied the relationships between the performance of the participant organizations in the 6th Framework Programme (6FP) and their publication productivity and impact (Avedas et al. 2009; Larrue et al. 2009).

At the country level, we can highlight the works of Gusmao (2000, 2001) about the cohesion of the ERA through the EU research programmes, concluding that those programmes are being a key instrument to built strong collaborative ties between research teams from different countries. She argues that these programmes are creating "European-minded" scientists. Lepori et al. (2007), through a comparative approach of several national funding systems, explored the development of comparable indicators between European countries, taking into account the singularities of each national research system. Braun et al. (2009) also developed specific indicators to measure the performance of organizations and countries in their participation on the EU Framework Programmes as a way to assess the integration of the European Research Area.

Objectives

This paper aims to explore how the different research partners are related among them in the 6FP of the EU, specifically the "Life sciences, genomics and biotechnology for health" thematic area. We try to know what is the role of each country in these programmes, how they interact with other partners. To sum up, we try to explain how the collaborative research processes are generated in a research programme using social network analysis (SNA) tools, introducing these techniques as a suitable tool for the understanding of the collaboration processes in science. It also attempts to answer if there are any relationships

between traditional R&D indicators and structural indicators such as centrality degree and betweenness centrality.

Methods

We have modelled a one-mode network set up by 2,132 organizations which participate in 601 research projects belonging to the "Life sciences, genomics and biotechnology for health" thematic area from the 6FP of the EU. These data were obtained through the Centre for the Development of Industrial Technology (CDTI), the Spanish public body depending of the Ministry of Science and Innovation in charge of promoting and funding innovation and technological development. CDTI supplied us an own database from eCORDA data (e-CORDA 2010). That ad-hoc database contains the list of organizations (name, nationality and type of organization) which participate in each project (code, total cost and task) of the health thematic area. Participation table includes subvention, percentage of subvention, percentage of participation and role. However, a confidentiality rule only let us to operate with aggregated data and percentages.

This network represents the collaboration relationships between several research institutions through different research projects. This network was shrunk at the country level, obtaining a network of 31 countries. Data analysed in this study were:

- % Funds: Percentage of the incomes that every organization from one country receives for its participation in a project, over the total amount of available funds in the 6FP.
- Organizations: number of individual participant organizations in each country.
- Role: the performance of the organization in a project. It can be partner or coordinator:
  - Coordinators: Number of projects in which an organization of a country was coordinator.
  - Partners: Number of projects in which an organization of a country was a partner.

A normalization process was carried out to correct the name of each institution to a standard name in English, removing names of the same institution in other language. We also removed acronyms, except when these are better known than their extended name, i.e. INSERM, IRCCS, etc. This normalization process reduced to 17% the number of organizations. Similar studies, after a cleaning process, found similar number of projects and partners (European Comission 2008; Avedas et al. 2009), which reinforce the data validity and the results consistency.

Several variables were used in order to add information about the network configuration and to design different analysis and relationships between variables and countries. Nodes size shows the % Funds of each country. Arc width shows the number of project in which both countries participate. Countries were classified in four geographical and political classes: EU-15 countries, EU-27 countries, European no EU countries and No European countries. Network graph only shows countries that collaborate with two or more countries in the research programme.

The program Pajek 1.02 (Nooy et al. 2005) was used to build and visualise the network, and the Fruchtermann and Reingold (1991) was used to energize it. Several network indicators and measurements were calculated from the network using Ucinet 6 (Borgatti et al. 2002). In this study we have used the following indicators:

- Centrality Degree (k): It measures the number of lines incident to a node (Freeman 1979). This can be normalized (nDegree) by the total number of nodes in the network. This indicator allows detecting countries that have a high collaboration degree with other different countries, showing a high activity in the research programmes.
- Freeman's Betweenness centrality (Freeman 1980): It measures the capacity of one node to help connect those nodes that are not directly connected to each other. Its normalization is the percentage over the total number of nodes in the network. From a scientometric point of view, this measurement allows us to detect hubs or gateways that connect different countries to the core of the networks, showing the capability of certain countries for attracting partners to the research programmes.

Several regression models were carried out to estimate and quantify the relationship between programme variables and network indicators. Linear regression allows us to know if exists a relationship of dependence between variables. Two assumptions on this model are necessary: the independence of the observations and the normality of the distribution. The first one states that none of the observations determine the following one. The second assumption obliges to the variables to have a normal distribution which density function has to be symmetric.

Percentage of Funds follows a no-gaussian distribution, so it was transformed to a logarithmic scale. Logarithm regressions can be seen as a straight line on a log-normal graph since, transforming the dependent variable to a logarithmic scale converts the logarithmic equation into:

$$\log(y) = k(x) + \log(a)$$

These variables and attributes were analysed and processed with SPSS 15 and XLStat 2008 statistical packages.

Results

Country network

Figure 1 shows that the EU-15 countries are the most frequent participant countries in the health thematic area of the 6FP. This maybe due to their large experience in those research programmes. The main countries in the network according to their centrality degree are United Kingdom and France ($k = 30$) followed by Germany ($k = 29$). However, we appreciate that there are non EU-15 countries with a centred position such as Switzerland ($k = 28$), Hungary ($k = 23$) and Czech Republic ($k = 22$). Switzerland is an example of the traditional scientific collaboration, which participates in those research programmes as a full member (Swiss State Secretariat for Education and Research 2007). Hungary and Czech Republic are emerging countries in the new EU-27 framework which wish to increase their position in the EU research programmes. On the contrary, we observe EU-15 countries with a low centrality degree such as Portugal ($k = 15$), Ireland ($k = 17$) and Greece ($k = 21$) which although being older EU members show a low degree of research collaboration.

Table 1 shows the most important countries by the percentage of funds received per number of participant organizations. Germany receives the largest proportion of funds (18.54%) followed by United Kingdom (16.58%) and France (13.06%). However, there is a size factor that influences on this appreciation, because these same countries contribute

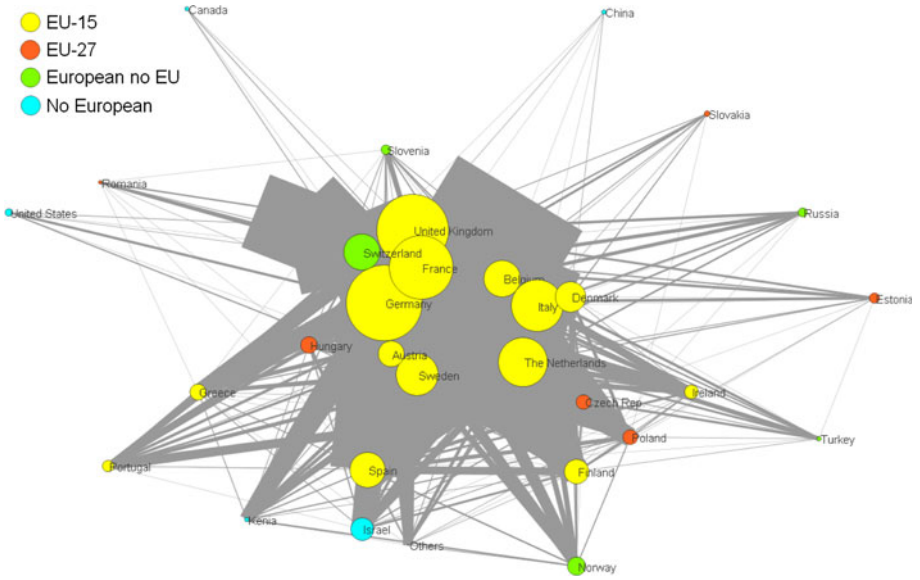

Fig. 1 Country collaboration graph of the health thematic area of the 6FP

Table 1 20 top countries ranked by fund percentage per number of participant organizations

Countries	Funds (%)	Organizations	Organizations (%)	Funds/organization (%)
United Kingdom	16.58	247	11.59	.0671
Sweden	5.67	86	4.03	.0659
The Netherlands	7.76	118	5.53	.0657
Finland	1.91	33	1.55	.0580
Germany	18.54	322	15.10	.0576
Switzerland	4.20	78	3.66	.0538
France	13.06	248	11.63	.0527
Italy	8.62	187	8.77	.0461
Denmark	2.96	68	3.19	.0436
Belgium	4.28	100	4.69	.0428
Israel	1.66	41	1.92	.0404
Spain	3.97	106	4.97	.0375
Greece	.83	24	1.13	.0347
Austria	2.16	63	2.95	.0342
Norway	1.06	31	1.45	.0341
Czech Republic	.68	21	.98	.0324
Ireland	.61	19	.89	.0320
Hungary	.88	34	1.59	.0260
Estonia	.34	14	.66	.0241
Poland	.70	32	1.50	.0218
Total	100	2132	100	.0469

with the largest number of organizations to the health programmes as well. Thus, 15.1% of the participant organizations are German, 11.63% French and 11.59% British. We have normalized the percentage of funding by the number of organizations in each country (%*F*/Org) in order to avoid this effect and to show a new indicator more closely related to the effort of each country in achieving research funds. According to this indicator, United Kingdom is the country that most percentage of funds achieves by organization (%*F*/Org = .067), followed by Sweden (%*F*/Org = .066) and The Netherlands (%*F*/Org = .066). It is interesting to notice the emergence of Sweden, The Netherlands and Finland, while Germany (%*F*/Org = .058) or France (%*F*/Org = .053) move to average positions. It is also interesting to observe that non EU countries such as Switzerland (%*F*/Org = .054) or Israel (%*F*/Org = .04) have better performance than important EU countries such a Spain (%*F*/Org = .038) and Austria (%*F*/Org = .034).

We assume that a country which research teams participate in the 6FP more as coordinators than as partners, they are leaders of that research issue. At the country level, we may observe which country holds more leader institutions or research groups in an EU research programme. Table 2 shows the participant countries ranked by the percentage of projects coordinated/total projects in each country. It shows that Iceland (60%) and Norway (33.33%) are the countries with the highest coordinator/partner percentages, followed by Germany (23.51%) and Belgium (23.29%). However, Iceland and Norway have a scarce participation, so we think that these percentages are not representative due to their small weight in the EU research programmes. So, we have calculated the percentage of

Table 2 Countries ranked by the percentage of coordinators

Country	Partners	Coordinators	Coordinators/partners (%)	Coordinators (%)
Germany	438	103	23.52	17.14
France	357	83	23.25	13.81
United Kingdom	380	80	21.05	13.31
Italy	288	64	22.22	10.65
The Netherlands	267	49	18.35	8.15
Belgium	176	41	23.3	6.82
Sweden	217	40	18.43	6.66
Austria	115	23	20	3.83
Spain	215	23	10.7	3.83
Denmark	137	19	13.87	3.16
Switzerland	193	17	8.81	2.83
Norway	42	14	33.33	2.33
Greece	51	10	19.61	1.66
Finland	94	10	10.64	1.66
Israel	95	7	7.37	1.16
Hungary	76	5	6.58	.83
Poland	80	4	5	.67
Portugal	41	3	7.32	.5
Island	5	3	60	.5
Ireland	47	2	4.26	.33
Slovenia	28	1	3.57	.17
Total	3719	601	16.16	16.16

coordinators over the total number of granted projects in the health thematic area, giving largest weights to the most participant countries. This indicator was already utilized in previous national studies (BMBF 2009). Germany (17.14%), France (13.81%) and United Kingdom (13.31%) are the countries with a highest leadership, while the countries with lowest leadership are Slovenia (.17%), Ireland (.33%) and Island (.5%). It is interesting to notice the low position of Switzerland (2.83%), which even though it has a great participation, in fact it leaders few projects. Or Norway (2.33%), although not belonging to the EU, it has a good leadership score.

Regression models

Several regression analyses were made to solve the previous question about the relationship between the percentage of funds and the centrality measures such as centrality degree and betweenness centrality. Our aim is to know if a good collaboration degree in the 6FP network makes possible to achieve more funds than other countries as well as to quantify those relationships. A contingency table was obtained in order to calculate the Pearson's chi-square and to test if the response variable (%Funds) is independent from the explanatory variables (centrality degree and betweenness centrality). The chi-square test shows that the explanatory variables are independent from the %Funds ($X^2 = .558$), them they are suitable predictors of the %Funds variable.

Figure 2 shows the relationship between the percentage of funds and the centrality degree. This relationship follows a logarithmic equation in which the percentage of funds has been log- transformed while the centrality degree has not. Figure 2 shows that there is a strong relationship between both variables and the centrality degree may explain the 77% of the percentage of funds that a country may raise in the 6FP. Then, we can make an estimation in which an increase of one centrality degree may cause an increase of the 4.9% of the percentage of funds of a country.

Figure 3 shows the relationship between the percentage of funds and the Betweenness centrality. In this case, the relationship also follows a logarithmic equation ($R^2 = .73$). This good fit allows us to state that the Betweenness—interpreted as the capacity to attract

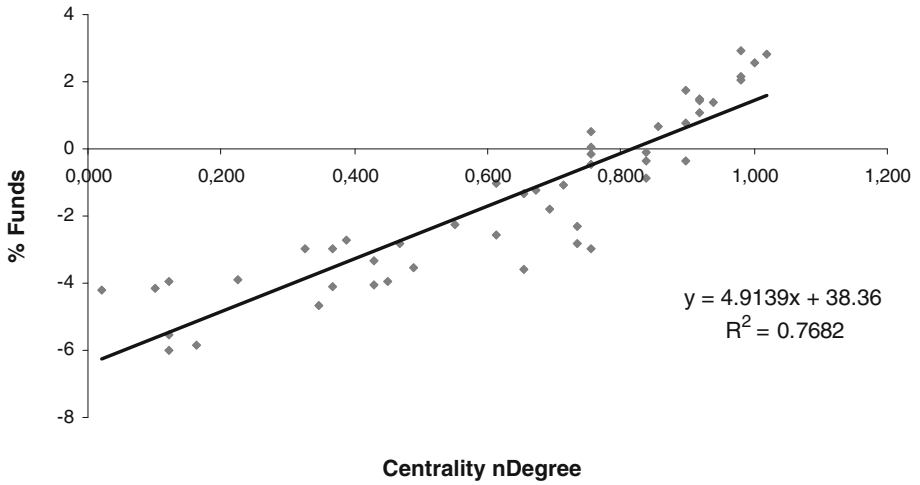

Fig. 2 Scatter plot (log-normal) between percentage of funds and centrality degree of each country

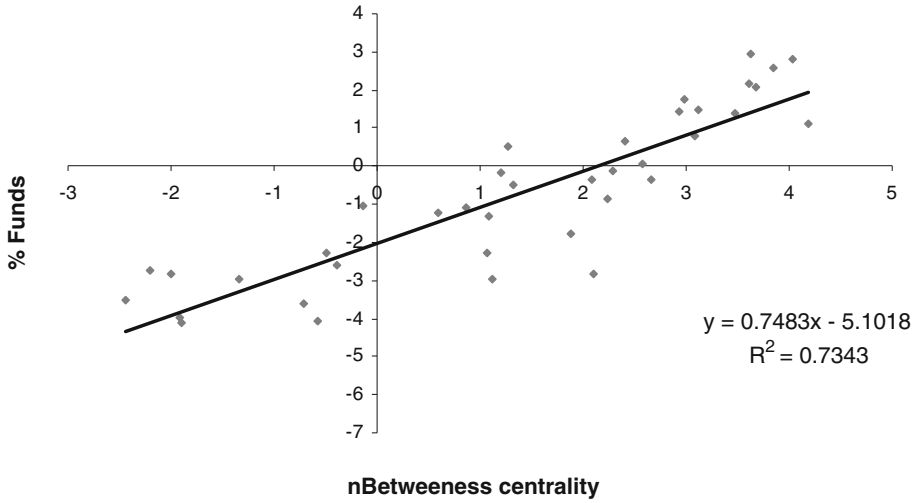

Fig. 3 Scatter plot (log-normal) between percentage of funds and Betweenness centrality of each country

new organizations to the research programmes—is also an important variable to raise funds from the 6FP. However, the estimation is lower than the one obtained from centrality degree because an increase of one betweenness centrality may only cause an increase of the .75% of the percentage of funds of a country.

Conclusions and discussion

The structural analysis of the participant countries in the health programme of the 6FP has made possible to know the research relationships of the participant organizations at the country level, showing a picture of the principal countries in the network, their relationships and their collaboration degree in this research programme. Social network measures (centrality degree and betweenness centrality) not only have assessed the collaboration performance of these countries, but also have estimated and quantified the funds that a country may receive participating in the EU research programmes. The most important conclusion from a methodological point of view is that the social network analysis is a very suitable tool to analyse the research collaboration in research programmes and put in relation R&D indicators, such as funds and participation degree, with network indicators such as centrality degree and betweenness centrality.

Although these indicators were already used or proposed in previous studies (BMBF 2009; Braun et al. 2009), the availability of this rich data has made possible to apply these R&D indicators in order to describe and assess the research activity of the participant countries. The proportion of funds by organization (*%F*/Org) has shown the effort of the organizations of each country in achieving research funds, while the percentage of coordinators has ranked the capacity of their organizations to coordinate projects. These indicators may be used to measure qualitative aspects such as leadership and effort, being very useful to value the role of a country in the new ERA.

According to the results, we may conclude that the United Kingdom, France and Germany are the best located countries in the network of the health research programme

and the best ranked ones according to the calculated indicators. These results can be compared with Gusmao (2001), which found similar country rank distribution in the 3rd and 4th Framework Programme. Avedas et al. (2009, p. 53) also showed a similar distribution in the country participation of the whole 6PM.

We also conclude that Switzerland is a key partner in the EU research activity due to its high collaboration degree and its weight in the health research programme, while Czech Republic and Hungary are potential members which are taking an important part in the EU research programmes. These results are similar to the ones observed by Avedas et al. (2009, Fig. 32), mainly identifying the central position of United Kingdom, France and Germany; and the detection of Czech Republic, Poland and Hungary as emergent countries in the 6FP. However, they omit the important contribution of Non-EU countries such as Switzerland or Norway and they only show the coordinate collaborations, causing the absence of the whole interactions between countries. Kuitunen et al. (2008) also present network graphs of the participation in the 6FP but limited to those organizations and countries that collaborate with Finland.

Results obtained in the regression models have shown that the increase of the collaboration degree between countries may cause an increase of 5% of the funds that a country may receive, while to attract new countries to the network may increase .75% these same funds. Obviously, the most actives countries, making new contacts and attracting new partners to the network, are the countries that more funds attract. However, our results allow to quantify and estimate those relationships, as well as to compare the performance of both structural indicators. Thus, the regression model shows that to collaborate with countries inside the network is more beneficial (5%) than attract new members to the programme (.75%). We think that these results are important because they could help to define research policies, which promote the collaboration inter-country as an effective way of achieve more funds form the research programmes and to increase the scientific performance of a country.

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