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Describing national science and technology systems through a multivariate approach: country participation in the 6th Framework Programmes

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Abstract The objective of this work is to describe the distribution of different types of participating organizations in the health thematic area of the 6th Framework Programme. A total of 2132 different organizations were classified according to four types and then grouped by country. A Principal Component Analysis (PCA) was carried out on the percentage of funding obtained by each type of organization. Results show a countries map plotted around the "private" and "public" principal components. It is observed that there are countries which research is basically performed by government research centres, while others are supported in the university activity. We conclude that the PCA is a suitable method to plot the distribution of research organizations by country and the results could be used as a tool for theoretical studies about the scientific activity in a country.

Keywords Scientometrics · Multivariate analysis · 6th Framework Programme · Biomedicine · Triple Helix

Introduction

The European Union (EU) Framework Programmes were raised with the objective of strengthening the scientific and technological capabilities of the European industry in order to increase their international competitiveness (Single European Act 1987). So, different organizations from every member country participate in these research programmes with the aim of achieving leading knowledge in order to increase their scientific and technological capabilities; and reinforcing contacts with prominent partners

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which make possible the development of new ideas and methodologies. Due to this, to compete in the EU research programmes is a great effort for any research organization and just a reduced set of them achieve financing to their research projects—the proposal success rate was 18% in the 6thFP (European Commission 2008). This effort could be considered as an indicator of excellence and competitiveness (Hornbostel 2001), because this selected group of institutions constitutes the scientific and technological elite of their countries.

However, the science and technology system of each country differs considerably from one to each other's (Nelson1993; Edquist 2006). It can be observed that different organizations assume different roles. For example, in the United Kingdom, the principal performer of basic research is the university, while this same task is mainly assumed by large public research bodies in the French system (CNRS, INSERM, etc.) (Chesnay 1993). These differences allow to characterize different models of science and technology systems as well as proposing a theoretical model for regional innovation such as the Triple Helix model (Etzkowitz and Leydesdorff 2000), which stressed the importance of developing policies which consider the importance of the relationships between the three different actors, industry, government and university. We hypothesize that the different types of organizations which participate in the EU Framework Programmes represent the most outstanding research institutions of their countries and this selected sample may describe the whole science and technology system of their countries.

Related research

Several works have analysed the participation in the EU Framework Programmes as a way to asses and evaluate the success of these programmes in general (Georghiou 1995; Luukkonen 1998) or focusing in certain actors such as universities (Geuna 1998), companies (Luukkonen 2002) and public sector (Laredo and Mustar 2004). Other papers have described country performance in such programmes (Gusmao 2000, 2001), while several reports have addressed the participation in these programmes at the country level, such as Finland (Uotila et al. 2004) Czech Republic (Albrecht and Vanecek 2008) or Sweden (Arnold et al. 2008). Other papers have studied the network configuration of the EU research programmes with the aim of describe the relationships among organizations (Breschi and Cusmano 2004; Roediger-Schulga and Barber 2007). However, no papers intended to visualize the particular typological configuration of the participant organizations of each country.

Principal Component Analysis is a statistic tool widely used in Scientometrics field, because it allows to resume a large number of scientific indicators in a couple of components which make easier the understood of the research interactions. It has been used to built scientific profiles of individual researchers according their publication activity (Costas and Bordons 2008), or as a way to relate bibliometrics indicators and usage metrics (Bollen et al. 2009). Baldini et al. (2007) studied what are the principal factors that motivate the patenting of innovations, while Ramani (2002) classified the Indian biotech firms according to their expenditure, publication and other variables. Recently, Dehon et al. (2009) identified the main groups of indicators used in the Academic Ranking of World Universities of the Shanghai University. However, other multidimensional techniques have been used in order to characterize and classify research profiles as clustering (Thijs and Glänzel 2008, 2009), Multidimensional scaling (Mccain 1990) or Neural networks (Polanco et al. 1998).

Objectives

The aim of this work is to describe the distribution of different types of organization that successfully applied in the health thematic area of the 6th Framework Programme. We intend to characterize each country according to the funded provided to the companies, universities, etc. that participate in that thematic area. Our main objective is to know if these different distributions of subventions by type of organizations may inform us about the R&D system of each country. We try to group these countries according to similar patterns. Methodologically, the objective is to test the Principal Component Analysis (PCA) as a suitable method to classify countries according to the percentage of subvention of organizations which participate in the EU research programmes. We want to explore if this method may be a good tool to visualize the Triple Helix theoretic model.

Methods

Data

We have obtained a database which contains the organizations participant in the projects belong to the “Life sciences, genomics and biotechnology for health” thematic area from the 6th Framework Programme of the EU. This thematic area includes 601 projects and 2,132 organizations. These data were provided by the Centre for the Development of Industrial Technology (CDTI), the Spanish public body depending of the Ministry of Science in charge of promoting and funding innovation and technological development. This database was previously cleaned, solving the following cases:

- Organizations with several names in different languages was revised, mainly native and English language
- Institutes and departments of an organization were merged in a same name. This was usual with research councils (i.e. CNRS, IRCC, etc.)
- Company’s branches were considered as independent organizations and located in the their country seat

Then, each organization was classified according to four types of organization: Company, University, Government and Non-Profit Organization (NPO). Criteria to classify these entities were obtained from the Frascati Manual (OEDC 2003). We extract from each organization the percentage of subvention along the health programme. These organizations were grouped by country, and we selected the countries with five or more organizations in this programme, given a total of 41 countries and 2,069 organizations. Previous to the statistical analysis, we have calculated the total percentage of subvention of each type of organization by each country. This cause more differences between the variables and the contribution of the observations are more balanced.

Principal Component Analysis

The Principal Component Analysis (PCA) (Pearson 1901; Hotelling 1933) is a multivariable technique related with the factor analysis. The aim of the PCA is to reduce the dimension of p variables to a set of new variables (principal components) which contain the highest amount of information from the before variables. It is desirable that all variables are well correlated between them, because this is symptomatic of redundant information and therefore a lower number of new variables (components) will be necessary to explain the model. These components are uncorrelated between them, because the fist one has the highest amount of information, and the second one has the information that the previous does not contain and so on.

These components are interpreted according to their correlation with the previous variables, because they contain part of the information of the original variables. Thus these components allow us to plot the observations in a new reduced space and to observe how these observations are related with the variables and the other observations. To simplify the component structure and therefore makes its interpretation easier and more reliable, it is usual to apply rotations to the components. Varimax, which was developed by Kaiser (1958), is the most popular rotation method; because it makes that each component represents only a small number of variables. PCA and graph edition was done with the Excel plug-in XLStat 2008.

PCA requires the assumption of normality and the variables can be expressed in different scales. These properties require to transform the percentage of subvention to a logarithm scale.

Results

Descriptive analysis

Table 1 shows the percentage of subvention for each type of organization listed by participant countries. It is ranked by the total percentage of subvention that achieves each country. We observe different patterns, for example, Iceland (84.4%) and the United States (58.98%) are the countries with the highest weight of companies, while Luxembourg (79.5%) and China (75.9%) have more Government presence in that thematic area. In general, University (49.85%) and Government (25.33%) are the types of organization that most amount for subvention achievement, followed by Company (21.31%) and NPO (2.28%). So we observe that the participation in the health programmes is mainly supported by universities, while the government institutions and the firms have a similar percentage.

PCA results

PCA was applied to four variables: percentage of subvention obtained by the universities, companies, governments and NPO's distributed by each country. Two components were obtained with a correlation of 43.25% to the first one and 31.28% to the second one, being a cumulate of 74.52%. If we observe the matrix correlation of the variables we found low correlations between them. The highest is −0.74 between University and Government and the lowest is −0.1 between University and NPO. Notice that all the correlations are negative because we calculate the proportion of subvention, so when one increases the other ones decrease. This low correlation causes that we found only two components with 74.52% of the variance. A third factor will explain the 100%, but does not allow us to plot the observations in a two dimension plane. So we have decided to use only the two-first components because they are enough to visually describe the relationships between variables and observations.

Table 2 shows the Pearson's correlation between the variables and the principal components obtained from those variables. First component (F1) may be labelled as a "public

Table 1 Percentage of subvention of each type of organization by country

Country	Country code	Company (%)	NPO (%)	University (%)	Government (%)	Subvention (%)
Germany	DE	20.73	0.35	44.1	34.82	18.54
United Kingdom	UK	17.24	0.78	64.81	17.17	16.58
France	FR	34.41	1.06	15.15	49.38	13.06
Italy	IT	23.18	12.8	39.93	24.09	8.62
The Netherlands	NL	13.21	1.57	71.18	14.04	7.76
Sweden	SE	19.04	1.39	76.74	2.83	5.67
Belgium	BE	16.38	5.02	71.80	6.81	4.28
Switzerland	CH	19.64	0.75	71.40	8.21	4.20
Spain	ES	17.68	3.3	33.19	45.83	3.97
Denmark	DK	29.83	1.24	55.29	13.65	2.96
Austria	AT	37.32	1.64	51.93	9.12	2.16
Finland	FI	18.35	1.49	71.34	8.82	1.91
Israel	IL	23.45		71.35	5.19	1.66
Norway	NO	12.89	1.15	52.96	33.01	1.06
Hungary	HU	25.38	0.33	28.55	45.73	0.88
Greece	GR	7.51	10.87	28.85	52.77	0.83
Poland	PL	0.81	0.09	39.46	59.64	0.7
Czech Republic	CZ	9.93	0.1	30.07	59.9	0.68
Ireland	IE	17.26		82.63	0.11	0.61
Portugal	PT	11.46	1.92	29.65	56.97	0.42
Estonia	EE	24.32	0.35	46.09	29.24	0.34
Iceland	IS	84.47	3.47	9.73	2.32	0.34
Slovenia	SI	31.64		25.9	42.47	0.29
Russia	RU	14.05		14.11	71.84	0.26
United States	US	58.98		38.5	2.52	0.17
Slovakia	SK	1.7		36.89	61.41	0.1
Latvia	LV	18.99	2.38	58.46	20.17	0.1
South Africa	ZA	1.26		97.62	1.12	0.09
Croatia	HR	47		32.95	20.05	0.07
Turkey	TR	19.98		68.56	11.45	0.06
Australia	AU	6.82		44.06	49.12	0.06
China	CN			24.03	75.97	0.06
Canada	CA			94.85	5.15	0.05
Romania	RO	3.11	61.25	34.15	1.49	0.04
Argentina	AR		21.16	45.03	33.81	0.03
Lithuania	LT	44.14		5.2	50.65	0.03
Bulgaria	BG		6.04	80.41	13.55	0.02
Cyprus	CY	15.03		10.5	74.47	0.02
India	IN	24.11		60.3	15.59	0.02
Brazil	BR			77.96	22.04	0.01
Luxemburg	LU	17.2	3.26		79.54	0.01
Total		21.31	2.28	49.85	25.33	98.77

Table 2 Correlation between factors and variables (varimax rotation). In bold, the highest correlations

Variables	F1 (public)	F2 (private)
Company	0.014	**0.952**
NPO	−0.041	**−0.484**
University	**−0.914**	−0.266
Government	**0.945**	−0.197

component” because it is highly correlated with University (−0.91) and Government (0.95). Although there are private universities, the public universities are majority, so we have decided to label that factor with that tag. Contrarily, the second component (F2) is defined as “private component” because is correlated with NPO (−0.48) and Company (0.95). NPOs may include private or public entities, but its correlation with F2 component suggest us to consider that the majority of these entities have a private profile.

It is interesting to observe that both components are correlated with different sign with the variables. Thus, University is inversely and Government is directly correlated with the “public component”, while NPO is negatively correlated and Company is positively correlated with the “private component”. This is due to the already mentioned reason, because the variables were quantified as percentages, so when one increases the other ones decreases. Thus we may observe on one hand a “public” axe (*x*) in which the positive values show countries which participation is highly supported by government institutions, and the negative ones display countries in which the universities contribute more actively. On the other hand there is a “private” axe (*y*) where the positive values identify countries with a high business activity, while the negatives show an important presence of NPO.

Figure 1 shows the bi-dimensional projection of the variables (lines) and observations (dots) according to the two principal components. To increase the visualization added value of the map we have represented the size of the dot according to the total percentage of subvention of each country. We also have coloured each dot according to a geographical

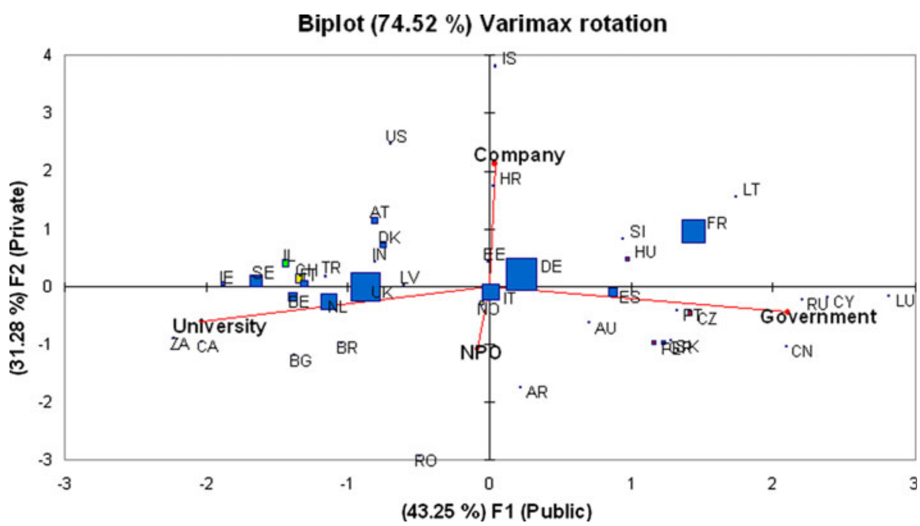

Fig. 1 PCA map with the two main components, variables and observations. Variance (74.52%) with varimax rotation

classification in which blue is used for the EU-15 countries, red is for the EU-25 ones, yellow represent the European countries non-EU members and green is reserved for non-European countries.

To understand Fig. 1 we firstly have to observe the projection of the variables. As we have seen before (Table 1), "public" component (horizontal axe) mainly contains information from the University and Government variables, while the "private" component (vertical axe) shows information of Company and NPO variables. The vectors length shows the contribution of the variables to their components, thus we observe that the contribution of Company (72.49%), Government (51.58%) and University (48.31%) to their components is very high, but NPO (18.75%) is quite low. This causes that the observations are scarcely affected by this last variable, and the observations are mainly distributed along the horizontal axe.

Figure 1 allows us to group the observations by their relationship with the components. Thus the upper-half part shows the countries which participation in this research programme is mainly supported by companies. In this group we can highlight Iceland (IS), the United States (US) and Croatia (HR). Contrarily, the lower-half part shows countries in which the weight of the NPO is more important such as Romania (RO) and Argentina (AR).

If we observe the "public" axe we locate in it the major proportion of countries. In the right-half part there are the countries with participation carried out profusely by universities. In this homogenous group are the United Kingdom (UK), the Netherlands (NL), Belgium (BE) and Sweden (SE). In the left-half are located countries which governments play a central role in their activity in the health thematic area, like France (FR), Spain (ES) and Greece (GR).

Finally, we can observe countries located in the centre of the map, these are countries that do not have a specific pattern, because the weight of the four types of organizations is similar. Those countries are Germany (DE), Italy (IT) and Norway (NO).

Discussion

Obviously, the obtained results may not be generalized and they are not representatives of the Science and Technology system of a country at all. Due to the type of organizations distribution could vary according to different programmes and it should be taken into account that not every research organizations of a country participate in the European research programmes. Roediger-Schulga and Dachs (2006) found significant differences in two EU programmes. They detected that while the telecommunication programme had more industrial partners and require greater funding; the agricultural one was dominated by public research institutions and attract less income. Our results show that the universities are the sector most active, while the presence of firms and government is rather balanced. We have observed that the firms' presence might be due to the emergence of biotechnology sector (Gravalos et al. 2002), while the government presence is related with the social aspect of the health. Although Hughes-Wilson (2004) claims that the business presence was lower than the expected in this thematic area.

In spite of these limitations, the obtained results allow to map the principal characteristic of the Science and Technology system in each country, at least in the health thematic area. Hence, one can observe that the countries closer to the "government" variable are countries with strong government research councils such as the CNRS in France, the CSIC in Spain, and the MPG in Germany. Together with these countries, we also detect other ones that come from command economies and where they still have an important presence of government organizations. In this set we identify eastern countries such Hungary, Poland, Czech Republic or Russia and others still with command economy such as China. On the other side, close to the “university” variable, we find countries where the basic research is mainly supported by universities because their research councils are basically oriented to the research investment. The United Kingdom, the Netherlands, Belgium and Sweden are countries in this set. It is interesting to notice that important countries such as Germany, Italy and Norway are located in the centre of the plot. This suggests that these countries share out the research performance between government research centres, university and private laboratories in a balanced way. For example, Germany has a strong private sector whose performance amounts for around two-thirds of the German R&D activity, while the government research councils (MPG, Fraunhofer, etc.) and universities are responsible of the rest of the research (Federal Ministry of Education and Research 2002). This balanced distribution, in which each sector fairly participates in the R&D system, suggests that these countries go toward the Triple Helix model (Etzkowitz and Leydesdorff 2000). This theoretical model suggests that an intense participation of the Government, University and Industry organizations in a coordinate way increases the innovation in a regional system. So we understand that that equilibrated position of Germany, Italy and Norway could be a good indicator of the joint role of these agents in the biomedical research of those countries.

Conclusions

PCA has made possible to plot the percentage of subvention by each type of organization in each country. This multivariate approach has shown the principal characteristics of the S&T system in each country, showing countries which research is supported mainly by government and other ones which it is carried out by universities. We conclude that the PCA is a suitable methodology to show this kind of information because allows to present in a easy way how is the research system in each country and observe if there is any relationship with other variables such as the R&D investment or the successful in research programmes. We think that this representation in which the observations are plotted along three or four variables, allows us to bring closer the Triple Helix dimensionality (Leydesdorff and Scharnhorst 2002; Priego 2003). We suggest that this method could be a suitable tool to present this theoretical model and to explore the development of the Triple Helix from a visual point of view.

Results let us to claim that there are mainly two groups of countries. Countries which research system rest basically on government research centres such as France, Spain and post-communist countries. The other one is set up by countries in which the universities are the principal actor performing research, being United Kingdom, Switzerland, and Sweden an example. We have also observed that there are countries such as Germany, Italy and Norway that have a balanced distribution of their research performance. Thus we may conclude that there are different model of S&T system, but they do not affect to the success in the EU research programmes because the main countries have different models which go from the government-oriented model of France to the university-based model of the United Kingdom or the balanced model of Germany.

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