Paper to be presented at the

35th DRUID Celebration Conference 2013, Barcelona, Spain, June 17-19

Cooperative Research Centres and Sectoral Systems of Innovation: a typology based on the Spanish case

INES ANDUJAR
CSIC
IESA
iandujar@iesa.csic.es

SANDRO GIACHI
CSIC
IESA
sgiachi@iesa.csic.es

Abstract

This paper develops a typology of Cooperative Research Centres (CRCs) in Spain through the sectoral system of innovation (SSI) approach. According to this approach, and based on the Spanish CRCs experiences, our initial expectations were: (1) To find different types of Spanish CRCs according to their knowledge base, their basic technologies, inputs and demand characteristics. (2) To find some linkages between specific types of CRCs and specific sectors of economic activity and (3) To find linkages between specific types of CRCs and regions in Spain. In order to perform the analysis, we use data from a multi-method survey directed to the heads of 163 CRCs in Spain (final sample of 123 CRCs). Based on the SSI approach, we first selected a set of variables proxis to some elements of the SSI-building blocks and conducted a factor analysis with such variables, suggesting a typolopoly of four types of CRCs: ?Local potential innovators?, ?Transnational potential innovators?, ?Local technologic developers? and ?Transnational technologic developers?.

Jelcodes:P13,L3

Cooperative Research Centres and Sectoral Systems of Innovation: a typology based on the Spanish case

DRUID Conference 2013: "Innovation, Strategy and Entrepreneurship"

PAPER IN PROGRESS

1. Introduction

Synergistic interactions among heterogeneous R&D agents ─ for example, universities, research organizations, private companies and government ─ are key and valuable connections for the creation, transformation and diffusion of new knowledge and innovation (for example, Kline and Rosemberg, 1986; Von Hippel, 1988; Dosi, 1988; Etzkowitz and Leydersdorff, 2000). In this context, the so-called Cooperative Research Centres (CRCs) arise as promising organizational arrangements for public-private research collaboration. A CRC is a type of R&D organization that joins different public and private R&D actors and carries out collaborative market-oriented research on areas of industrial relevance (CREST, 2008). Studies on CRCs developed in the USA and in Australia stress the key role of these centres for the strategic use of science and technology, for transferring know-how and new ideas from the Academy to the productive sector and for analysing how to face important organizational challenges due to different expectations and goals of the agents involved (for example, Boardman and Gray, 2010; Feller at al., 2002; Garrett-Jones and Turpin, 2010; Roessner 2000 or Turpin et al. 2005). In Europe, Arnold et al., (2004) report similar results of CRCs experiences in some countries like Austria, Norway or Sweden. However, CRCs in Spain are a recent and unexplored phenomenon (Fernández-Esquinas and Ramos-Vielba, 2011).

As a first step for the understanding of these centres in the Spanish R&D System, this paper develops a typology of CRCs in Spain based on the concept of Sectoral System of Innovation (SSI). We use the SSI approach given the market and sectoral orientation of CRCs and their potential innovator role. In order to perform the analysis, we use data from a multi-method survey directed to the heads of 163 CRCs in Spain (final sample of 123 CRCs). This survey was conducted in the framework of the "ES-CRCs" research project ─ "Emerging Forms of Cross Sector Collaboration between Science and Industry: Cooperative Research Centres in the Spanish R&D System".

The paper is structured as follows. Section 2 presents the SSI concept and the CRCs from this conceptual approach. Section 3 describes our data, sample and variables. In section 4 we present the results of our empirical analysis and in section 5 we discuss possible implications of our study.

2. Sectoral Systems of Innovation and Cooperative Research Centres

The SSI concept

As it is widely acknowledged in the literature, innovation follows different sectoral patterns (for example, Nelson and Winter, 1982; Pavitt, 1984; Malerba and Orsenigo, 1999). These contributions have often identified innovation sectors with traditional sectors of economic activity, focusing on specific differences among them. The sectoral system of innovation concept (SSI) departs also from the traditional concept of sector but enlarges it taking into account additional actors, interactions and processes. In doing so, the SSI approach integrates the wide range of findings on innovation reported in the specialised literature and proposes a dynamic view of the innovation sectoral boundaries. A SSI is "a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products" (Malerba, 2002: 248). This concept is grounded in the evolutionary theory. According to this approach, sectoral boundaries are defined by specific features of three building-blocks (Malerba, 2007): (1) The knowledge and technological domain (knowledge base, learning processes and basic technologies, inputs and demand); (2) The interactions and networks among agents (individuals and organizations) and (3) the institutions (norms, routines, laws, etc.).

According to the SSI approach, each one of these building blocks co-evolves with the others through processes of creation of variety and selection, shaping dynamic sectoral boundaries. The evolutionary theory particularly stresses the interactions among heterogeneous agents ─building block 2─ as a key factor of the innovation process (for example, Loasby, 2001; Potts, 2000). These interactions, according to Malerba (2002, 2007), differ between each sectoral system as a consequence of the features of the knowledge base, the basic technologies, inputs and the characteristics of demand─ i.e., building block 1. Relating to building block 3, institutions ─ understood as a set of rules and routines commonly adopted ─ are referred to different levels of aggregation ─ supranational, national, regional ─ or limited to the boundaries of firms or other organizations. A particular feature of SSI approach is that it considers and allows studying the co-existence of these local, national and/or global dimensions of a sector (Malerba, 2007).

In spite of their multiple denominations in the specialised literature (competence centres, hybrid centres, boundary organizations or engineering research centres, among others), there is an agreement in pointing out the following main features of CRCs (CREST, 2008: 4-5): (i) They are formal autonomous organizations; (ii) Their main goal is to carry out collaborative research among private enterprises, research performing organizations and public service organizations and (iii) They conduct market-oriented research typically focused on medium/long term issues and on areas of direct industrial relevance. CRCs pose important issues for current research systems. According to Boardman and Gray (2010), the new social and organizational forces emerged within current innovation systems – such as the collectivization of research, the rise of a cooperative paradigm for research policy or the emphasis of open innovation strategies within industry – have led to the emergence and consolidation of CRCs. These centres mobilize the knowledge reservoir of public research organizations and private companies for conducting market-oriented research. This may "encourage firms to undertake more radical kinds of innovation than normal, based on more fundamental understanding of the technologies with which they work" (CREST, 2008: 8) and enables the use of science and technology to address social and economic problems that academic units, government actors and private companies cannot easily face unilaterally (Boardman and Gray, 2010: 452). Within current research systems, CRCs appear then as promising creators and diffusers of new knowledge and innovation.

From the SSI perspective, CRCs can be thought as a type of interaction among heterogeneous agents ─ private companies, universities and research organizations, and government ─ structured by formal collaborative R&D arrangements:

- In relation to company members, literature finds different goals and profiles of the firms involved in a CRC. For example, Santoro and Chakrabarti (2001) find out that large firms participate in CRCs with the aim of investigating in the long term, whereas SMEs search the solving of very specific needs in the short term. Tornatzfy et al. (2002) also find that the main goal of high-tech companies is the staff recruitment, whereas low-tech firms search the access to such capabilities and facilities by their participation in CRCs. Besides, according to various studies (for example, Roessner, 2000; Adams et al., 2001 and Gray et al., 2001), the major benefits for firms steamed from their participation in CRCs are the "collaborative" ones, in form of access to new ideas and know-how, faculty consulting, publications in co-authorship with university scientists and recruitment of graduated students, in opposition to the "technical results" – new products and processes – which would come in a second place.

- Regarding universities and research centres, Cohen et al. (1998) report for the case of USA that universities usually get involved in CRCs because of the funding that they offer. In return, the research they conduct is more applied and the diffusion of their findings more restricted. For the Australian case, Turpin and Garret- Jones (2010) find that for researchers, one of the most valued aspects of CRC membership is the extension of their research networks and the access to new research users. These authors have also evidenced that researchers involved in CRCs usually still working at universities, discussing the different structure of incentives and career tracks of these researchers (Turpin et al., 2005; Turpin and Deville, 2005).

- Relating to Public Administrations, CRCs are often promoted by governments through R&D national plans. In United States, Australia and Canada, the emergence of CRCs began in the 1980s as a result of national policy programs – the Industry/University Cooperative Research Centers Program in the USA or the Cooperative Research Centres Program in Australia. Within the evaluation projects of these programs, CRCs have been subject of extensive analysis (for example, Roessner, 2000; Gray et al. 2001; Gray, 2011; Atkinson et al. 2001; Howard Partners, 2003). In some European countries, like Austria, Norway, Sweden and, more recently, Ireland, similar policy programmes appeared in the 1990s (Arnold et al., 2004; Ryan et al 2008; Ryan and Kennedy, 2010). However, in Spain, CRC experiences are not the result of a unique public policy programme but the effect of different policy plans at the regional, national and European level emerged mainly since 2000s. Specifically, the regional administrations have been more active in this type of initiatives. In some regions like the Basque Country, CRCs are new university-industry-government organizations inspired by international experiences. In other regions, like Galicia or Valencia, they come from previous industrial research associations strongly connected with the needs of local firms. In regions like Madrid or Catalonia, CRCs are private institutes created from scratch, with a strong presence of the public sector (Sanz-Menendez and Cruz-Castro 2007). This fact has given rise to a wide variety of different organizational and legal structures (Fernández-Esquinas and Ramos-Vielba, 2011).

As far as we know, the existing literature on CRCs does not apply the SSI approach, although there is evidence of sectoral differences in relation to these centres. Hayton et al. (2010), for example, evidence for the case of USA that firms in more competitive industries and with higher technological opportunity, are more likely to join CRCs. They also find that firms operating in weaker patent protected sectors – like electronic or mechanical industries – are more likely to join CRCs than firms operating in sectors with a more effective patent protection – like biotechnology, pharmaceutical or chemical industries. Surprisingly, we do not find in the literature any systematic research that has studied different types of CRCs according to sector and to their organizational features. However we think that, given the interactive character of CRCs, their market and innovative orientation and their sectoral and regional connections, the SSI approach could be very suitable for the understanding of CRCs for the Spanish case.

In particular, we stress the focus that the SSI notion makes on interactive and heterogeneous actors. There is an increasing interest in these formal R&D cooperative agreements and hybrid centres, emphasizing the role of university-industry relationships as a source of innovation and change. Referring to such organizations, the SSI approach highlights that their structure will differ from sectoral system to sectoral system depending on the characteristics of their building blocks components (Malerba, 2007). Correspondingly, we expect that the Spanish CRCs will vary according to their knowledge base, their basic technologies, inputs and demand characteristics. We also expect to find some linkages between specific types of CRCs and specific sectors of economic activity, although it is expected also that different CRC models could co-exist within the same sector. Finally, we expect to find linkages between specific types of CRCs and regions, given the important role that regional plans have had in promoting CRCs in Spain.

3. Methodology

Data and sample

We use data from a multi-method survey directed to the heads of CRCs in Spain (final population of 163 CRCs and final sample of 123 CRCs). This survey was conducted in the framework of the "ES-CRCs" research project ─ "Emerging Forms of Cross Sector Collaboration between Science and Industry: Cooperative Research Centres in the Spanish R&D System"[1]. Based on Boardman and Gray (2010), we define CRCs as centres that: (1) have a formal structure and have a separate legal entity; (2) conduct R&D activities and (3) have at least one public and one private actor among their

[1]Previously to the survey, we identified the whole population of CRCs. In Spain, CRCs are quite recent an unexplored phenomena, so there is not any complete institutional directory of such type of organizations. In consequence, we built a map of R&D collaborative arrangements existing in Spain through a systematic review of secondary documentary sources of data, as R&D and innovation public programs and plans, institutional web directories of R&D organizations and the webpages of the research centres. We performed this search at both the national and regional levels. Through this documentary review, we identified a large set of R&D arrangements for cooperative research (234 cases). Next, we selected a subset of research centres whose characteristics were consistent with a closer definition of CRC. This subset shapes the final population framework of CRCs in Spain (163). Then, the sample we obtained is not based on a probabilistic criterion that allows the application of inferential techniques, but it represents a "strategic" sample of CRCs.

partners. The survey includes a wide range of questions about the main activities, resources, organizational issues and results of CRCs[2].

Results of the field were satisfactory. The response rate was 75.46% (123 centres) of the whole population, although the rate of full responses to the questionnaire was 60.12% (98 centres). Nevertheless, we did not find a significant difference in the geographical distribution of CRCs between the population and our sample (Table 1): all differences are lower than 1-2%.

Table 1. Geographical distribution of CRCs in Spain

Region	**Population**		**Sample**	
	Frequency	**Percentage**	**Frequency**	**Percentage**
Andalucía	31	19,0	25	20,3
Aragón	5	3,1	4	3,3
Asturias	8	4,9	6	4,9
Baleares	6	3,7	6	4,9
Canarias	6	3,7	4	3,3
Cantabria	2	1,2	2	1,6
Castilla La Macha	4	2,5	3	2,4
Castilla y León	3	1,8	1	,8
Cataluña	22	13,5	18	14,6
Cdad. Valenciana	18	11,0	11	8,9
Extremadura	4	2,5	4	3,3
Galicia	9	5,5	5	4,1
Madrid	15	9,2	10	8,1
Murcia	2	1,2	2	1,6
Navarra	4	2,5	2	1,6
País Vasco	21	12,9	17	13,8
Rioja (La)	3	1,8	3	2,4
Total	**163**	**100,0**	**123**	**100,0**

Source: Own elaboration based on ES-CRCs Project data.

Operationalization of the SSI approach and selection of variables

Given the wide scope of the SSI concept, the studies that apply this approach usually focus on some specific features and factors of the building blocks. For example, very recently Adams et al. (2013) analyse the magnitude of innovation by demand (specifically, by intermediate user firms) in the semiconductors sector. The sectoral system perspective is taken by regarding innovation and production as processes in which different types of actors (final and intermediate consumers among them) are

[2] The survey was performed using a structured questionnaire directed to the heads of the Spanish CRCs. We used a postal/web mixed-mode technique (Diment & Garrett-Jones 2007): we sent an on-line questionnaire to centre's directors by email, accompanied by a postal letter informing about the aims of research. On-line access to questionnaire has been opened from August to October 2012. We sent 6 e-mail and 3 postal remainders to the centres. In addition, we performed also a telephone remainder using the CATI-system, for identifying specific response problems.

actively involved. The authors use a single specific class of technology patent (rather than a predefined list of firms in the industry) as the starting point to identify the different actors involved in the semiconductors sector. Oltra and Saint-Jean (2009) use also the sectoral system approach but in order to identify the determinants of environmental innovations. The authors stress the co-evolving interdependence of the various elements of the system, and specifically between the environmental innovations and the industrial dynamics of the automotive sector in France. In order to operationalize the SSI concept, they limit the broad "institutions building-block" to the instruments of environmental and innovation policy for the case of the low emission vehicles. Other studies that apply the SSI approach (for example, Faber and Hoppe, 2013; Köhler et al., 2012 or Chaminade and Edquist, 2005) have also operationalized it in a reductive way, focusing on some specific elements of the building blocks and according to their particular research interests and questions.

Similarly, for the application of the SSI approach to our study of CRCs, and based on data availability, we consider a reduced set of variables *proxies* to the knowledge base, inputs and demand of CRCs — building block 2 — and to some attributes of the universities, research centres, firms and Public Administrations involved in CRCs — building block 1. The list of our variables is the following (Table 2):

- In relation to the *Attributes*, we use: private firms share in the CRC property *(% Industrial property*) and public organizations share in the CRC property (*% Public property*); proportion of firms involved in the CRC with less than 50 employees, over the total number of firm-partners (*% Small firms*) and proportion of firms involved in the CRC with more than 250 employees over the total number of firm-partners (*% Large firms*). In the questionnaire, we asked to the heads of the CRCs about the proportional distribution that each type of partner — universities and research centres, firms and Public Administrations — has in the ownership of the centre (A2) and about the number and size of their firm partners (A8).

- *Inputs* are proxied by the proportion of the CRC funding coming from direct public aids on the total budget (*% Public subsidies on total budget*) and the proportion of the CRC funding coming from contracts and services to firms on the total budget (*% Market incomes on total budget*); the proportion of researchers who attain a PhD over the total CRC's employees (*% researchers with a PhD)* and the proportion of pre-doctoral researchers over the total CRC's employees (*% Phd students*). In the questionnaire, we asked to the heads of the CRCs about the proportional distribution of different sources over the total budget of the centre and about the number and qualification of their employees.

- *Types of knowledge* are proxied by the level of importance of the basic research in the CRC (*Relevance of basic research*) and by the level of importance of the technical services provision in the CRC (*Relevance of technological services).*

- Finally, as proxies to *demand*, we use the level of importance of orienting the CRC's activities to the benefits of their own partners (*Relevance of economic benefits for CRC partners*) and the level of importance of orienting the CRC's activities to the benefits of their users and/or customers (*Relevance of economic benefits for customers and users*). All variables referring to type of knowledge and demand were measured using a five-point scale, ranging from 1 ("Activity is absolutely no important") to 5 ("Activtiy is very important").

Our expectation is that CRCs will vary according to these variables, so that it will be able to build a typology of the Spanish CRCs.

Table 2. Variables used in the analysis

	Name	**Description**
Attributes of heterogeneous agents and connections	% Industrial property	% of the private firms in the CRC's property (A2.12)
	% Public property	% of the public organizations in the CRC's property (A2.34)
	% Small firms	% of micro and small firms participating in the CRC (over the total number of firm-partners involved) (A8.12)
	% Large firms	% of big firms participating in the CRC (over the total number of firm-partners involved) (A8.4)
Indicators on the knowledge base, inputs and demand of CRCs	% Public subsidies on total budget	% of the CRC's funding coming from direct public aids (B3.1)
	% Market incomes on total budget	% of the CRC's funding coming from contracts and services to firms (B3.4)
	% researchers with a PhD	% of post-doctoral researchers (over the total CRC's employees) (B5.1)
	% PhD students	% of pre-doctoral researchers (over the total CRC's employees) (B5.5)
	Relevance of basic research	Level of importance of the basic research in the CRC (C3.1)
	Relevance of technological services	Level of importance of the technical services provision in the CRC (C3.4)
	Relevance of economic benefits for CRC partners	Level of importance of orienting the CRC's activities to the benefits of their own partners (C4.2.)
	Relevance of economic benefits for customers and users	Level of importance of orienting the CRC's activities to the benefits of their users and/or customers (C4.3)

Additionaly, the questionnaire contains a question about the economic sector related with the activities and the partners of the CRC based on NACE classification (11 categories). Due to analytical reasons, we grouped this category in four groups as Table 3 shows.

Table 3. Distribution of CRCs by sectors of economic activity

Sector of Economic Activity		Frequency	Percentage
Primary Sector	Primary sector (agriculture, hunting, fishing, forests, etc.)	10	9,7
Second Sector	High Tech Industry	27	26,2
	Medium Tech Industry	13	12,6
	Low Tech Industry	16	15,5
Third Sector	ICTs, informatics, technological consultancy, etc.)	16	15,5
	Professional business services (law, accountability, taxes, marketing, design etc.)	4	3,9
	Other services	3	2,9
Others	Energy and Water	9	8,7
	Construction	5	4,9
Total		**103**	**100,0**

Source: Own elaboration based on ES-CRCs Project data.

4. Results

Empirical findings

Tables 5 and 6 show the summary statistics and the correlations matrix the used variables referred to our sample of CRCs in Spain. We observe that almost all show a quite normal distribution, being the proportion of PhD students over the total personnel the strongest exception, although its distribution is not very asymmetrical (Table 5).

Table 5. Summary statistics

Variable (N of list = 90)	N	Min	Max	Mean	S.E.	Asymmetry	Kurtosis
% Industrial property	123	,00	100,00	54,8160	33,14358	-,363	-1,095
% Public property	123	,00	100,00	41,2270	32,70015	,497	-,942
% Small firms	107	,00	100,00	41,0707	39,09293	,264	-1,560
% Large firms	107	,00	100,00	38,8115	40,00216	,537	-1,374
% Public subsidies on total budget	107	0	100	24,06	27,529	1,075	,133
% Market incomes on total budget	107	0	95	31,02	25,647	,487	-,765
% researchers with a PhD	101	,00	83,33	21,6831	21,51732	1,004	,214
% PhD students	101	,00	31,75	4,8520	7,62874	1,677	2,229
Relevance of basic research	104	1	5	2,70	1,570	,324	-1,438
Relevance of technological services	105	1	5	3,90	1,229	-,925	-,092
Relevance of economic benefits for CRC partners	103	1	5	2,81	1,541	,218	-1,450
Relevance of economic benefits for customers and users	103	1	5	3,75	1,281	-,796	-,403

Source: Own elaboration based on ES-CRCs Project data.

The correlations matrix (Table 6) shows some significant correlations among our variables, many of them negative. In particular, the structure of property, the budget composition and the workforce qualification are the most correlated variables, while the level of importance of orienting CRC's activities to the benefits of their own partners, other customers or users are the least correlated dimensions. Excluding the inverse correlations among items of the same dimension, we find stronger correlations (> 0.5) between:

- Proportion of public property and public subsidies (positive)
- Proportion of post-doctoral researchers and relevance of basic research (positive)
- Proportion of market incomes and relevance of basic research (negative)
- Proportion of post-doctoral researchers and relevance of technological services (negative).

Table 6. Correlation matrix

Variable (N of list = 90)	% Industrial property	% Public property	% Small firms	% Large firms	% Public subsidies on total budget	% Market incomes on total budget	% researchers with a PhD	% PhD students	Relevance of basic research	Relevance of technological services	Relevance of economic benefits for CRC partners	Relevance of economic benefits for customers and
% Industrial property	1	-,850**	,310**	-,398**	-,460**	,300**	-,395**	-,379**	-,259*	,336**	,334**	,092
% Public property	-,850**	1	-,349**	,449**	,533**	-,335**	,421**	,318**	,294**	-,320**	-,371**	-,178
% Small firms	,310**	-,349**	1	-,837**	-,183	,194	-,333**	-,224*	-,227*	,154	,158	,216*
% Large firms	-,398**	,449**	-,837**	1	,292**	-,278**	,430**	,259*	,359**	-,266*	-,271*	-,227*
% Public subsidies on total budget	-,460**	,533**	-,183	,292**	1	-,538**	,410**	,271*	,285**	-,340**	-,167	-,309**
% Market incomes on total budget	,300**	-,335**	,194	-,278**	-,538**	1	-,462**	-,284**	-,501**	,354**	,151	,322**
% researchers with a PhD	-,395**	,421**	-,333**	,430**	,410**	-,462**	1	,459**	,636**	-,569**	-,341**	-,378**
% PhD students	-,379**	,318**	-,224*	,259*	,271*	-,284**	,459**	1	,447**	-,465**	-,116	-,049
Relevance of basic research	-,259*	,294**	-,227*	,359**	,285**	-,501**	,636**	,447**	1	-,463**	-,145	-,305**
Relevance of technological services	,336**	-,320**	,154	-,266*	-,340**	,354**	-,569**	-,465**	-,463**	1	,129	,179
Relevance of economic benefits for CRC partners	,334**	-,371**	,158	-,271*	-,167	,151	-,341**	-,116	-,145	,129	1	,481**
Relevance of economic benefits for customers and users	,092	-,178	,216*	-,227*	-,309**	,322**	-,378**	-,049	-,305**	,179	,481**	1

Source: Own elaboration based on ES-CRCs Project data.

Given this descriptive view, we conduct a factorial model with our variables[3] in order to build an empirical-based typology of CRCs in Spain. Using only the non-missing values for all the variables we included, the size of our sample was reduced to 90 CRCs (73.2% of the total sample and 55.2% of the whole population).

[3] The high correlations among variables showed in Table 3 justify the application of a factorial model To this aim, we decided to standardize all these variables (normal Z, ranging from 0 to 1).

We first perform a simple principal component analysis (PCA)[4]. The resulting analysis shows that there are four components with an eigenvalue higher than 1, explaining the 72.27% of the total covariance (see Table 1-A in the Annex). However, we decided to consider only two factors in the analysis because:

- The first two components could explain the 51.86% of the total covariance.
- As the component matrix shows (Table 2-A in the Annex, the third and fourth factors are built by variables that participate mainly in the first two components).
- As the scree-plot suggests (Graph 1-A in the Annex), the first two components have a good explanatory capacity, in comparison with the others.
- Besides, two components facilitate to a great extent the theoretical interpretation of our model.

In order to build the factorial model we apply a common factor procedure, using the algorithm of principal axes factorization and pre-fixing the two first factors. Table 7 shows the main characteristics of the factorial model. The first factor explains the 35.5% of the common variance, the second one the 8.9% and together the 44.4%. There is a minor increase of explanation of variance from the second to the third factor, supporting our choice to select only the first two dimensions (Graph 1). Besides, the control of the fitting shows that there is a good adaptation of our data to the model: the determinant of the correlation matrix is near to 0, the KMO Index is superior to 0.5 and the Bartlett's Chi-Squared is significantly different to 0.

Table 7. Factor Analysis Explained Variance

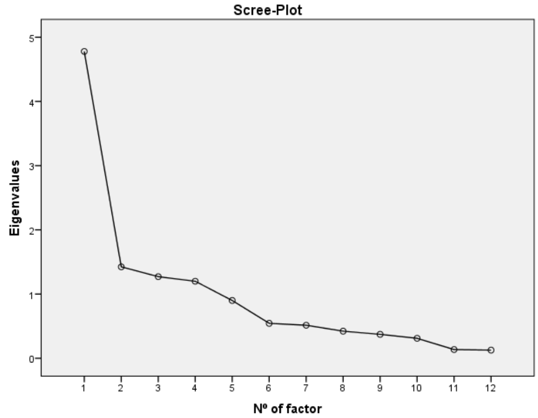
Factor	Eigenvalues			Squared sum of saturations		
	% of variance	% cumulate	% of variance	% cumulate	% of variance	% cumulate
1	4,778	39,821	39,821	4,265	35,540	35,540
2	1,424	11,866	51,686	1,067	8,889	44,429
3	1,271	10,592	62,279			
4	1,200	9,996	72,275			
5	,900	7,501	79,775			
6	,544	4,536	84,311			
7	,515	4,288	88,600			
8	,422	3,517	92,117			
9	,372	3,104	95,221			
10	,311	2,593	97,813			
11	,136	1,132	98,945			
12	,127	1,055	100,000			

Fitting Index		Value
Determinant of the correlation matrix		0,02
Kaiser-Meyer-Olkin.(KMO) Index		,760
Bartlett test of sphericity	Chi-squared	515,064
	DF	66
	Sig.	,000

Source: Own elaboration based on ES-CRCs Project data.

[4] In order to identify the most relevant factors and to control the extent of the covariance explained by our variables, we synthetize all the variance existing in our dataset.

Graph 1: Factor Analysis Scree-Plot



Source: Own elaboration based on ES-CRCs Project data.

Table 8 shows the factor loadings for the rotated factorial model[5] and Graph 2 shows the distribution of our variables in the factorial space (for rotated axes). As it can be observed, almost all the variables are important for building the final factors. Besides, although we cannot interpret the axes in the same form they appear in the graph because they are not orthogonal but oblique, we observe however that the main factor is formed by:

- Structure of property (A02)
- Composition of budget (B03)
- Qualification of personnel (B05)
- Research orientation (C03) and
- Objectives of the centre (C04).

In particular, the first factor (horizontal axis) is positively related with proportion of public property (A02_34), proportion of subsidies (B03_1), proportion of researchers with a PhD (B05_1), proportion of PhD students (B05_5) and relevance of basic research (C03_1). Instead, the other variables are negatively related with factor 1. On the other hand, factor 2 is clearly formed by the size of firm partners, being positively

[5] We first conducted a factorial model without rotating axes but the percentage of small and large firms appear highly correlated with the first and the second factor in an inverse way. To solve this problem, we decided to rotate the axes of the factorial model, also in order to improve the fitting of the variables to the model and their theoretical interpretation. We tried with an orthogonal rotation (VARIMAX procedure), but this change did not eliminate the problem. Then, we tried with an oblique rotation (OBLIMIN procedure). The model obtained with such procedure was judged as satisfactory, as we achieved to group the explained variance by the percentage of small and large firms in the second factor. Besides, with this last model we achieved a stronger concentration into the first factor, the following variables: Composition of budget, Qualification of the personnel, and Relevance of different research activities. However, as the axes of this model are not perpendicular, we have to be quite careful in explaining results.

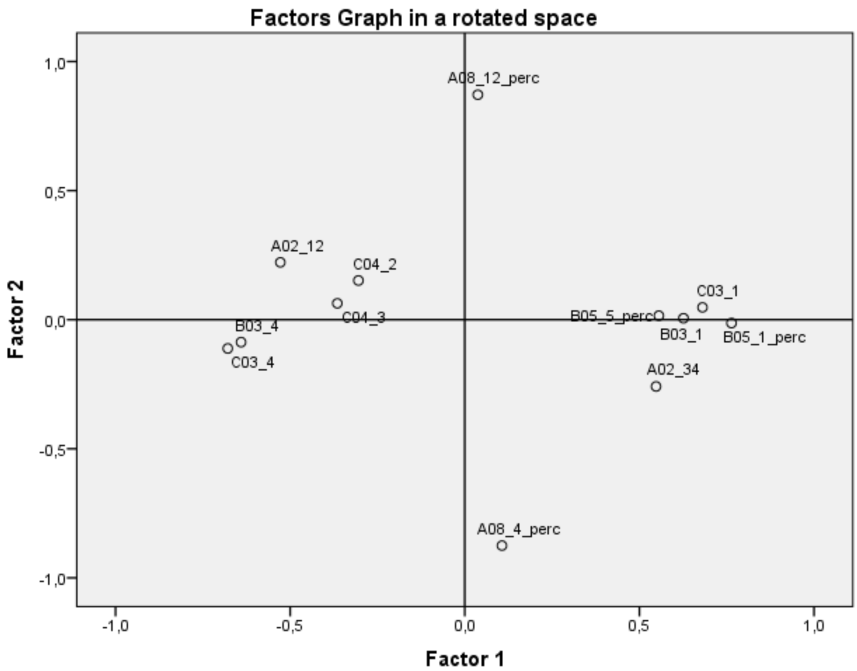
related with the proportion of small firms (A08_12). We observe also that the relation between the axes is not fairly orthogonal, independently of the oblique rotation.

Table 8. Factor Loadings (rotated model)

Variable	Factor of rotated model 1	2
% Industrial property	-,528	,222
% Public property	,548	-,259
% Small firms	,037	,871
% Large firms	,106	-,875
% Public subsidies on total budget	,626	,006
% Market incomes on total budget	-,641	-,087
% researchers with a PhD	,764	-,013
% PhD students	,556	,015
Relevance of basic research	,681	,048
Relevance of technological services	-,679	-,111
Relevance of economic benefits for CRC partners	-,304	,152
Relevance of economic benefits for customers and users	-,365	,063

Source: Own elaboration based on ES-CRCs Project data.

Graph 2. Factors Graph (rotated model)



Source: Own elaboration based on ES-CRCs Project data.

A suggested typology of CRCs in Spain

The results of the factor analysis allow us to develop an empirical-based typology of CRCs in Spain. Using the factor loadings of the rotated model as guidelines (Table 8), the interpretation of the factor loadings is quite clear: On one hand, Factor 1 cuold be labelled under the name "Academic vs. Market Orientation of CRCs". It would summarize the different share of the academic and industrial features of CRCs organization, human resources, funds and demand. So, CRCs close to the "Academic" pole (positive values of Factor 1) would be characterized by a "more public" nature ─ with greater public support and higher share of public institutions into the organizational structure of CRCs ─ and a more "academic" character ─ with a higher proportion of post-doctoral researchers and PhD students and a higher importance of basic research activities. By contrast, CRCs close to the "Market" pole (negative values of Factor 1) would be characterized by a "more private" nature ─ with greater industrial support and higher share of funding from the market ─ and a stronger "productive" character ─ with higher importance of technological applications and services and bigger market orientation to their firm partners, customers and users. On the other hand, we could label Factor 2 under the name "Size of firm-partners". Positive values of this factor represent a strongest presence of small firm partners within the CRC, while negative values indicate a bigger presence of large firms in CRCs.

Combining dimensions 1 and 2, we can finally suggest an empirical-based typology of the Spanish CRCs of our sample, based also on the SSI approach. These types have to be understood as ideal and non-exhaustives. We disinguish four types of CRCs (Table 9):

- Type 1: This type of CRCs has a high proportion of small firm partners and academic orientation. Given the structural characteristics of the Spanish economy, it is unlikely that this type is very frequent. In Spain, small firms represent 90% of the total number of companies and are characterised by having a low rate of innovation and a strong orientation to the domestic and local market. The fact that these small firms join CRCs shows that, in spite of their small size they support innovation, getting close to universities and research centres to access to academic specialized knowledge and skills, what makes CRCs of this type highly "Local potential innovators". It is probably then that this type of CRCs operates in high tech industrial sectors.

- Type 2: This type of CRCs has a high proportion of large firm partners and academic orientation. Large firms in Spain represent a very low percentage of the total number of companies but they employ a high proportion of population. They show also a higher rate of tecnology capacity, innovation and internationalization. It is very likely that large firms that join CRCs with an academic orientation ─ like companies of this type ─ have long-term objectives and more ambitious aims in terms of innovation, obtaining benefits from the knowledge created by post-doctoral researchers and PhD students. It is also probably that this type of CRCs operates in high tech industrial sectors. Given these characteristics we call CRCs of type 2 "Transnational potential innovators".

- Type 3: CRCs of this type have a high proportion of small firm partners and market orientation. We think that this will be the most common model of CRC in Spain, given the structural characteristics of the Spanish productive sector ─ in which small firms represent 90% of the total number of companies and are characterised by having a low rate of innovation and a strong orientation to the domestic and local market. Firms involved in CRCs of this type will probably have short-term objectives of production and a more local and technical orientations. It is probably also that this type of CRCs operates in sector less R&D intense and with lower productivity. Given these characteristics we call CRCs of type 3 “Local technologic developers”.
- Type 4: CRCs of this type have a high proportion of large firm partners and market orientation. They probably have similar features that CRCs of type 3, so we call CRCs of type 4 “Transnational technologic developers”.

Table 9: Suggested typology of Spanish CRCs

		Size of firm-partners (Factor 2)	
		Small	*Large*
Academic vs. Market Orientation (Factor 1)	*Academic*	**1. “Local potential innovators”**	**2. “Transnational potential innovators”**
	Market	**3. “Local technologic developers”**	**4. “Transnational technologic developers”**

Source: own elaboration.

To contrast our typology with the sectoral affiliation of the centres (and other control variables), we group the CRCs of our sample according to the suggested typology. To this aim, we first estimate the values of the factors for each case using an Anderson-Rubin procedure. Such procedure guarantees that factors would be orthogonal one to one, also if they are built on an oblique rotation of the factor model. Table 3-A in the Annex shows the coefficients matrix for calculating factorial scores[6]. Then, we apply a cluster analysis using the estimated factors as classificatory variables. We use a K-means procedure based on Euclidean distances and set the clustering of CRCs into four groups. The algorithm reached convergence quite easily, stopping at the step number 6 and without big differences between initial and final centres of clusters (see Table 4-A

[6] In order to manipulate and interpretatie the estimated factors, we transformed such values in percentage. Distribution of estimated factors is quite normal and without anomalous fashions.

in the Annex). Clusters are also sufficiently distant among them, as the value of the F-statistics is significantly different to 0 (see Table 5-A in the Annex)[7].

Table 10 shows the distribution of frequency of the resulting clusters. As expected, type 3 cluster ─ *"Local technologic developers CRCs"* ─ is the largest one, corresponding to a half of the sample; and type 1 cluster ─ *"Local potential innovators CRCs"* ─ is the smallest one, only 10%. Clusters of types 2 and 4, both characterized by a high proportion of large firm partners are equally distributed.

Table 10. Distribution of CRC clusters

Cluster	Frequency	Percentage
Type 1 *"Local potential innovators"*	9	10,0
Type 2 *"Transnational potential innovators"*	18	20,0
Type 3 *"Local technologic developers"*	46	51,1
Type 4 *"Transnational technologic developers"*	17	18,9
Total	**90**	**100,0**

Source: Own elaboration based on ES-CRCs Project data.

Table 11 shows the distribution by type of CRC across sectors of economic activities. We observe that there is a good fit between our typology and the sector affiliation of CRCs. The association index is significantly different to 0 and superior to 0.4. We observe that CRCs of type 3 ─ *"Local technologic developers"* ─ operate in the Agriculture sector, in Low-Tech industries and in the Service sector. This fact is in line with our expectations, since such sectors in Spain are characterised by a low rate of innovation and productivity. CRCs of type 2 ─ "*Transnational potential innovators"* ─ mostly operate in High-Tech Industry, what again is coherent with the Spanish reality and economic structure. On the other hand, CRCs of type 1 and 4 ─ *"Local potential innovators"and "Transnational technologic developers",* respectively ─ do not show a clear specific connection with any economic sector of activity, appearing spread across diverse sectors without a well-defined observable trend.

[7] However, the centres of the clusters are not centred in the "heart" of any quadrant formed by the factorial axes (Graph 2-A). For example, we observe that the centre of "type 4 cluster" is close to 0, while the centre of "Type 1 cluster" is the most distant to 0. Distribution of the centres of the clusters, as we said, is quite irregular. This is probably due to two reasons. First, we can see this result as a consequence of the oblique rotation of the factor matrix. The second reason is that type 1 is the most frequent case in our dataset, whereas type 1 the less frequent, as we will show now. The distribution of frequency of our clusters has a direct influence on the position of their centres.

Table 11. Distribution of CRC clusters by sectors of economic activities

Sector of economic activity	Cluster **Type 1** *"Local potential innovators*	**Type 2** *"Transnation al potential innovators"*	**Type 3** *"Local technologic developers ,,*	**Type 4** *"Transnation al technologic developers"*	**Total**
Agriculture	1	1	5	0	7
High-Tech Industry	2	12	4	3	21
Medium-Tech Industry	0	0	7	5	12
Low Tech Industry	2	0	14	0	16
Services (including ICTs)	1	1	13	5	20
Energy, Water and Construction	3	3	3	4	13
Total	**9**	**17**	**46**	**17**	**89**
V=0,426 (sig.=0,000)					

Source: Own elaboration based on ES-CRCs Project data.

Finally, we also controlled our typology also for geographical region (Table 12) and find some significant connections. For example, we observe that in Madrid and Basque Country — regions with a high R&D intensity — CRCs of type 2 predominate — "*Transnational potential innovators*". In these two regions, public regional initiatives have recently promoted the creation of networks of new R&D centres for public-private cooperation. These centres are usually foundations supported by a unique policy program at the regional level of administration. Examples of this type are the BERC and the CRC programs in the Basque Country[8], and the IMDEA Network in Madrid[9]. It is surprising, however, that in Catalonia and Valencia — regions also with a high R&D intensity — the most common model of CRC is type 3 — *"Local technologic developers"*. Maybe in these regions, policies fostering private-public cooperation have been more based on the transformation of pre-existing Technological Centres, closer to industrial needs and supported by local SMEs and governments (Olazarán et al., 2009). More research is needed. Finally, and with the exception of Andalusia that concentrates CRCs of type 3, there is no a clear connection between type of CRC and region, also due to the small number of CRCs in many of them.

Table 12. Distribution of CRC clusters by Region

	Cluster **Type 1** *"Local potential innovators"*	**Type 2** *"Transnational potential innovators"*	**Type 3** *"Local technologic developers"*	**Type 4** *"Transnational technologic developers"*	**Total**
Andalucía	1	1	11	6	19
Aragón	0	1	0	3	4
Asturias	1	1	2	0	4
Baleares	1	0	2	0	3
Canarias	1	0	2	0	3
Cantabria	0	0	2	0	2
Castilla La Macha	1	0	1	0	2

[8] http://www.innobasque.com
[9] http://www.imdea.org/

Castilla y León	0	0	1	0	1
Cataluña	1	1	8	1	11
Cdad. Valenciana	0	2	6	1	9
Extremadura	0	0	2	1	3
Galicia	1	0	0	2	3
Madrid	0	4	1	1	6
Murcia	0	1	1	0	2
Navarra	1	0	0	1	2
País Vasco	1	7	5	1	14
Rioja (la)	0	0	2	0	2
Total	**9**	**18**	**46**	**17**	**90**
V=0.495 (sig.=0.042)					

Source: Own elaboration based on ES-CRCs Project data.

5. Summary of results and discussion

This paper develops a typology of Cooperative Research Centres (CRCs) in Spain through the sectoral system of innovation (SSI) approach. According to this approach, and based on the Spanish CRCs experiences, our initial expectations were: (1) To find different types of Spanish CRCs according to their knowledge base, their basic technologies, inputs and demand characteristics. (2) To find some linkages between specific types of CRCs and specific sectors of economic activity and (3) To find linkages between specific types of CRCs and regions in Spain. In order to perform the analysis, we use data from a multi-method survey directed to the heads of 163 CRCs in Spain (final sample of 123 CRCs). Based on the SSI approach, we first selected a set of variables proxis to some elements of the SSI-building blocks and conducted a factor analysis with such variables, suggesting a typolopoly of four types of CRCs: “Local potential innovators”, “Transnational potential innovators”, “Local technologic developers” and “Transnational technologic developers”.

Our findings show that our typology is quite consistent with the sectoral, regional and organizational point of view. In particular, we observe that for Agriculture and Low-Tech industry predominate the “Local technologic developers-CRCs” and for High-Tech industry the “Transnational potential innovators” model of CRC. Also, we find that these last models are more frequent in R&D intense Spanish regions like Madrid and the Basque Country.

These findings are also in line with the specific characteristics of the Spanish economic structure and with the SSI approach. Malerba (2002) points out that quite often sectoral and regional systems interplay, and Gabaldón et al. (2012) introduce the concept of “Districtual Innovation System” to integrate the innovation system approach with a geographical-local focus based on the concept of industrial district. This sectoral-regional integration could be an intersting line of research in the future for studying CRCs. Besides, the existence of different organizational models into the same sectoral system is consistent with the SSI approach: CRCs could reflect organizational patterns that have emerged in different periods and they could also be a proof of the existence of a diversified set of actors and need that centres links through their collaborative activities. CRCs could be a factor that permit innovation and change within the sectoral system.

Finally, our suggested typology of CRCs could be use to policy recomendations. According to the typology, CRCs seem to be potential innovators when firms, both small and large, have an academic orientation to universities and research centres, conduct basic research activities and access to high qualified research personnel. Our results find that these types of CRCs usually operate in Hih-Tech sectors and in R&D intense regions. In Spain, large firms employ the largest number of population; wihle small companies are the most numerous. The participation of both types of firms in these types of CRCs is then desirable for the creation of economic growth and employment. Public policy should consider promoting this kind of CRCs as promising means to get out of the current economic crisis.

References

Arnold, E. Deuten, J. and van Giessel, J.F. (2004) *An international review of Competence Centre Programmes*, Brighton: Technopolis Group.

Boardman, C. and D. Gray (2010) The new science and engineering management: cooperative research centres as government policies, industry strategies and organizations, *Journal of Technology Transfer*, 35: 445-459.

CREST (2008): Industry led competence centres. Aligning academic/public research with enterprise and industry needs (Report of the CREST working group), OMC Action Plan.

Cruz-Castro, L. and L. Sanz-Menéndez (2007) New Legitimation Models and the Transformation of the Public Research organizational Field, *International Studies of Management and Organization* 37 (1): 27-52.

Diment, K. and S. Garrett-Jones (2007): "How demographic characteristics affect mode preference in a postal/web mixed-mode survey of Australian researchers", *Social Science Computer Review* 25 (3): 410-417.

Feller, I., C.P. Alies y J.D. Roessner (2002) Impacts of research universities on technological innovation in industry: evidence from engineering research centres, *Research Policy*, 31: 457-474.

Fernández-Esquinas, M. and I. Ramos-Vielba (2011) Emerging forms of cross-sector collaboration in the Spanish innovation system, *Science and Public Policy*, 38(2): 135-146

Gabaldón, D.; I. Fernández de Lucio and Molina, F.X. (2012) Sistemas Distrituales de Innovación, *Ciencia, Pensamiento y Cultura*, 188-753: 63-73

Garrett-Jones, S. and T. Turpin (2010).Reward, risk and response in Australian cooperative research centres, *International Journal of Technology Transfer and Commercialisation*, 9 (1/2), 77-93.

Loasby, B. (2001) Time, knowledge and evolutionary dinamics. Why connections matter, Journal *of Evolutionary Economics*, 11(4): 393-412.

Malerba, F. (2007) Sectoral Systems: How and Why Innovation differs across Sectors, in Fagerberg, J. et.al. (Eds.) *The Oxford Handbook of Innovation*. Oxford: Oxford University Press.

Malerba, F. (2002) Sectoral Systems of Innovation and Production, *Research Policy*, 31: 247-264.

Olazarán M., Albizu E. and B. Otero (2009) Technology Transfer between Technology Centres and SMEs: Evidence from the Basque Country, *European Planning Studies* 17: 3-23.

Potts, J. (2000) *The New Evolutionary Microeconomics. Complexity, competence and adaptive behaviour.* Edward Elgar.

Roessner, D. (2000) Outcomes and impacts of the State/Industry-University Cooperative Research Centres (S/IUCRC) Program.Final Report.

Turpin, T., S. Garrett-Jones and K. Diment (2005) Scientists, career choices and organizational change: Managing human resources in cross-sector R&D organizations, *Journal of the Australian and New Zealand Academy of Management*, 11(2): 13-26.

Turpin, T. and Garrett-Jones, S. (2010), 'Reward, risk and response in Australian cooperative research centres', *International Journal of Technology Transfer and Commercialisation*,17.

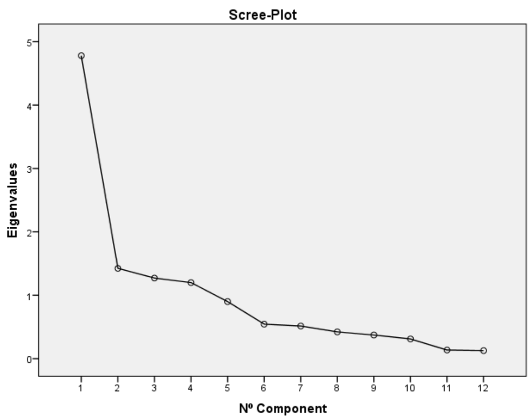
ANNEX

Table 1-A: PCA Explained Variance

Component	Eigenvalues		
	Total	% of variance	% Acumulate
1	4,778	39,821	39,821
2	1,424	11,866	51,686
3	1,271	10,592	62,279
4	1,200	9,996	72,275
5	,900	7,501	79,775
6	,544	4,536	84,311
7	,515	4,288	88,600
8	,422	3,517	92,117
9	,372	3,104	95,221
10	,311	2,593	97,813
11	,136	1,132	98,945
12	,127	1,055	100,000

Source: Own elaboration based on ES-CRCs Project data.

Graph 1-A: PCA Scree-Plot



Source: Own elaboration based on ES-CRCs Project data.

Table 2-A: Component Loadings

Variable	Component			
	1	2	3	4
% Industrial property	-,707	,242	-,333	,459
% Public property	,745	-,274	,229	-,452
% Small firms	-,557	,590	-,070	-,499
% Large firms	,679	-,513	,061	,417
% Public subsidies on total budget	,649	,126	,003	-,347
% Market incomes on total budget	-,606	-,349	,147	,020
% researchers with a PhD	,768	,242	-,116	,152
% PhD students	,577	,294	,370	,137
Relevance of basic research	,665	,394	-,044	,314
Relevance of technological services	-,621	-,413	-,170	-,108
Relevance of economic benefits for CRC partners	-,457	,265	,539	,298
Relevance of economic benefits for customers and users	-,454	-,012	,778	-,005

Source: Own elaboration based on ES-CRCs Project data.

Table 3-A: Coefficients Matrix for Factorial Scores

Variable	Factor 1	Factor 2
% Industrial property	-,138	,006
% Public property	,158	-,014
% Small firms	,163	,391
% Large firms	-,147	-,722
% Public subsidies on total budget	,170	,045
% Market incomes on total budget	-,174	-,060
% researchers with a PhD	,310	,077
% PhD students	,133	,037
Relevance of basic research	,204	,062
Relevance of technological services	-,197	-,071
Relevance of economic benefits for CRC partners	-,052	,006
Relevance of economic benefits for customers and users	-,069	-,010

Source: Own elaboration based on ES-CRCs Project data.

Table 4-A: Initial and Final centres of Clusters

Initial centres of clusters	Cluster 1	2	3	4
Factor 1	202,50	101,03	-197,69	-88,05
Factor 2	167,05	-133,48	-189,47	75,54
Final centres of clusters	**Cluster 1**	**2**	**3**	**4**
Factor 1	140,16	126,27	-77,58	-48,16
Factor 2	124,62	-99,45	-122,55	59,83

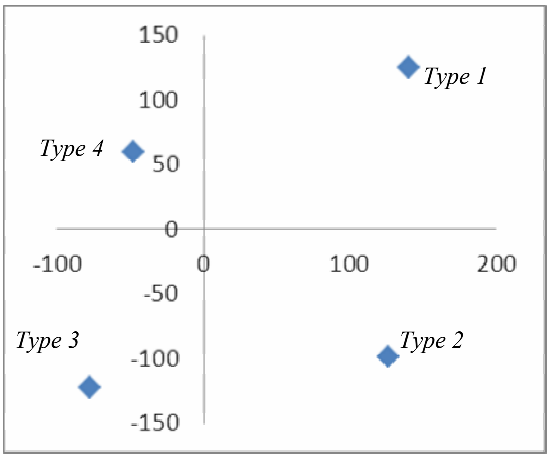
Source: Own elaboration based on ES-CRCs Project data.

Table 5-A: ANOVA of centres of Clusters

	Cluster		Error			
	Squared Mean	DF	Squared Mean	DF	F	Sig.
Factor 1	224262,625	3	2525,722	86	88,791	,000
Factor 2	245917,794	3	1770,310	86	138,912	,000

Source: Own elaboration based on ES-CRCs Project data.

Graph 2-A. Centres of the Clusters in the Factor Model Space



Source: Own elaboration based on ES-CRCs Project data.