Chapter 3

Patterns of Academic Scientific Collaboration at a Distance: Evidence from Southern European Countries

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Additional information is available at the end of the chapter

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Abstract

The main objective of this chapter is to examine the trends of academic scientific collaboration (SC) at a distance among public universities located in peripheral countries: Spain, Italy, Greece, and Portugal. The data to capture scientific collaboration consists of a set of co-authored articles published between 2001 and 2010 by universities located in the mentioned Southern countries, indexed by the Science Citation Index expanded (SCI Expanded) of the Information Sciences Institute (ISI) Web of Science (WoS) database. We link this data to institution-level information provided by the EUMIDA dataset. In addition, we retrieved regional data on economic variables from Eurostat. The methodology relies on a descriptive analysis of the evolution of co-publications at different notions of proximity. Our results show a trend toward collaboration over longer distances, although we find heterogeneity by countries and disciplines. Building on our results, we provide some policy implications.

Keywords: scientific collaboration (SC), co-authorship, proximity dimensions, geographical distance

1. Introduction

In the last decades, there has been an increasing trend toward scientific collaboration (SC) [1, 2]. Getting more insights about trends in scientific collaboration (SC) is important because SC is assumed to enhance the quality of the research for a number of stemming benefits largely discussed in the literature [3–5]. It brings together complementary knowledge and expertise. The presence of co-authors often implies a higher internal quality control than

single-authored papers; learning, social networks creation, knowledge diffusion, and cross-fertilization across individuals and/or disciplines are enhanced. From an economic viewpoint, SC also provides benefits including access to a wide variety of resources and new foundations or instruments. These benefits, together with the well-known role of knowledge creation and diffusion as the main sources for sustainable economic growth in the long run [6, 7], have shaped the European policy. The European government initiative aimed to convert Europe into the "the most competitive and dynamic knowledge-based economy" [8] giving priority to invest more in knowledge and innovation and to give Europe a new "fifth liberty," the free circulation of knowledge in order to construct a European research area [9].

The contribution of this research is twofold. First, we provide a comprehensive analysis of the evolution of geographical, cognitive, institutional, social, and organizational proximity on scientific collaboration. Apart from these, we also add economic distance as suggested in the recent literature [10, 11]. Second, we provide a joint analysis of trends in SC in all disciplines included in the Science Citation Index (SCI) of the Web of Science (WoS), and a separated analysis for *Chemistry & Chemical*, *Life Sciences* and *Physics and Astronomy* in order to examine whether there are differences across disciplines. We have chosen these disciplines because, jointly with *Medicine & Biomedicine*, they have the highest publication and collaboration share[1]. For our purpose, we use an original dataset containing information on 152,140 collaborations in publications in Science and Engineering (excluding social sciences) indexed in the Science Citation Index (SCI) provided by WoS and co-authored among academics from different universities. Our analysis includes 175 public universities from peripheral countries in Southern Europe: Spain, Greece, Italy, and Portugal. Focusing on peripheral countries is relevant because they usually include universities and regions far from core centers of knowledge with the lower level of resources and fewer opportunities to integrate in collaboration networks.

The remainder of the chapter is organized as follows. In Section 2, we review the relevant literature. Section 3 describes the data and explains the methodology. Section 4 provides the results. The main conclusions and policy implications are obtained at the end of the paper.

2. Literature review

The French school of proximity dynamics was pioneer to consider other notions of proximities beyond the geographical [12–14]. Drawing upon this line of research, Boschma [15], from a theoretical point of view, identified five kinds of proximities: geographical, cognitive, institutional, social, and organizational. Recent research has also highlighted the relevance of economic differences as an explanatory factor of SC [5, 10, 11, 16]:

- *Geographical distance* among actors hinders SC because face-to-face interactions that facilitate knowledge flows and tacit knowledge sharing become costly as distance increase

[1]Note that we do not perform a detailed analysis for *medicine & biomedicine* because some of the publications may be associated with university hospitals, which may have been or not co-authored by academics. Publications, for which we could not establish a clear link with an academic institution, have been excluded from our sample. Thus, our study may underestimate the scientific output in this discipline.

(e.g. [4, 17, 18]). Despite some authors claimed the death of distance due to ICT development, Hoekman et al. [18] found that physical distance still impedes research collaboration, with no evidence of a declining effect in the period 2000–2007.

- *Cognitive proximity*, that is, the degree of the shared knowledge base of organizations, facilitates knowledge transfer by contributing to building absorptive capacity that enables actors to identify, acquire, understand, and exploit knowledge available from others [19]. Nevertheless, recent studies have shown a certain degree of cognitive distance as a potential source of complementarities in order to improve knowledge base [20, 21]. Thus, the challenge is to collaborate with actors that provide access to heterogeneous sources of knowledge to generate sufficiently diverse complementarities, while ensuring the absorption capacity enabled by the shared knowledge base.

- *Institutional proximity* is defined by the degree of similarity in formal institutions, such as laws and rules, and informal institutions, like culture norms and habits, may enable knowledge flows by facilitating trust and reducing uncertainty and risks [15, 22]. Hoekman et al. [18] found that SC is more likely to occur within the same sub-national region, within the same country, and within the same linguistic area. Hennemann et al. [23] look in detail at the spatial structures of scientific activity (epistemic communities) showing that intra-country collaboration is more likely to occur than international collaboration.

- *Social proximity*, that is, socially embedded relations based on friendship, kindship and past experience between agents at the micro-level, is expected to stimulate interactive learning due to the trust and commitment [15]. It is commonly accepted to measure social proximity based on prior collaborations or previous research experiences [24–26].

- *Organizational proximity* can be understood as a variable capturing organization that share the same or similar regulation and routines at a micro-level. In that sense, a certain degree of organizational proximity is desirable to reduce uncertainty and opportunism in knowledge creation within and between organizations. In research collaboration literature, this dimension has been often included by a variable capturing whether partners to the same institutional arrange, for example, by belonging to the same corporation [27]. In this research, difficulties to consider organizational proximity in Boschma's sense, arises due to the absence of hierarchical relations among universities. However, they cannot be considered homogenous organizations because research institutions differ in their norms, structure, size, and strategy [28, 29].

- *Economic distance* (differences in economic resources among geographic areas) may determine the spatial patterns in SC, as derived from the center-periphery hypothesis applied to research collaboration [10, 11]. According to this literature, scientists in peripheral countries are willing to collaborate with core countries to gain access to resources, while core areas seek for complementarities [16]. However, empirical evidence provided by Acosta et al. [10] using data on a sample of co-authored papers among regions in EU-15 showed that differences in per capita income do not affect collaboration, while having similar levels of resources devoted to R&D play a positive role. They argue that having access to greater resources increase opportunities for mobility and attendance to international conferences, which enables establishing and reinforcing personal contacts for future collaborations.

3. Methodology and data

The empirical data used in this chapter consists of a set of 152,140 collaborations by scientists affiliated to different universities and published in journals indexed by the Science Citation Index Expanded (SCI Expanded) provided by the Thomson Reuters Web of Science (WoS). Socio-economic and humanities disciplines are excluded from our analysis. Our period of analysis is 2001–2010. This dataset was built following a similar procedure to Acosta et al. [10, 30]. Since our focus is at the university level, we had to harmonize the name variations of universities, mainly stemming from the use of the native versus the English name or the use of different acronyms. Then, papers were assigned to universities following the full counting process (crediting one publication to each co-author institution). Next, data on academic collaboration was placed into a symmetrical matrix containing all co-publications between university *i* and university *j* and, therefore, excluded intra-university collaboration. Publications where classified into 12 scientific disciplines following the Centre for Science and Technology Studies (CWTS) classification, using again the full counting method for those publications included in journals related to more than one discipline.

In a further step, we matched this dataset with EUMIDA dataset (Data Collection 1) in order to get information about organizational characteristics of the universities. EUMIDA data is the result of an initiative of the European commission to provide a complete census of European universities and provides information at the university level including organizational details such as education offered and staff employed[2]. Our final sample includes only those universities that were present in both datasets, that is, 175. Consequently, there are potentially (175*174) ÷ 2 = 15,225 collaboration links (observations). Additional information about regional Gross Domestic Product (GDP) and R&D expenditures was extracted from Eurostat.

In order to estimate the influence of different proximity dimensions on university SC, we put forward several variables:

- Geographical distance (*Geodist*) is measured as the Euclidean distance between universities *i* and *j*.
- Cognitive distance (*Cogndist*) is captured as the correlation index calculated as Paci and Usai [31] for the 12 discipline composition of scientific papers in university *i* and university *j* for the period 2001–2005. This coefficient ranges between zero (minimum distance, identical specialization) and one (maximum distance).
- Institutional proximity is measured by two binary variables. *Region* is a dummy variable, which takes value 1 when universities *i* and *j* are in the same region, 0 otherwise. *Country* is a dummy variable, which takes value 1 when universities i and j are in the same country, 0 otherwise.

[2]A description of data and the collection procedure is provided in EUMIDA 2010. Feasibility Study for Creating a European University Data Collection [Contract No. RTD/C/C4/2009/0233402]. Data collection 1 is available at http://ec.europa.eu/research/era/areas/universities/universities_en.htm. (Accessed at 18/10/2012). Data collection 2, which contains more detailed data, was not available to us by the time of this research.

- Social proximity (*Socialprox*) is represented by a dummy variable which takes value 1 if universities "i" and "j" have collaborated for the five-years previous period 2001–2005. However, this indicator does not allow us to provide evidence on trends in social distance since we did not have data on previous collaborations for the period 2001–2005.
- Organizational proximity is captured by two variables. *Educprox* is the correlation coefficient between the nine education fields, as identified in EUMIDA, corresponding to university *i* and university *j*. *Staffdist* is the absolute difference in total staff of universities *i* and *j*. These variables refer to year 2008, which is the reference year for EUMIDA dataset.
- Economic distance is measured by three variables. *GDPdist* is the absolute difference in the average GDP in 2004–2008 between regions, where universities *i* and *j* are located. *R&Ddist* is calculated similarly but using the absolute difference in higher education R&D expenditures as % of the GDP. *Convergence* is a dummy variable that equals one if the two universities are located in convergence regions; zero otherwise.

Note that the description of the variables refers to data for all 12-disciplines. For separated descriptive by disciplines, collaborations, and previous collaborations refer to the respective counts for that specific discipline. At the discipline level, $Cogndist_{ij}$ represents the dissimilarity in specialization in a certain discipline. Since it is not possible to calculate it as a correlation coefficient or Paci and Usai index [31], it was calculated following a different procedure for models by disciplines: first, we calculated for each university the share of publications in each discipline over its total number of publications; second, we obtained the absolute difference in this indicator for each pair of universities.

It is worth noting that organizational proximity measures attempt to capture a complex phenomenon difficult to measure. Then, we choose the differences in educational profiles and size as factors capturing organizational characteristics that may shape their culture or orientation. In addition, we did not have access to data on R&D funding information at the level of institutions, so we have included the amount of R&D expenditures in the region in which the university is located.

In order to identify trends in scientific collaboration, we calculate the descriptives of distances for those pairs collaborating during 2001–2005 and, then, for those pairs collaborating during 2006–2010. **Table 1** shows some descriptives on collaborations in our sample: the number

	01–05	**06–10**
Pairs (a)	15,225	15,225
Collaborating pairs (b)	3669	4775
Total Collaborations (c)	60,522	91,618
b/a	24.10%	31.36%
Collaboration intensity (c/b).	16.50	19.19

Source: ISI Web of Science. Own elaboration.

Table 1. Number of collaborations and collaboration intensity 2001–2010.

of collaborating pairs has increased from 3669 to 4775 and total collaboration has substantially increased by 51.38%. From all possible pairs of universities, 24.10% has collaboration in 2001–2005, while it increases to 31.36% in 2006–2010. The intensity of collaboration (number of average collaborations among pairs) has increased from 16.50 to 19.19.

4. Results

In order to analyze the evolution of collaboration across distance, we obtain the mean and standard deviation of each proximity dimension in the period 2001–2005 and 2006–2010 for Spain, Greece, Italy, and Portugal. **Table 2** displays the results including data for all disciplines. **Tables 3–5** show the descriptives for *Chemistry & Chemical*, *Life Sciences* and *Physics & Astronomy*, respectively.

The following conclusions are drawn from the results of **Table 2**:

- The average geographical distance among partners has increased over time by 9.42%. This result holds for the four countries in our sample, with an increase ranging from 2.74% in Portugal to 9.53% in Italy. Therefore, we can identify a strong pattern of increasing collaboration among universities throughout longer geographical distance.
- The mean cognitive distance has slightly increased (0.65% on average for peripheral countries), suggesting a trend toward collaboration with universities specialized in different fields of research.
- The coefficients of *region and country* strongly decrease over the period of analysis (by 15.30 and 10.74%, respectively), suggesting that institutional proximity decays over time. Thus, there is a trend toward interregional and international collaboration. Focusing on detailed country data, Spain shows the strongest decrease in intra-regional collaboration and intra-national collaboration (25.12–15.49%, respectively). It is also remarkable that Portugal, despite showing a similar decrease in intra-regional collaboration, displays a smaller decrease in intra-national collaboration, and suggesting differences in international openness across these countries.
- The coefficients of variables capturing similarities in educational profile and differences in size decrease in the period 2006–2010 by 1.88–3.14%, respectively. Based on these results, we cannot distinguish a clear trend in organizational distance. Country data shows that similarities in educational profile decrease in Greece, Italy, and Portugal but increase in Spain. Differences in size decrease in all countries, with the exception of Portugal.
- The co-efficient of *GDPdist* remains almost steady for peripheral countries as a whole, while differences in R&D slightly decrease over time. However, there are differences by countries: *GDPdist* increases in all countries but in Greece, where it decreases by 6.35%; and *R&Ddist* increases in Spain, Greece, and Portugal, but decreases in Italy. When focusing in collaboration among convergence regions, it arises that universities tend to collaborate more over time with other universities also located in convergence regions, suggesting that economic distance is increasing its importance as a barrier to SC. Italy is the country, where collaboration among convergence regions experienced the strongest increase (by 5.41%).

	All Countries			ES			GR			IT			PT		
	01–05	06–10	%	01–05	06–10	%	01–05	06–10	%	01–05	06–10	%	01–05	06–10	%
Geographical distance															
$Geodist_{ij}$	8.6937	9.5126	9.42	10.4664	11.2584	7.57	14.2690	15.2108	6.59	9.8263	10.7625	9.53	11.0458	11.3480	2.74
	(7.34)	(7.84)		(7.21)	(7.59)		(10.81)	(11.14)		(7.16)	(7.36)		(9.55)	(9.50)	
Cognitive distance															
$Cogndist_{ij}$	0.7817	0.7868	0.65	0.7834	0.7869	0.45	0.7970	0.8034	0.80	0.7769	0.7819	0.64	0.7898	0.7962	0.81
	(0.05)	(0.05)		(0.04)	(0.04)		(0.05)	(0.06)		(0.05)	(0.05)		(0.04)	(0.04)	
Institutional distance															
$Region_{ij}$	0.0621	0.0526	−15.30	0.0430	0.0322	−25.12	0.0638	0.0581	−8.93	0.0353	0.0289	−18.13	0.0760	0.0569	−25.13
	(0.24)	(0.22)		(0.20)	(0.18)		(0.24)	(0.23)		(0.18)	(0.17)		(0.27)	(0.23)	
$Country_{ij}$	0.6173	0.5510	−10.70	0.4313	0.3645	−15.49	0.3161	0.2940	−6.99	0.5330	0.4642	−12.91	0.2496	0.2267	−9.17
	(0.49)	(0.50)		(0.50)	(0.48)		(0.47)	(0.46)		(0.50)	(0.50)		(0.43)	(0.42)	
Social proximity															
$Socialprox_{ij}$	—	0.6848	—	—	0.6554	—	—	0.4513	—	—	0.6876	—	—	0.5248	—
		(0.46)			(0.48)			(0.50)			(0.46)			(0.50)	
Organizational proximity															
$Educprox_{ij}$	5.7874	5.6786	−1.88	6.1203	6.0237	4.64	3.8997	3.7790	−3.10	5.7466	5.6445	−1.78	6.3322	6.2153	−1.85
	(1.80)	(1.82)		(1.57)	(1.61)		(2.16)	(2.04)		(1.80)	(1.82)		(1.30)	(1.41)	
$Staffdist_{ij}$	1939.01	1878.22	−3.14	2037.58	1947.88	−1.58	1767.02	1744.74	−1.26	2024.37	1985.35	−1.93	1620.53	1644.70	1.49
	(1676.61)	(1631.56)		(1717.26)	(1650.28)		(1621.03)	(1579.96)		(1734.05)	(1692.64)		(1399.37)	(1414.75)	
Economic distance															
$GDPdist_{ij}$	0.0062	0.0063	1.61	0.0060	0.0061	1.67	0.0063	0.0059	−6.35	0.0066	0.0068	3.03	0.0066	0.0067	1.52
	(0.00)	(0.00)		(0.00)	(0.00)		(0.00)	(0.00)		(0.00)	(0.00)		(0.00)	(0.00)	

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	All Countries			ES			GR			IT			PT		
	01–05	**06–10**	**%**	**01–05**	**06–10**	**%**	**01–05**	**06–10**	**%**	**01–05**	**06–10**	**%**	**01–05**	**06–10**	**%**
$R\&Ddist_{ij}$	0.1092	0.1086	−0.55	0.0957	0.0969	1.25	0.1064	0.1091	2.54	0.1340	0.1336	−0.30	0.0854	0.0855	0.12
	(0.09)	(0.09)		(0.07)	(0.07)		(0.09)	(0.09)		(0.09)	(0.09)		(0.07)	(0.08)	
$Convergence_{ij}$	0.4044	0.4241	4.87	0.4126	0.4227	2.45	0.4800	0.4972	3.58	0.3792	0.3997	5.41	0.5091	0.5316	4.42
	(0.05)	(0.49)		(0.49)	(0.49)		(0.50)	(0.50)		(0.49)	(0.49)		(0.50)	(0.50)	
N°. Obs.	3669	4775	30.14	1929	2612	35.41	329	534	62.31	2210	2807	27.01	605	966	59.67

Source: ISI Web of Science, EUMIDA and Eurostat. Own elaboration.

Table 2. Change in average distance of collaborations per country. About 12 disciplines (Mean and standard deviation).

	All Countries			ES			GR			IT			PT		
	01–05	06–10	%	01–05	06–10	%	01–05	06–10	%	01–05	06–10	%	01–05	06–10	%
Geographical distance															
$Geodist_{ij}$	6.8711	7.9993	16.42	8.9700	9.7482	8.68	13.0388	15.2434	16.91	7.5760	8.9951	18.73	8.3953	9.8989	17.91
	(6.30)	(7.04)		(6.80)	(7.06)		(11.23)	(11.54)		(6.30)	(6.85)		(8.27)	(8.78)	
Cognitive distance															
$Cogndist_{ij}$	0.0924	0.0988	0.07	0.1133	0.1166	2.91	0.0821	0.0847	3.17	0.0833	0.0894	7.32	0.0926	0.0991	7.02
	(0.08)	(0.08)		(0.09)	(0.09)		(0.07)	(0.07)		(0.07)	(0.07)		(0.07)	(0.07)	
Institutional distance															
$Region_{ij}$	0.0879	0.0694	−21.05	0.0808	0.0557	−31.06	0.0575	0.0513	−10.78	0.0549	0.0413	−24.77	0.1009	0.0710	−26.63
	(0.28)	(0.25)		(0.27)	(0.23)		(0.23)	(0.22)		(0.23)	(0.20)		(0.30)	(0.26)	
$Country_{ij}$	0.7357	0.6465	−12.12	0.5271	0.4517	−14.30	0.4138	0.3282	−20.69	0.6874	0.5810	−15.48	0.3571	0.2759	−22.74
	(0.44)	(0.48)		(0.50)	(0.50)		(0.50)	(0.47)		(0.46)	(0.50)		(0.48)	(0.45)	
Social proximity															
$Socialprox_{ij}$	—	0.6439	—	—	0.5842	—	—	0.4462	—	—	0.6723	—	—	0.4828	—
		(0.48)			(0.49)			(0.50)			(0.47)			(0.50)	
Organizational proximity															
$Educprox_{ij}$	6.1203	5.9715	−2.43	6.4282	6.2213	−3.22	4.2184	3.8615	−8.46	6.0781	5.9531	−2.06	6.4664	6.3732	−1.44
	(1.61)	(1.69)		1.32	(1.51)		(2.21)	(2.16)		(1.64)	(1.70)		(1.09)	(1.21)	
$Staffdist_{ij}$	1973.42	1933.14	−2.04	1998.80	1981.83	−0.85	1883.60	1822.17	−3.26	2033.37	2012.00	−1.05	1531.05	1569.63	2.52
	(1661.11)	(1646.25)		(1622.16)	(1625.04)		(1767.60)	(1675.70)		(1723.08)	(1721.78)		(1199.39)	(1318.44)	
Economic distance															
$GDPdist_{ij}$	0.0059	0.0061	3.39	0.0056	0.0058	3.57	0.0059	0.0057	−3.39	0.0062	0.0065	4.84	0.0064	0.0065	1.56
	(0.00)	(0.00)		(0.00)	(0.00)		(0.00)	(0.00)		(0.00)	(0.00)		(0.00)	(0.00)	

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	All Countries			ES			GR			IT			PT		
	01–05	**06–10**	**%**	**01–05**	**06–10**	**%**	**01–05**	**06–10**	**%**	**01–05**	**06–10**	**%**	**01–05**	**06–10**	**%**
$R\&Ddist_{ij}$	0.1081	0.1079	−0.19	0.0921	0.0945	2.61	0.1030	0.0999	−3.01	0.1367	0.1373	0.44	0.0738	0.0768	4.07
	(0.09)	(0.09)		(0.08)	(0.08)		(0.08)	(0.08)		(0.09)	(0.09)		(0.07)	(0.07)	
$Convergence_{ij}$	0.3776	0.4004	6.04	0.3945	0.4094	3.78	0.4353	0.4740	8.89	0.3498	0.3734	6.75	0.5210	0.4970	−4.61
	(0.48)	(0.049)		(0.49)	0.49		(0.50)	(0.50)		(0.48)	(0.48)		(0.50)	(0.50)	
N°. Obs.	1763	2738	55.30	829	1419	71.17	87	195	124.14	1075	1599	48.74	238	493	107.14

Source: ISI Web of Science, EUMIDA and Eurostat. Own elaboration.

Table 3. Change in average distance of collaborations per country. Chemistry and chemical (Mean and standard deviation).

	All Countries			ES			GR			IT			PT		
	01–05	**06–10**	**%**	**01–05**	**06–10**	**%**	**01–05**	**06–10**	**%**	**01–05**	**06–10**	**%**	**01–05**	**06–10**	**%**
Geographical distance															
$Geodist_{ij}$	7.1094	7.5915	6.78	9.1112	9.4409	3.62	13.8785	13.7744	−0.75	7.5194	8.2657	9.92	10.5613	9.9425	−5.86
	(6.78)	(6.87)		(6.88)	(7.04)		(11.86)	(11.30)		(6.65)	(6.68)		(10.31)	(8.88)	
Cognitive distance															
$Cogndist_{ij}$	0.0826	0.0905	9.56	0.0856	0.0924	7.94	0.1051	0.1079	2.66	0.0716	0.0788	10.06	0.1357	0.1285	−5.31
	(0.08)	(0.09)		(0.07)	(0.08)		(0.10)	(0.10)		(0.08)	(0.08)		(0.11)	(0.10)	
Institutional distance															
$Region_{ij}$	0.0817	0.0705	−13.71	0.0796	0.0585	−26.51	0.0769	0.0643	−16.38	0.0500	0.0448	−10.40	0.0803	0.0628	−21.79
	(0.27)	(0.26)		(0.27)	(0.23)		(0.27)	(0.25)		(0.21)	(0.21)		(0.27)	(0.24)	
$Country_{ij}$	0.7427	0.6786	−8.63	0.5361	0.4712	−12.11	0.3846	0.3684	−4.21	0.7116	0.6441	−9.49	0.3092	0.2601	−15.88
	(0.44)	(0.47)		(0.50)	(0.50)		(0.49)	(0.48)		(0.45)	(0.48)		(0.46)	(0.44)	
Social proximity															
$Socialprox_{ij}$	—	0.5828	—	—	0.4901	—	—	0.3275	—	—	0.6159	—	—	0.4081	—
		(0.49)			(0.50)			(0.47)			(0.49)			(0.50)	
Organizational proximity															
$Educprox_{ij}$	6.2551	6.1164	−2.22	6.5286	6.4119	−1.79	4.2596	4.1813	−1.84	6.2348	6.0814	−2.46	6.6426	6.5381	−1.57
	(1.43)	(1.53)		(1.27)	(1.30)		(2.16)	(2.07)		(1.32)	(1.50)		(0.95)	(1.07)	
$Staffdist_{ij}$	2023.76	1913.63	−5.44	2067.18	1964.94	−4.95	1708.24	1679.84	−1.66	2106.67	2008.19	−4.67	1673.21	1573.48	−5.96
	(1712.73)	(1634.33)		(1686.91)	(1635.40)		(1572.05)	(1585.78)		(1781.08)	(1696.95)		(1451.14)	(1325.04)	
Economic distance															
$GDPdist_{ij}$	0.0059	0.0060	1.69	0.0057	0.0059	3.51	0.0059	0.0058	−1.69	0.0065	0.0065	0	0.0063	0.0064	1.59
	(0.00)	(0.00)		(0.00)	(0.00)		(0.00)	(0.00)		(0.00)	(0.00)		(0.00)	(0.00)	

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	All Countries			ES			GR			IT			PT		
	01–05	**06–10**	**%**	**01–05**	**06–10**	**%**	**01–05**	**06–10**	**%**	**01–05**	**06–10**	**%**	**01–05**	**06–10**	**%**
$R\&Ddist_{ij}$	0.1076	0.1066	−0.93	0.0882	0.0896	1.59	0.1026	0.1047	2.05	0.1341	0.1360	1.42	0.0864	0.0821	−4.98
	(0.09)	(0.09)		(0.07)	(0.07)		(0.09)	(0.09)		(0.09)	(0.10)		(0.08)	(0.07)	
$Convergence_{ij}$	0.3773	0.3991	5.78	0.3881	0.4226	8.89	0.5146	0.5146	0	0.3616	0.3703	2.41	0.5100	0.5269	3.31
	(0.48)	(0.49)		(0.49)	(0.49)		(0.50)	(0.50)		(0.48)	(0.48)		(0.50)	(0.50)	
N°. Obs.	1811	2483	37.11	804	1242	54.48	104	171	64.42	1120	1450	29.46	249	446	79.12

Source: ISI Web of Science, EUMIDA and Eurostat. Own elaboration.

Table 4. Change in average distance of collaborations per country. Life sciences (Mean and standard deviation).

	All Countries			ES			GR			IT			PT		
	01–05	**06–10**	**%**	**01–05**	**06–10**	**%**	**01–05**	**06–10**	**%**	**01–05**	**06–10**	**%**	**01–05**	**06–10**	**%**
Geographical distance															
$Geodist_{ij}$	7.3162	8.0470	9.99	9.5294	10.2536	7.60	14.1949	15.3879	8.40	8.0791	8.9452	10.72	9.4753	9.8693	4.16
	(6.49)	(7.28)		(6.90)	(7.61)		(10.52)	(11.25)		(6.36)	(7.01)		(8.74)	(9.02)	
Cognitive distance															
$Cogndist_{ij}$	0.1065	0.1047	−1.69	0.0888	0.0877	−1.24	0.0860	0.0938	9.07	0.1193	0.1178	−1.26	0.0745	0.0732	−1.74
	(0.93)	(0.09)		(0.07)	(0.07)		(0.07)	(0.07)		(0.11)	(0.10)		(0.06)	(0.06)	
Institutional distance															
$Region_{ij}$	0.0875	0.0820	−6.29	0.0769	0.0651	−15.34	0.0729	0.0571	−21.67	0.0495	0.0480	−3.03	0.1256	0.1022	−18.63
	(0.28)	(0.27)		(0.27)	(0.25)		(0.26)	(0.23)		(0.22)	(0.21)		(0.33)	(0.30)	
$Country_{ij}$	0.7035	0.6534	−7.12	0.4842	0.4433	−8.45	0.2813	0.3029	7.68	0.6430	0.5886	−8.46	0.3478	0.2972	−14.55
	(0.46)	(0.48)		(0.50)	(0.50)		(0.45)	(0.46)		(0.48)	(0.49)		(0.48)	(0.46)	
Social proximity															
$Socialprox_{ij}$	—	0.6168	—	—	0.5409	—	—	0.3543	—	—	0.6554	—	—	0.4149	—
		(0.48)			(0.50)			(0.48)			(0.48)			(0.49)	
Organizational proximity															
$Educprox_{ij}$	5.8197	5.7896	−0.52	6.0315	6.0474	0.26	4.1770	4.2229	1.10	5.7806	5.7815	0.02	6.2512	6.1920	−0.85
	(1.83)	(1.82)		(1.65)	(1.61)		(2.05)	(2.02)		(1.90)	(1.88)		(1.28)	(1.33)	
$Staffdist_{ij}$	2042.42	2007.24	−1.72	2107.02	2075.72	−1.49	1856.37	1772.30	−4.53	2126.58	2074.59	−2.44	1529.81	1584.70	3.59
	(1683.19)	(1665.54)		(1663.22)	(1643.10)		(1682.12)	(1572.16)		(1763.80)	(1725.96)		(1139.38)	(1387.78)	
Economic distance															
$GDPdist_{ij}$	0.0059	0.0061	3.39	0.0058	0.0059	1.72	0.0062	0.0063	1.61	0.0063	0.0065	3.17	0.0062	0.0067	8.06
	(0.00)	(0.00)		(0.00)	(0.00)		(0.00)	(0.00)		(0.00)	(0.00)		(0.00)	(0.01)	

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	All Countries			ES			GR			IT			PT		
	01–05	**06–10**	**%**	**01–05**	**06–10**	**%**	**01–05**	**06–10**	**%**	**01–05**	**06–10**	**%**	**01–05**	**06–10**	**%**
$R\&Ddist_{ij}$	0.1095	0.1066	−2.65	0.0931	0.0939	0.86	0.0962	0.1076	11.85	0.1350	0.1312	−2.81	0.0786	0.0724	−7.89
	(0.09)	(0.09)		(0.08)	(0.08)		(0.7)	(0.09)		(0.10)	(0.09)		(0.07)	(0.07)	
$Convergence_{ij}$	0.3469	0.3734	7.64	0.3506	0.3727	6.30	0.4681	0.5202	11.13	0.3282	0.3468	5.67	0.4493	0.5046	12.31
	(0.48)	(0.48)		(0.48)	(0.48)		(0.50)	(0.50)		(0.47)	(0.48)		(0.50)	(0.50)	
N°. Obs.	1703	2158	26.72	793	1076	35.69	96	175	82.29	1112	1332	19.78	207	323	56.03

Source: ISI Web of Science, EUMIDA and Eurostat. Own elaboration.

Table 5. Change in average distance of collaborations per country. Physics & astronomy (Mean and standard deviation).

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Next, we check if these results hold for *Chemistry & Chemical*, *Life Sciences* and *Physics & Astronomy* when analyzed separately (**Tables 3–5**). As shown by **Table 3**, geographical distance in *Chemistry & Chemical* increases, with a growth rate ranging from 8.68% in Spain to 18.73% in Italy. Specialization distance also rises, from 2.91% in Spain to 7.32% in Italy. Institutional proximity, that is, collaboration among universities located in the same region/nation decreases over time in peripheral countries. Organizational distance, as measured by differences in staff decreases over time, with the exception of Portugal (where it increases by 2.52%). However, it also comes that there is a trend toward collaboration between universities with different educational profiles, suggesting that organizational distance is increasing throughout the period of analysis. Generally, economic distance in terms of the difference in GDP and R&D expenditures among partners for each country also increases along time, excepting in Greece where it decreases. Our results also show a trend toward collaboration among convergence regions (average growth of 6.04%), except in Portugal.

Table 4 displays the evolution of distance dimensions for *Life Sciences*. Geographical distance shows contradictory results by countries, with an increase in average collaboration distance in Spain (3.62%) and Italy (9.92%), but a decrease in average distance in Greece and Portugal (0.75 and 5.86%, respectively), specialization distance also increases in Spain (7.94%), Greece (2.66%) and Italy (10.06%). Again, Portugal shows a decrease in average distance (5.31%). Variables capturing institutional proximity show that there is a decrease in intra-regional collaboration and national collaboration, in favor to interregional and international collaboration. In contrast, organizational distance is decreasing over time, with an average decrease of 2.22% in education proximity, 5.44% differences in size. This is universities tend to collaborate more over time with other universities with similar institutional characteristics. Economic distance yields different results for each indicator. GDP distance increases in collaboration pairs in Spain and Portugal but a decrease in Greece. Focusing on R&D distance, there is an increase in Spain (1.59%), Greece (2.05%), and Italy (1.42%) and a decrease in Portugal (4.98%). There is also a trend toward collaboration between convergence regions in Spain, Italy, and Portugal, while Greece remains equal.

Table 5 shows that geographical distance in collaboration in *Physics & Astronomy* increases in peripheral countries, ranging from an increase of 4.16% in Portugal to 10.72% in Italy. Specialization distance decreases by 1.69% in peripheral countries, being Greece an exception (with an increase of 9.07%). Generally speaking, institutional proximity strongly decreases over time, with an increasing share of international and interregional collaboration. The results show that universities tend to collaborate more and more with other universities with similar educational profiles, with the exception of Portugal where it slightly decreases by 0.85%. Distance in size decreases by 1.72% in the whole sample, with the exception of Portugal, where it increases by 3.59%. Economic distance in GDP also increases along time, from 1.61% in Greece to 8.06% in Portugal. Distance in R&D shows different growth rates across countries. It increases in Spain and Greece and decreases in Italy and Portugal. Our results also show a strong trend (7.64%) toward collaboration among convergence regions in all peripheral countries.

5. Conclusions

The objective of this chapter was to analyze patterns of SC along different notions of proximity in the period 2001–2010. For this purpose, we use data on 152,140 collaborations in publications in Science and Engineering (excluding social sciences) indexed in the Science Citation Index (SCI) provided by the ISI Web of Science (WoS) and co-authored among academics from different universities. Our analysis includes 175 public universities from peripheral countries in Southern Europe: Spain, Greece, Italy, and Portugal. The methodology relies on a descriptive analysis of collaborations in 12 scientific fields in which publications in science and engineering can be classified. In addition, we also provide descriptives for *Chemistry & Chemical*, *Life Sciences* and *Physics & Astronomy*, which are among the disciplines with the highest rate of collaboration over publications.

Our results for the whole sample and also for each country and discipline show that there is a clear trend toward collaboration along the greater geographical distance in peripheral countries. This result is in line with the finding obtained by Hoekman et al. [18] for 33 European Countries. There is also a trend toward increasing collaboration across cognitive and institutional distances. We cannot obtain clear conclusions for the evolution of organizational distance since we obtain controversial results for each of the indicators that measure this notion. Besides, our data reveals a trend toward collaboration among convergence regions, an increase in collaboration across larger economic distance in terms of GDP differences, but the opposite result is obtained in terms of R&D differences.

From a policy viewpoint, we can make some contributions. First, despite we find some heterogeneity in the results by scientific fields and countries, general patterns described in this chapter suggest a decrease in the importance of distance as a barrier to scientific collaboration in peripheral countries. Therefore, this evidence for peripheral countries suggests that there has been an advance in the construction of a European Research Area, as pursued by the EU policy. However, differences across countries and disciplines in the evolution of distance in collaborations suggest the convenience of elaborating tailor-made EU research policies adapted to their specific needs[3]. For example, for the model for all disciplines (**Table 2**), it is clear that although Portugal is collaborating across larger geographical distance (2.74%), it is lagging behind the rest of countries in our sample (Spain 7.57%, Greece 6.59%, and Italy 9.53%). Then, Portugal might benefit from policies oriented toward promoting the creation and diffusion of knowledge in collaboration across universities located at a distance. By doing so, it could catch up with the rest of peripheral countries. A similar analysis for the evolution of the rest of proximity notions could serve as a guide to elaborate EU policies for peripheral countries.

This study has four main limitations. First, we cannot provide evidence on trends in social distance since we did not have data on previous collaborations for the period 2001–2005. Second, we formatted our data as a cross-sectional series and measured variables at a unique time reference for the two periods, so we are not able to provide yearly statistics

[3]As pointed out by Hoekman et al. [18] it may be that each scientific discipline has different requirements due to their research topics or needed infrastructures.

on collaboration and different notions of proximity. Third, we do not control for scientific quality of universities that may be a factor affecting scientific collaboration patterns (see Hoekman et al. [18]). Fourth, our results must be taken with caution because we do not consider all countries in EU, but only peripheral countries in Southern Europe: Spain, Greece, Italy, and Portugal. Thus, future research may aim at providing evidence on collaboration across all EU countries, which may serve to extract policy implications on a wider framework.

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