Faculdade de Economia, Universidade do Porto

Master in Economics

Internship report in Economics

The economic value of knowledge: the case of University of Porto partnerships

by

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Biographic note

João Vítor Freitas Sampaio was born in Fafe, Portugal, on January 23 of 1992. He started his undergraduate studies at Faculty of Economics – University of Porto (FEP.UP) in September of 2010. He finished his university degree at the year of 2013, when got into the master on Economics. His first professional experience came in September of 2014 in the Shared Services of Faculty of Engineering through an internship that was possible because of an agreement between Faculty of Economics and Faculty of Engineering.

This internship formed the basis for the preparation of this internship report and database access was provided by University of Porto.

Actually, he is an assistant tax consultant at KPMG Portugal.

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Apart from my life in Porto, I want to refer my family, which is my first concern and the reason of my effort. To my beloved father, who always did everything for me and would love to see me growing up every year.

Resumo

Este relatório de estágio tem como objetivo analisar os projetos de cooperação em I&D entre a entidade onde decorreu o meu estágio - Faculdade de Engenharia da Universidade do Porto (FEUP) - e outras entidades entre 2006 e 2015 no que diz respeito, particularmente, às suas caraterísticas setoriais, localização geográfica, área científica de investigação e montante de investimento. Após uma breve revisão de literatura relativa às colaborações entre universidades e empresas, desenvolvemos uma avaliação quantitativa das parcerias da Faculdade de Engenharia recorrendo a estatística descritiva, inferência estatística e análise das redes sociais. Os nossos resultados mostram que o setor de atividade e área científica de investigação mais presentes são "Ensino superior" e "Ciências da Engenharia e Tecnologias", respetivamente, sendo que Porto corresponde ao município mais frequente de origem da entidade parceira. O *número médio de parceiros por projeto* corresponde a 3,9 e existem 32,42% de parceiros internacionais. Observamos que existem diferenças significativas nas variáveis *número de parceiros*, *dimensão média da entidade por projeto* e no *montante de investimento* de acordo com a dimensão e localização geográfica dos parceiros. Para além disso, os resultados mostram também que não existem diferenças significativas no *número de parceiros*, *dimensão média da entidade por projeto* e no *montante de investimento* de acordo com a área científica de investigação. O número de *ligações* por entidade varia entre 1 e 1342. Encontramos ainda um *núcleo* de 36 entidades que possuem 70 *ligações* dentro do *núcleo*. Os projetos nos quais estas entidades participam são internacionais.

Códigos-JEL: I23; O3; C89

Palavras-chave: Colaboração Universidade-indústria; I&D; Análise das redes sociais

Abstract

This internship report aims at analysing R&D cooperation projects between the entity where I was training - Faculty of Engineering, University of Porto (FEUP) - and other entities, from 2006 to 2015, with respect, in particular, to their sectorial characteristics, geographical origins, scientific research areas and investment amounts. After a brief literature review on collaboration between universities and firms, we develop a quantitative assessment of FEUP's partnerships by using descriptive statistics, statistical inference and social network analysis. Our results show that the most frequent sector of activity and scientific research area are "Higher Education" and "Science and technology engineering", respectively, and Porto is the most frequent municipality of partner's origin. The average number of partners *per* project is 3.9 and there are 32.42% international partners. We also conclude that there are significant differences in the number of partners, medium size *per* project and in the amount of investment according to partners' size and location. In addition, results also show that there are no significant differences in the number of partners, medium size *per* project or in the amount of investment according to the scientific research area. The number of links per entity varies between 1 and 1342. We also found a core of 36 entities that have 70 connections within the core. The projects where these entities participate are international.

JEL-codes: I23; O3; C89

Keywords: University-industry collaboration; R&D; Social network analysis.

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1. Introduction

> "Our main ambition is to work with existing firms. Innovation must incorporate scientific knowledge and produce businesses." José Caldeira, former director of INESC TEC - University of Porto.

Since the 1980s, many countries have implemented policies to promote and sustain university - industry partnerships (Fontana et al. (2006)). Sequeira & Teixeira (2011) justify these policies due to the profound consequences of the flows of ideas and technologies from universities and R&D institutions to firms over several economic variables. Through a coalition a firm can benefit from a broader scope of activities without spending precious resources to enter into new market segments. If there was no academic research, there would not have been many innovations and some of them would have come much later.

In the last decades, University of Porto (UP) is enrolled in innovation/technological development, scientific research, and international projects (as a proposing entity or partner) with a diversity of partners, partially supported by EU funds. Besides the possibility of accessing financial support, these projects also have spillover effects in UP's students, firms and the community in general.

University of Porto is "one of the largest educational and research institutions in Portugal and one of the hundred best European Universities. UP has about 32 000 students, 2 400 teachers and investigators, 1 600 non-teaching staff, 14 schools and 60 research units." (UP, 2015c). Its programmes cover all research areas and enroll 3 700 foreign students from 146 different countries. Some of the most productive and internationally recognized Portuguese centers of R&D belong to this entity. Additionally, UP has been establishing partnerships with some of the main national corporations to produce innovation as well as with international entities.

The Shared Services of the University of Porto (SPUP) are autonomous services of the University of Porto that perform centralized functions to support UP's organic units and also social policy actions to help students. It counts with about 30 collaborators, following up 800 projects and managing an investment of approximately 200 million Euros. The internship developed within Shared Services at U. Porto (in

FEUP) respects to the budgetary control of projects of innovation and technological development. Particularly, it deals with mission expenses, equipment acquisition for project development, scholarships, etc., as well as with the organization and follow up of their financial execution.

This internship report focuses on the Economics of Innovation, in which we intend to analyse partnerships between University of Porto - Faculty of Engineering (FEUP) and firms or other entities. It will focus in co financing and knowledge production, and intends to map the main characteristics of firms and other entities that collaborate with FEUP. Particularly, this report aims to answer the following questions: i) what are the main sectorial and geographical characteristics of FEUP's partners? ii) What are the core scientific research areas in FEUP's partnerships? iii) Are there significant differences in the number of partners, medium size per project or in the amount of investment according to partners' size or location? iv) Are there significant differences in the number of partners, medium size per project or in the amount of investment according to scientific research areas or duration of the project? v) What are the central actors in FEUP's research network?

In order to fulfil our goals, this research proceeds by carefully collecting information about FEUP's partnerships between 2006 and 2015, both near SPUP and in the database Amadeus (Bureau van Dijk), as well as through an extensive online search in partners' websites. We then develop a quantitative description of the data, as well statistical inference, particularly, non-parametric tests (Mann-Whitney and Kruskal-Wallis). Lastly, we implemented a social network analysis to go deeper into our goal and identify the core FEUP's partners.

This report is organised as follows. Section 2 briefly reviews the literature on collaboration between public research organisations and industry. Section 3 describes the internship host entity, University of Porto and Shared Services at U. Porto. Section 4 introduces the methodology and data. Section 5 presents and discusses the results. Section 6 concludes.

2. Collaboration between public research organisations and firms: an overview

The purpose of this section is to review the literature on collaboration between Universities/public research organisations and firms. We start by offering a brief clarification of the concept of research collaboration, and then we develop a review on the empirical studies on this topic.

2.1. The conceptual framework

According to Mota (1997), R&D activities have some public good features, as firms cannot fully appropriate the returns of their R&D investments, due to the existence of R&D spillovers. Therefore, R&D expenditures are usually lower than the social optimum. For this reason, R&D cooperation frequently emerges in order to internalize spillovers. Other advantages of R&D cooperation are to capture the economies of scale or complementarities in R&D, as well as potential beneficial effects coming from firms' coordination of research activities and the diffusion of know-how and R&D output among cooperating firms. Therefore, governments develop policies to encourage research partnerships (Hagedoorn et al. (2000)). Against these advantages is the fear that the participating firms may free-ride on other firms, as well as the possibility of reduction of competition in the product market, which would result in a welfare loss.

Technical knowledge can be explicit when it emerges in the form of a patent or design, or implicit, when is transmitted through informal contacts between people. Technical knowledge production typically implies uncertainty while its dissemination can induce opportunistic behavior (Hagedoorn et al. (2000)). Porter (1986) also states that through a coalition a firm can benefit from a broader scope of activities without spending precious resources to enter into new market segments.

Strategic alliance is defined as a "web of agreements whereby two or more partners share the commitment to reach a common goal by pooling their resources and coordinating their activities." (Teece (1992) apud Hagedoorn et al. (2000), p. 568).

According to Hagedoorn et al. (2000), research partnership is an "innovation - based relationship" that can be characterized in terms of the members of the relationship and in terms of its organizational structure. More attention is given to the latter because of the development of the theoretical and institutional literature.

Partners in a research partnership may come from either the public sector or the private sector. Many partnerships also involve universities and it is rarely the case that a university´s research is not publicly funded (Hagedoorn et al. (2000)).

Research partnerships may be informal because some firms collaborate with others in short-term research endeavors. These informal collaborations occur not only between firms but also between firms and universities, with the latter playing the role of specific subcontractor in a short-term project research (Hall et al. (1998) apud Hagedoorn et al. (2000)). However, this informality makes it impossible to present, in most cases, a detailed study of the partnerships (Hagedoorn et al. (2000)).

In what concerns formal collaborations, there are two categories: equity joint ventures that focus on R&D, which we call research corporations; and research joint ventures, which are mainly contractual arrangements (Hagedoorn et al. (2000)).

Several studies estimated that research collaborations may be unstable as about half of all R&D – “related equity joint ventures fall short of expectations or are disbanded.” (Berg et al. (1982); Kogut (1988b) apud Hagedoorn et al. (2000)). The problems come from sharing proprietary know-how, desire from control, different time - horizons, government policies or the effects of minimum efficient scale that come out of a R&D decentralization (Harrigan (1985); Hladik (1985); OECD (1986); Obleros & Macdonald (1988) apud Hagedoorn et al. (2000)).

On the other hand, non-equity agreements turn the resource gathering and activities undertaking possible without that complex creation of a new entity. However, this category of formal arrangement involves a strong commitment so that success appears.

2.2. Empirical studies

In order to characterize university-industry partnerships, this section presents a brief analysis of the research carried out in this topic. First we start by searching within Scopus database for the period 1981 to 2014 all articles that include the keywords "university + industry + collaboration" or "university + industry + partnership" in the articles' title, abstract, and in the keywords. Then, after a brief inspection of 808 articles' abstract, we select about 200 papers directly related with our goal (Appendix 1) in which we briefly identify the main goal, methodology and findings. Finally, from a more close inspection, we select some articles particularly useful for this literature review as well to our empirical research. In fact, Felsenstein (1996), Fontana et al. (2006) and Sequeira & Teixeira (2011) were extremely helpful for this literature review. Also, Pinheiro et al. (2015) was particularly useful to help in the selection of the methodology.

The extensive empirical literature on university-industry collaborations is mostly based on case studies, large surveys, and patent and bibliometric analysis.

From Felsenstein (1996) and Sequeira & Teixeira (2011) we define university as an organisation that receives inputs from households, governments and firms to pay its staff, equipments, services and other expenditures and produces outputs like human capital formation or knowledge production. The role of R&D institutions and knowledge production organisations in today's global economic development is significant as it generates economic growth and productivity.

Measuring the impact of universities on the national/regional economies focus essentially on public funding directed at scientific research and on the economic relevance of research. Perkmann et al. (2011) assessed the outcomes of university-industry collaborations by proposing a performance measurement system with prospective, retrospective, subjective and objective measures. Philbin (2008) investigated how to measure the performance of research and technological collaborations and subsequently how to improve the management of projects. The result was a new performance measurement tool incorporating some key findings. Other works (((Bailetti & Callahan (1992); Bozeman & Melkers (1993); Martin (1998); Bessette (2003); Coe & Helpman (1995); Verspagen (1997); Romer (1990); Dosi (1988); Trajtenberg (1990); Lichtenberg (1993); Bilbao-Osorio & Rodríguez-Pose

(2004)) apud Sequeira & Teixeira (2011)); Smilor et al. (1990); Goddard et al. (1994); Denison (1968); Steinnes (1987); Feller (1990) apud Felsenstein (1996) and Sequeira & Teixeira (2011)) focus on the relevance of outputs undertaken by universities and R&D institutions, as well as on the production of skills, know-how, patents, technology transfer, consultancy, new jobs formation, new firms formation, spin-offs or even consultancy made by these institutions. The induction of growth by universities is demonstrated in local labour markets (Bilbao-Osorio & Rodríguez-Pose (2004)), in firm formation rates, in the development of the local service sector and by human capital influence over local industry investment trends ((Florax (1992); Love & McNicoll (1988); Huggins and Cooke (1997); Newlands (2003); Steinacker (2005); Tavoletti (2007); Braunerhjelm (2008)) apud Sequeira & Teixeira (2011)).

Without any doubts, proximity is favourable to R&D transmission, once innovative clusters are found to support knowledge diffusion and knowledge spillovers ((Feldman (1994); Saxenian (1994); Audretsch (1998); Antonelli (1999); Carayole and Roux (2003); MacGarvie (2005)) apud Sequeira & Teixeira (2011)).

Felsenstein (1996) studied and described the 'seeding' effect of these organisations in a local economy. This author divides studies that attempt to estimate the impact on local or regional economies into accountability-type studies and demand-size analysis to university impact.

Most studies that focus on the regional economic impact of R&D institutions use input-output analysis (Felsenstein (1996); Helpman (1997); Bilbao-Osorio & Rodriguez-Pose (2004)), and conclude that university is viewed as a change-inducing factor. The accountability-type studies (Rosen et al. (1985)) estimate the effects of university on local businesses, local households and local government. Finally, there are also studies that use Keynesian-type income expenditures multipliers that found income, output and employment effects arising from the expenditure of faculty, staff and students ((Brownrigg (1973); Armstrong (1993)) apud Sequeira & Teixeira (2011)). Abramo et al. (2010) concluded that for each scientific discipline and each region it is possible to measure performance of individual universities in both-regional and extra-regional collaboration. Muscio et al. (2012) provides new insights into the effects of academic proximity to industrial area on university-industry collaboration by presenting robust evidence that proximity to industrial areas promotes the establishment of collaborative agreements. In 2003 Van Looy et al. created a study to demonstrate how regional economic policies to stimulate entrepreneurship and innovation can lead to success. Hong & Su (2013) provided an analysis of formal university-industry collaborations in China by focusing on geographic distance and stated that it is an obstructive factor in achieving partnerships.

Firm size influences the propensity of firms to collaborate with public research organisations, as we get from Mohnen & Hoareau (2003), Arundel & Geuna (2004) and Laursen & Salter (2004). Larger firms and start-ups are the ones which mostly benefit from academic research. Firms that invest more frequently in R&D tend to have a technological capability which allows them to absorb knowledge created externally to the firm. The role of 'absorptive capacity' was examined by Cohen & Levinthal (1990) and, if that one is significant, the firms with the higher R&D intensity are those that stablish greater collaborative R&D projects. It is also usually accepted that R&D activities tend to be concentrated at firm's headquarters (Fontana et al. (2003)). From Mohnen & Hoareau (2003) we have that independent firms take more advantage of collaborations with public research organisations than firms that are part of large organisations because in the latter there is a collaboration mediation by the headquarters. Social proximity and university prestige could also help bringing non-local academic and industrial partners together. There can be product and process innovation. Usually there exists a complex connection between the type of innovative activities carried out and the propensity for collaborating with public research organisations/extent of the collaboration (Fontana et al. (2006)). Swann (2002) states that firms involved in process innovation tend to cooperate more than firms that are more involved in product innovations. Perkmann & Walsh (2007), through an inductive study of university-industry collaboration in engineering, stated that basic projects are more likely to render academically valuable knowledge than applied projects. The latter show higher degrees of partner interdependence and lead to new ideas and projects.

If there was no academic research, there would not have been many innovations and some of them would have come much later. In an empirical qualitative study, Lee (2000) examined the sustainability of the collaborative experience by focusing on its outcomes and an overwhelming majority of the participants says that in the future they would expand or at least sustain that present level of collaboration. Heidrick et al.

(2005) presents a case study and concludes that both university engineering researchers and engineering managers from industry can derive valuable but different benefits from the same research project. Government investment can attract other investments and those projects have significant positive impact on related companies, as well as on the university, professors and students. Hicks (1993) examined the structure and funding of universities and indicators of the performance of Japanese science. He concluded that the system is evolving in directions more favorable for university research excellence and there are not insuperable barriers.

Landry et al. (1996) concludes that collaboration university-firms increases researchers productivity (patenting) as well as sales and firms productivity. Patenting has been gaining importance progressively in the last years and this tendency will continue. When we put ourselves into firms' perspective we get that they gain access to new ideas and innovation completion by partnering with public research organisations. ((Mansfield (1991); Beise & Stahl (1999); Cohen et al. (1998)) apud Fontana et al. (2006)).

While public research does not reach the importance of vertical chain elements, its importance is significant when compared with consultants, competitors and other sources that are not in the production chain. Channels of open science like publications, public meetings and conferences are essential. Collaborative research and preserving informal contacts are also highlighted ((Cohen et al. (2002a); Fontana et al. (2003); Meyer-Kramer & Schmoch (1998); Arundel & Geuna (2004)) apud Fontana et al. (2006)).

Barbolla & Corredera (2009) made an assessment of some of the most influential factors for success or failure in research contracts. The conclusions were that there are features beyond technology related to the corporate partner's strategic and functional characteristics that are decisive for success. Firms's real interest and involvement during technology transfer process, capacity to assimilate new knowledge and a confident attitude towards the university research group are key elements.

The notion of "open search strategy" was presented by Laursen & Salter (2004) and tells us that a firm's openness depends on the number of external channels of information that it uses to innovate. The more open a firm is, the more propension it has to consider useful the knowledge that universities have to give. They define "openness" as "the set of activities carried out by firms to both gather information from and voluntarily reveal knowledge to the external world". Firms implement *searching* and *screening* strategies (identifying the best information) together (Laursen & Salter (2004) apud Fontana et al. (2006)). When they reveal their technical and scientific capability with the intent to attract partners for possible collaborations they are *signalling*. Fontana et al. (2006) enhance the importance of *searching, screening and signalling* as activities conducted for knowledge acquirement.

Focusing on the barriers to university-industry knowledge spillovers, Van Dierdonck et al. (1990) examined the attitudes of Belgian academic community towards university-industry technology transfers. The authors did not detected a cultural barrier, and conclude that experience affects academic attitude towards industry positively. In addition, the results do not support the hypothesis that is needed a minimum level of scientific staff before the university can even start thinking of a partnership.

Lee et al. (2010) examined the roles and effects of industry liaison offices in Japan and concluded that alliances could overcome the limitations of traditional cooperative research projects. Meanwhile, in a empirical qualitative study Lee (1996) concluded that university-industry partnerships have interfered with academic freedom.

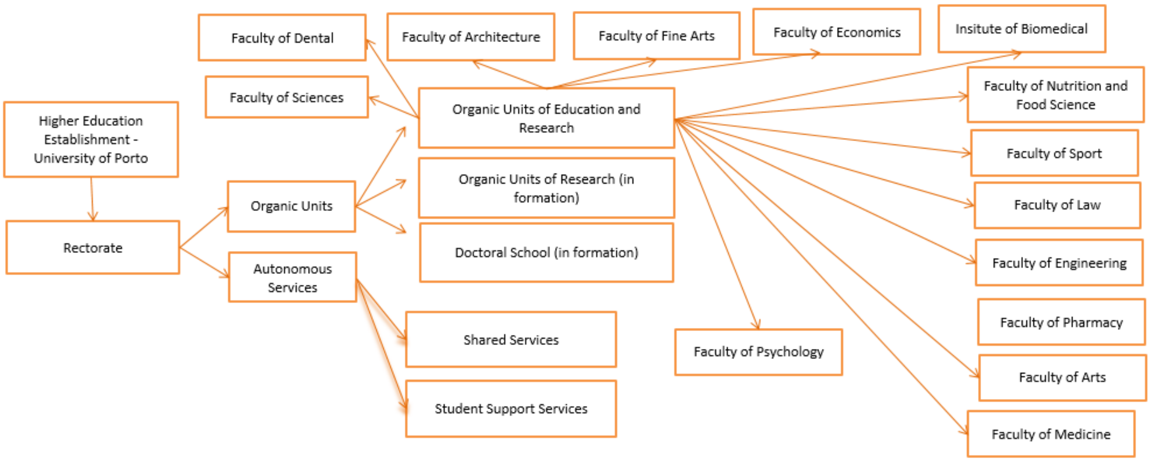
Pinheiro et al. (2015) tests the use of social network analysis as a new methodological approach to better understand university-industry relationships in the context of R&D cooperation networks for innovation. This work offers an illustration of the potential of using social network analysis methodology to assess university-industry networks and contributes to highlight the relevance of relational asymmetries shaping the innovation process within R&D projects.

3. University of Porto and the internship

3.1. The University

University of Porto (UP) is currently one the most prestigious Higher Education Institutions of Europe and the biggest producer of science in Portugal, whose origins date back to the eighteenth century. It has close to 31 000 students, 2 286 teachers or researchers, 1 542 administrative staff, 15 schools and 50 research units across 3+1 university sites located in the city of Porto. (UP, 2015)

UP provides a huge variety of courses, covering the whole range of scientific areas and all degrees of higher education.

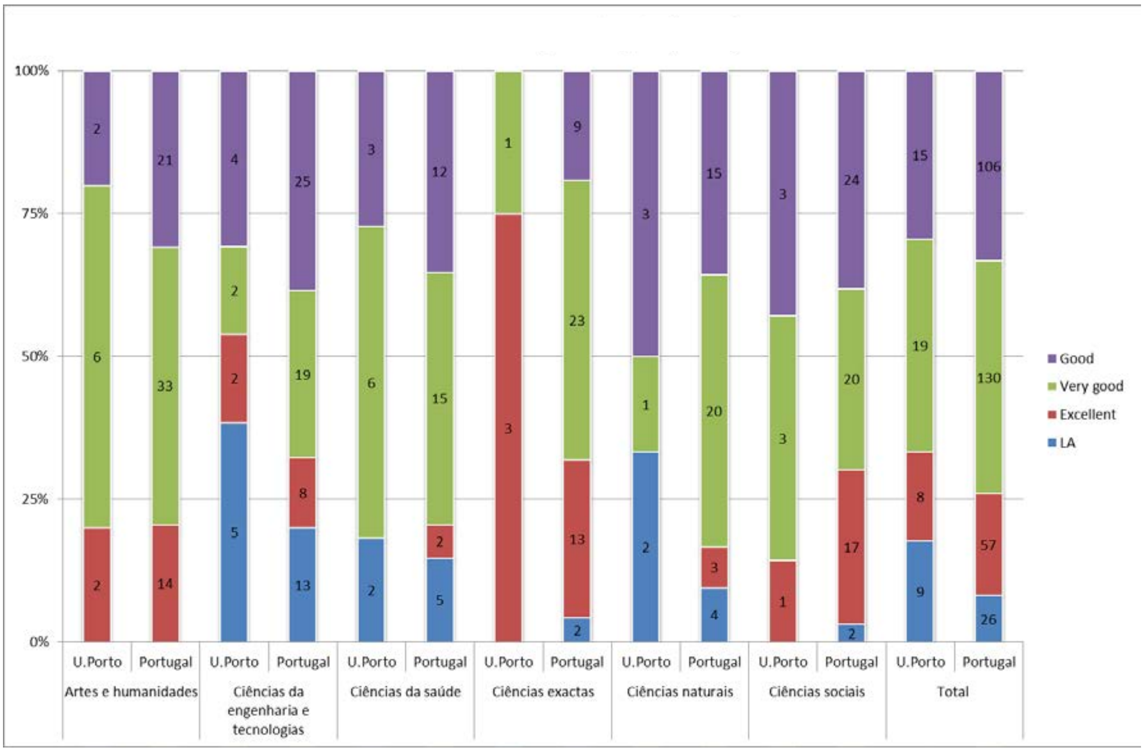


Source: UP (2015b)

Figure 1 - University of Porto: structure

The Rectorate is the organisational core of University of Porto and integrates all central governance bodies. As the scheme in Figure 1 shows, there are organic units and autonomous services. Organic units focus on teaching, research and other services. They have scientific, educational, administrative and financial autonomy. Autonomous services include Student Support Services (SASUP), which are responsible for implementing social policies at the University of Porto, in order to ensure the best conditions to the students - and Shared Services (SPUP, which are responsible for providing services to the organic units. It has administrative and financial autonomy and depends on the central government of the U. Porto (UP, 2015b). University of Porto has been enhancing the participation in non-profit associations in order to carry out R&D activities, the promotion and support to innovation, the economic valorization of knowledge and services provision to the community, key driving forces for the pursuit of its mission. This type of relationship brought advantages to University of Porto at a training level (because of the post-graduate, master's and doctoral students which complete their training by participating in R&D and innovation activities of those entities), at R&D level (activities are recorded in University of Porto through concluded projects, scientific papers published internationally, obtained funding, doctorates held), at an innovation and economic value of knowledge level (patents, spin-offs, technology transfers), at reputation level (many of those entities are in possession of great international prestige which reverts to the University's prestige), at a cooperation level with other universities (national and international) and in terms of obtained funding volume (becomes far superior because of the wider range of entities that can access to it). (UP, 2015b). Due to their geographical proximity and full cooperation, these entities are true extensions of University of Porto, being part of its universe. Some of these well known related entities are IBMC - Molecular and Cellular Biology Institute, INESC - Systems and Computers Engineering Institute or IPATIMUP - Pathology and Molecular Immunology Institute of University of Porto, which are also FCT (national funding agency for science, technology and innovation) associate laboratories.

University of Porto participates in 51 R&D organisms: 9 associate laboratories and 42 R&D units with multiannual funding (Figure 2). (UP, 2015)



Source: (Investigação U.Porto, 2015)

Figure 2 - Associate laboratories and R&D units with multiannual funding in 2013: UP vs Portugal

UP is also responsible for more than 23% of Portuguese articles indexed annualy in ISI *Web of* Science and resulted in the creation of more than 120 patents. (Investigação U.Porto, 2015)

Table 1 shows publishing in ISI *Web of* Science by Faculty, between 2009 and 2013, which evidence a growing tendency in almost all schools:

	2009	2010	2011	2012	2013	Total 2009-2013	TMVA
Architecture	1	1	2	2	4	10	50%
Fine Arts	1	0	1	3	0	5	0%
Sciences	562	710	771	801	955	3799	14,5%
Nutrition and Food Science	40	30	46	51	73	240	20,6%

Sport	54	101	124	191	157	627	36,5%
Law	3	4	2	1	1	11	-16,7%
Economics	51	38	43	81	82	295	19,3%
Engineering	454	532	591	665	732	2974	12,7%
Pharmacy	220	220	240	302	326	1308	10,7%
Arts	11	18	19	13	24	85	30,6%
Medicine	635	750	767	856	951	3959	10,8%
Dental Medicine	20	23	39	44	29	155	15,8%
Psychology and Educational Science	62	41	55	72	66	296	5,7%
Biomedical Sciences Abel Salazar	384	446	476	575	594	2475	11,7%
Total	2419	2827	3117	3522	3861	15746	12,4%

Source: (Produção científica da Universidade do Porto indexada na Web of Science 2009-2013, 2013)

Table 1 - Evolution 2009-2013 of ISI – WoS documents, by organic unit

3.2. The internship

The Shared Services at U. Porto (SPUP) are autonomous services guided by cooperation purposes with the organic unit to which the services are provided. SPUP present a supplier-customer relationship with the organic units, and want to be seen as partners which anticipate and meet the needs of the university community. SPUP provide support on different areas: legal, economic/financial, human resources, information and communication technologies and infrastructure areas. SPUP self-define their strategic objectives as providing "quality services", "monetize resources and optimize efficiency" and also "consolidate and share information and knowledge" (SPUP (2015)).

The internship is developed within the projects unit of SPUP. Having as coordinator Engineer Rita Marques (internship supervisor), the projects unit is responsible for the provision of quality services in issues related with the management of co-financing projects. Projects unit is in charge of administrative, economic and financial project management, which can be promoted only by University of Porto or result of partnerships with non-profit associations and also private entities. A huge support to teachers, researchers, teams and management staffs is here given. Some of the activities carried out by the employees in the projects unit are to update and disclose information about funding opportunities and applications management on co-financed projects, as well as the preparation of proposals, follow their financial execution, auditing, ensure the calculation of overheads or support the financial management of events related with the projects (SPUP (2015)). Projects unit is divided in 4 sub-areas: innovation and technological development, scientific research, structuring projects and international projects.

The traineeship tasks respect to the budgetary control of projects of innovation and technological development in which the Faculty of Engineering of the University of Porto (FEUP) is involved. This control goes through mission expenses, equipment acquisition for project development and all kinds of human resources imputation (teachers, scholarships, administrative staff). While updating projects dossier and verifying its concordance with reality, proceeded to projects financial execution, with all the bureaucracy inherent in funding entity procedures.

The Projects unit is located in the Rectorate and also in different organic units. The internship is located on FEUP and was in charge of some projects ON.2 - *O Novo Norte* (*Programa Operacional Regional do Norte 2007/2013*), whose term runs between January of 2013 and June of 2015. *Programa Operacional Regional do Norte 2007/2013* is a financial instrument which supports the regional development of *Região Norte* of Portugal, being part of *QREN - Quadro de Referência Estratégica Nacional*[1]. *Programa Operacional Regional do Norte 2007/2013* has a budget of 2.7 billion Euros.[2] Some of UP projects are also funded by *ADI – Agência de Inovação*, which is

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[1] *QREN - Quadro de Referência Estratégica Nacional* is the framework for the implementation of community policy to reach economic and social cohesion for the period 2007-2013 by applying 21.5 billion Euros (Quadro de Referência Estratégico Nacional, 2007).

2 There exist three incentive systems at ON.2: innovation and technological development (which tries to intensify the national effort on innovation and technological development and produce knowledge to raise firms competitive edge, promoting articulation between them and Scientific and Technological System

"essentially dedicated to the promotion of innovation and technological development with a view to facilitating closer ties between research activities and the Portuguese business sector." (Agência de Inovação (2015))

International projects are essentially funded by the European Commission, where University of Porto establishes several relationships with entities around the world in order to reach global objectives.

(SCT)); incentive to innovation (seeks innovation in firms through the production of goods, services and processes which support its progression in the value chain and reinforces an orientation towards international markets, as well as qualified entrepreneurship and structuring investment in potential areas of growth); and incentive to SME qualification (aims at promoting SME competitive edge by raising productivity, responsiveness and active presence in the global market) (ON.2 - O Novo Norte, s.d.).

4. Data analysis

This report intends to analyse the pattern of partnerships of the Faculty of Engineering of the University of Porto (FEUP) along different dimensions. For that purpose, we started by collecting information about 453 consortium projects to which FEUP belongs to. The projects selected started between 2006 and 2015. Then we classify each project according to the number of partners; the type of entity that cooperate with UP (profit and non-profit entity; sector of activity; size; location (country and NUTS3); total investment by the consortium; total investment/funding obtained by FEUP; duration; and scientific research area.

In order to fulfil our purpose, we develop a quantitative assessment of the data by using statistical inference, particularly, non-parametric tests (e.g. Mann-Whitney and Kruskal-Wallis). Then, we proceed with social network analysis to go deeper into our goal.

4.1. Data description

The information collected was obtained not only at SPUP - FEUP but also in the database Amadeus (Bureau van Dijk)[1], as well as through an extensive online search through partners' websites.

In a first step, we collect information about the 453 projects developed in the period 01/09/2006 to 28/02/2015 (many of them are still under development) in which FEUP is a partner. Our data shows that the average number of partners per project is 3.9 (Table 2):

Minimum	Maximum	Average	Standard deviation
1	46	3.926	5.411

Table 2 - Number of partners per project

[1] Amadeus (Bureau van Dijk) is a database of comparable financial information on around 21 million public and private companies across Europe (https://amadeus.bvdinfo.com/version-20151023/home.serv?product=amadeusneo).

The most frequent number of partners is 1 (only FEUP), which happens in 132 projects. In addition, 386 projects have 5 or less partners (Figure 3).

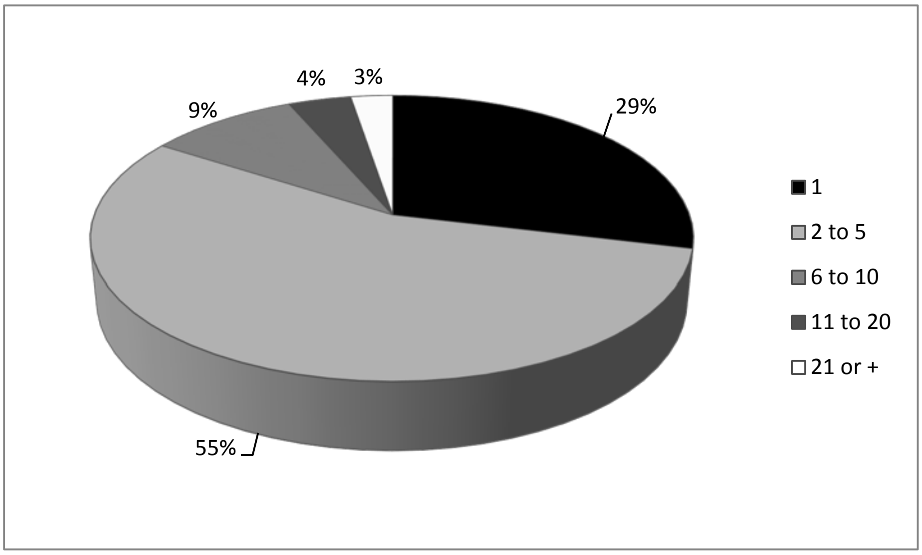

Figure 3 - Number of partners per project: relative frequency

With respect to each partner's sector of activity, we search for each entity's CAE (Portuguese classification of economic activities) (Appendix II). The CAE number 85420 – "Higher education" is the most frequent (696 times) and is followed by CAE number 72190 – "Research and natural/physical sciences development" (154 times). We must also note that 453 times of the 696 "Higher education" codes (85420) regard to FEUP. Some activities are seldom as they appear only once, e.g. "Manufacture of rusks and biscuits; manufacture of preserved pastry goods and cakes" (CAE number 10720) or "Manufacture of other cork products" (CAE number 16295). We may also note that there are 588 international partners for which the Portuguese CAE was not available (N/A). We represent in Figure 4 a simplified version by reducing the Portuguese classification of economic activities to one digit:

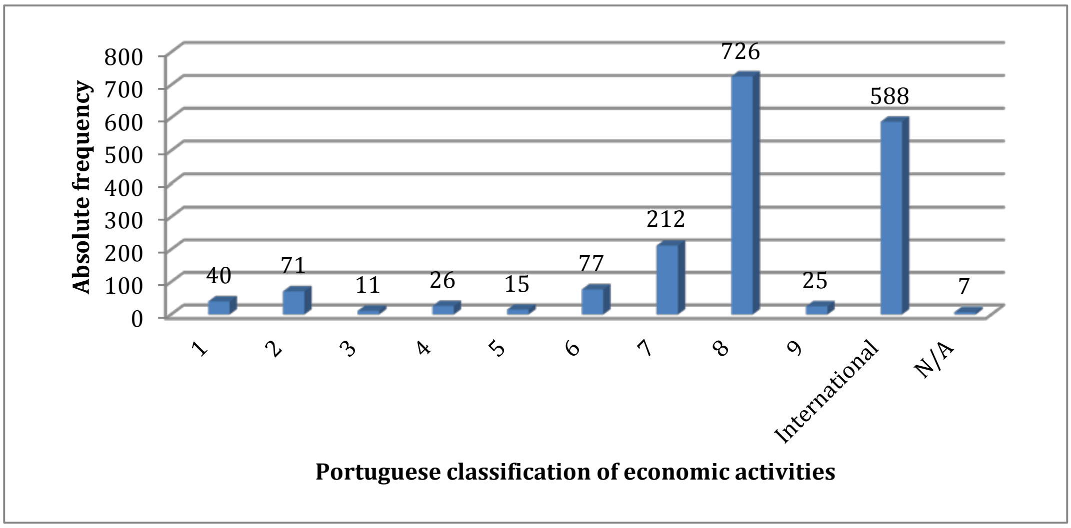

Figure 4 - Partners' CAE with one digit: absolute frequency

We also have nonprofit organisations 1364 times (75.86%) and profit entities 434 times (24.14%) (Figure 5). It is important to point out the fact that FEUP is a non-profit entity and is included in 453 projects, influencing these numbers.

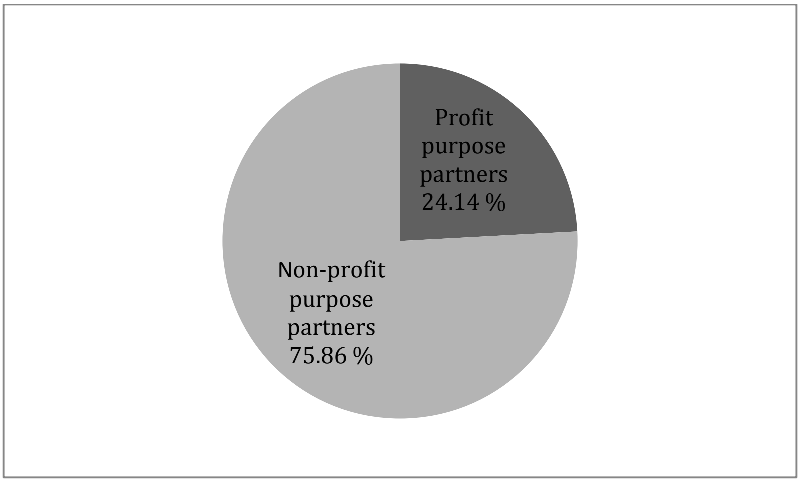

Figure 5 - Profit and non-profit purpose partners: relative frequency

Figure 6 shows that 67.58% of the partners are national and 32.42% are international.

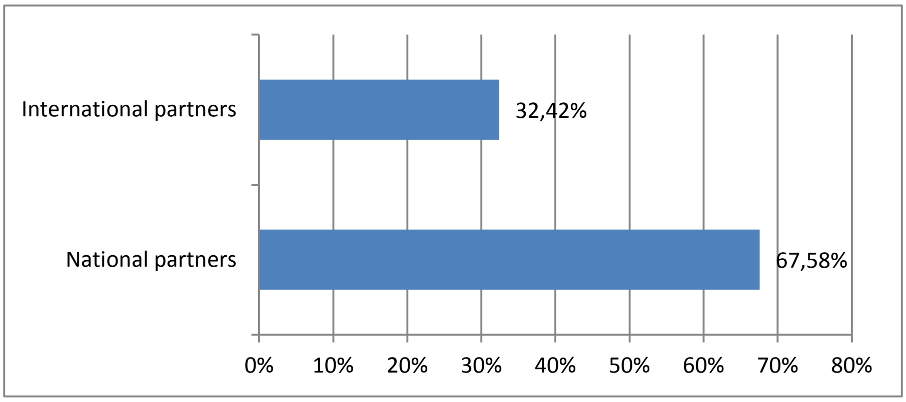

Figure 6 - Distribution of partners between national and international origin

Considering the national partnerships, the municipality of Porto (where FEUP is located) is repeated 649 times, followed by Lisboa (127 times) and Aveiro (55 times) (Appendix III). There are 18 municipalities that only appear once, like Açores or Faro. We use the Nomenclature of Territorial Units for Statistics (level 3) in Figure 7 to represent this information:

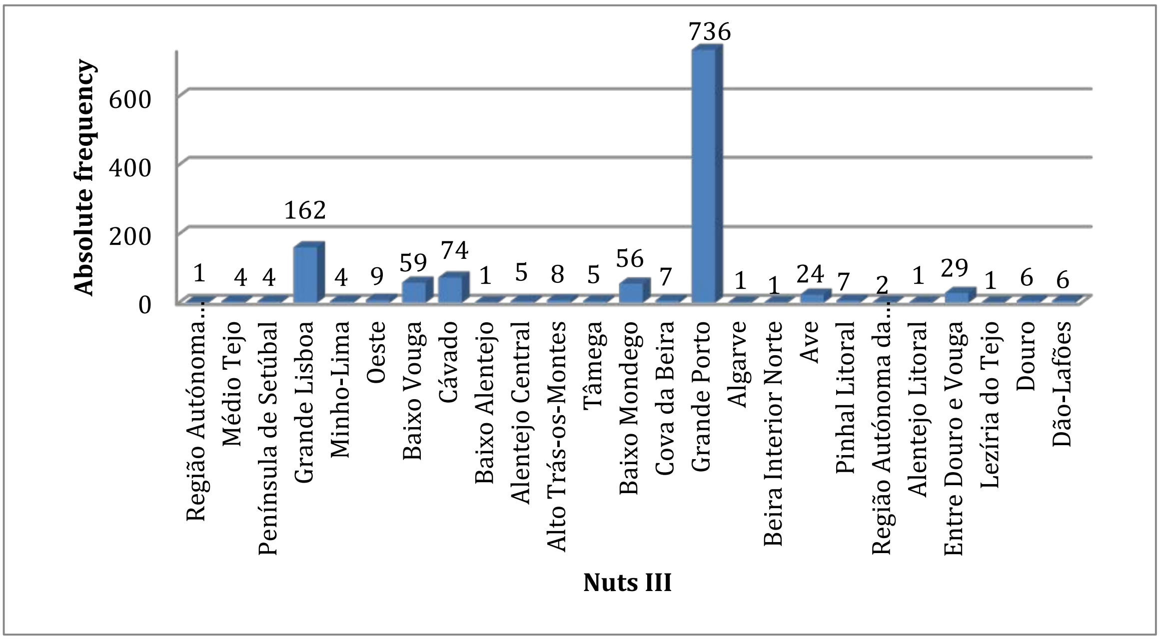

Figure 7 - National partners' location by Nuts III: absolute frequency

Focusing on the international partnerships, the most frequent countries are Germany (75), Spain (72) and France (65). Serbia, Macedonia, Romania, Tunisia, Angola, Slovakia, Chile, Morocco, Lithuania, South Korea, Bulgaria, Latvia, Republic of Ireland and Luxembourg are the host countries of one unique partner each.

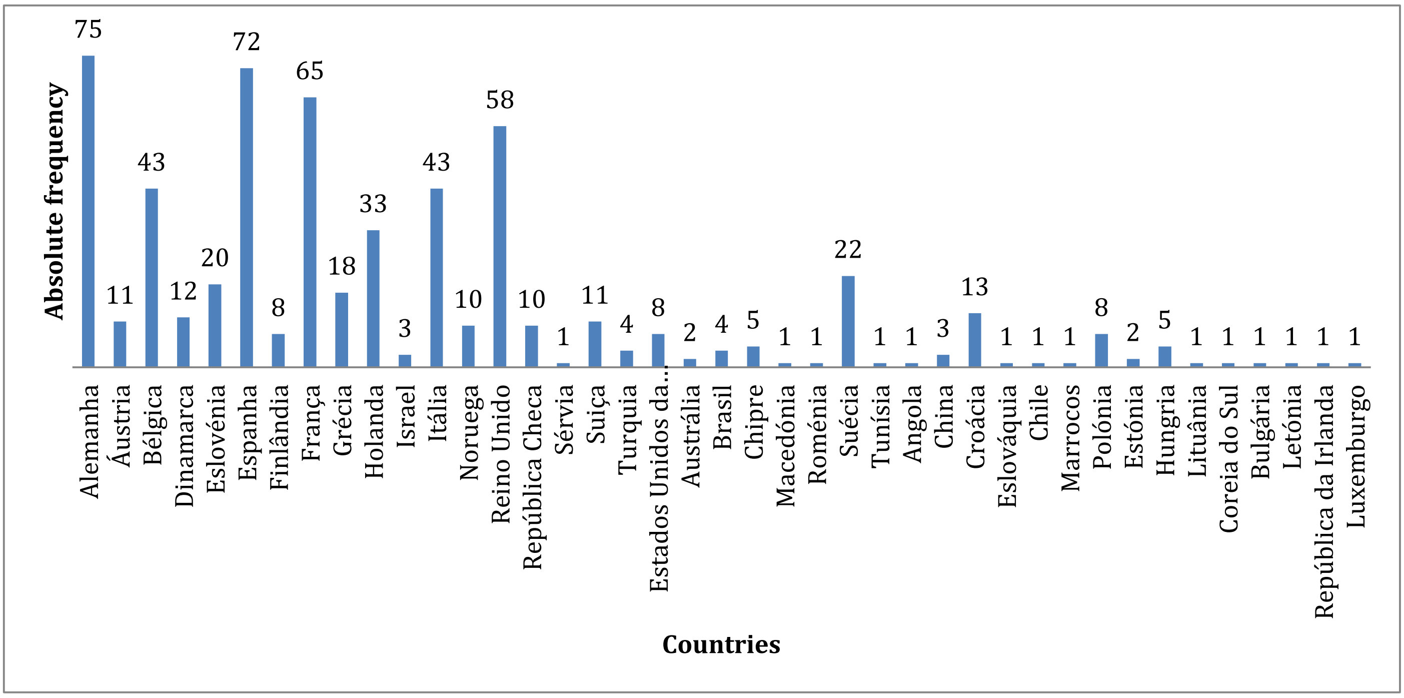

Figure 8 - Location of the international partners (countries): absolute frequency

Concerning the investment made by different partners, the average investment by project is 1198962.06 €. Focusing on FEUP, total average investment made by this entity is 156209.13 € and the average funding obtained by FEUP is 137853.33 €. The average duration of a project is 34 months (2 years and 10 months).

	Investment of the consortium	Investment by FEUP	Funding obtained by FEUP	Duration of a project
Minimum	0 €	0 €	0 €	5 months
Maximum	53291500 €	1989300 €	1989300 €	85 months
Average	1198962.06 €	156209.13 €	137853.33€	34 months
Standard deviation	3842084.15	223890.44	203255.21	11.07

Table 3 - Investment values, funding obtained and duration of projects

In what refers the scientific research area, science and technology engineering (396) is the most frequent research area. Theatre, social sciences, and agricultural science only appear once, twice and five times, respectively.

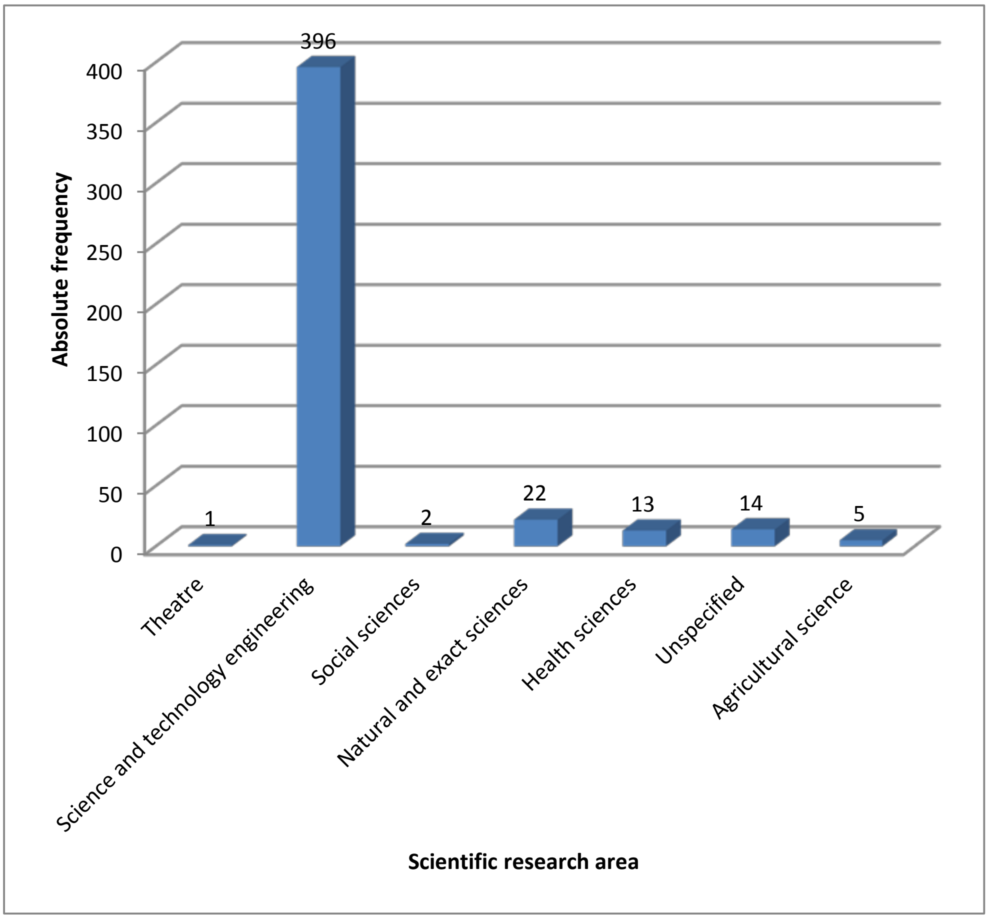

Figure 9 - Distribution of projects by scientific research area: absolute frequency

Proceeding to an analysis of partner's size we have the following table with the usual minimum, maximum, average and standard deviation analysis:

	Minimum	Maximum	Average	Standard deviation
Number of partner's employees	1	300000	2974.33	13433.48

Table 4 - Partner’s size

We also classified each partner's size in micro, small, medium and large. The micro partner has less than 10 employees, the small partner has between 11 and 50 employees and the medium partner has between 51 and 250 employees. The large partner has more than 250 employees (Figure 10). Note that if we exclude FEUP (with 907 employees and 453 projects as a partner), the absolute frequency of large partners decreases to 721).

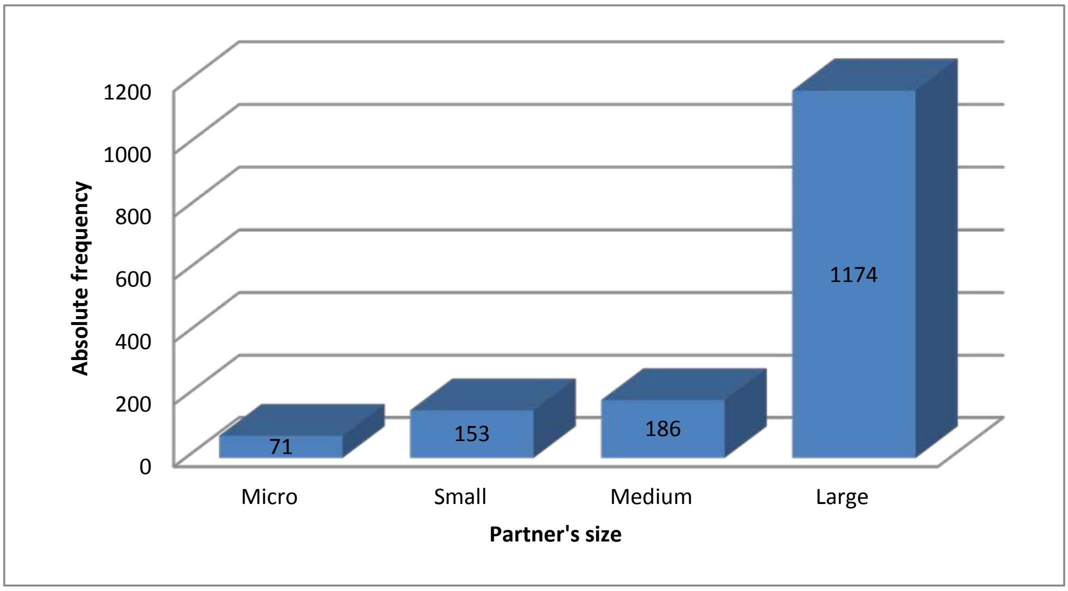

Figure 10 - Partner's size: absolute frequency

The total investment made by partners of the consortium (Figure 11) may be classified into micro (investment less than 50000€), small (50000€ and 100000€), medium (between 100000€ and 500000€) and large (larger than 500000€).

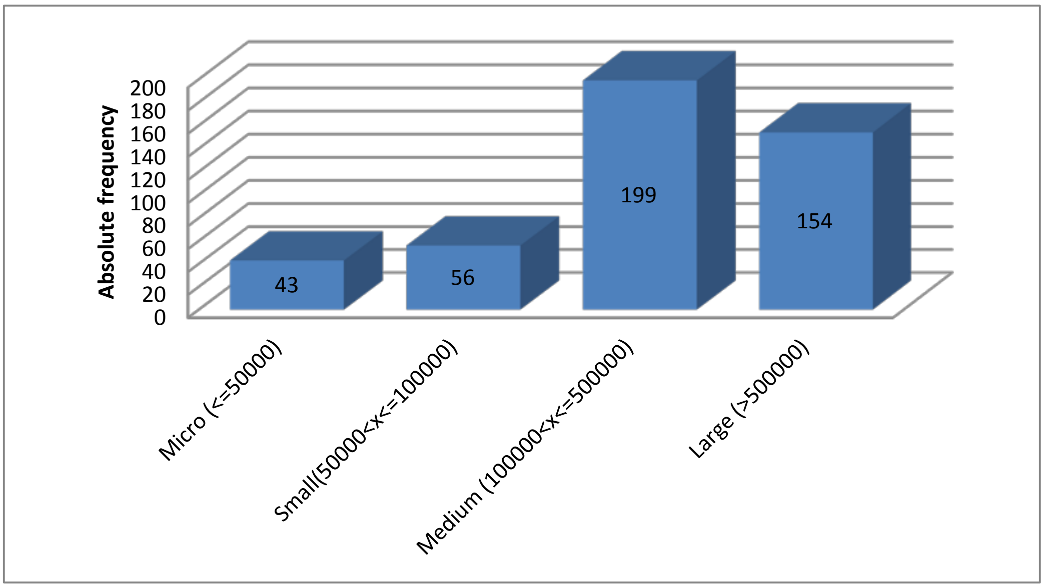

Figure 11 - Total investment of the consortium: absolute frequency

At last, we also classified the duration of projects into micro, small, medium and large. The micro projects last less than 10 months, the small ones have a duration of 11 up to 25 months, the medium projects have a duration of 26 to 50 months and the large projects last more than 50 months (Figure 12). As we can observe, projects typically last between 26 to 50 months.

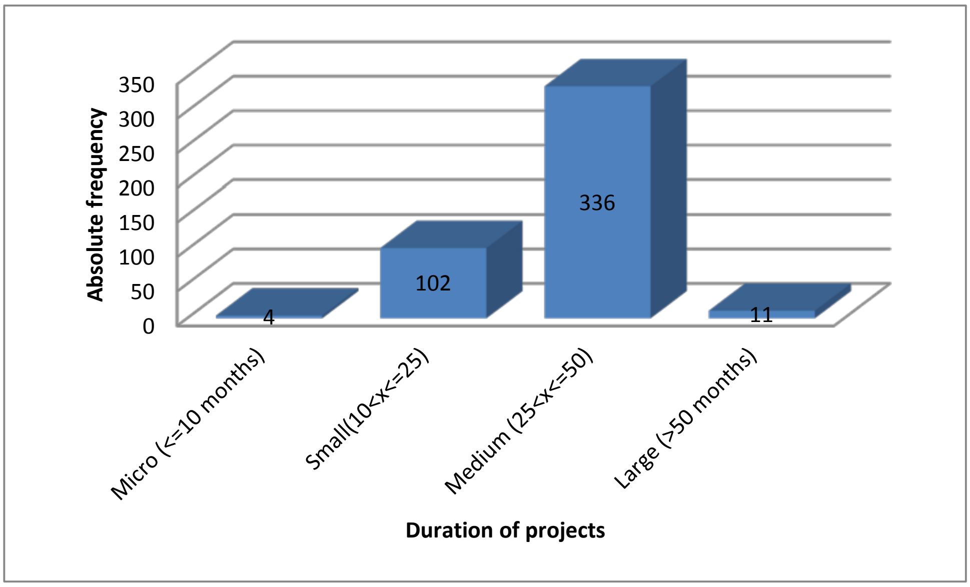

Figure 12 - Duration of projects

4.2. Hypothesis tests

Hypothesis testing is a procedure "where sample data are employed to evaluate a hypothesis, with the null hypothesis as a statement of no effect or no difference and the alternative hypothesis as a statistical statement indicating the presence of an effect or a difference". (Sheskin (2007), p.57)

Inferential statistics includes parametric and nonparametric tests. Parametric tests make specific assumptions with regard to the population parameters that caracterize the underlying distribution(s) for which the test is employed, particularly normality and sample size (Ibid, p.108). Nonparametric tests are alternative to parametric tests when assumptions as the normality of variables and sample size are not verified (Maroco (2010)). In addition, when dealing with nominal data, nonparametric tests are particularly suitable (Ibid, p.108).

Kolmogorov-Smirnov and Shapiro-Wilk tests are used to test if the sample is derived from a normal distribution. Even though most of our variables are nominal, we proceeded to the Kolmogorov-Smirnov Test with Lilliefors Significance Correction and Shapiro-Wilk Test (Appendix IV and Appendix V) to test the normality of the quantitative variables. All of the null hypothesis were rejected and none of the variables have a normal distribution in both tests. Therefore, we proceed with nonparametric tests.

We choose the nonparametric Mann-Whitney U Test (alternative to the parametric t Test), in which the experimenter has two samples from possibly different populations and wishes to test if the two populations are identical. (Conover (1999)). It assumes that both samples are random, there is mutual independence between them and the measurement scale is at least ordinal.

The null hypothesis of no diferences between populations may be rejected if the ranks associated with one sample tend to be larger than those of the other sample. It is calculated using the following formula 4.2.1:

$$\boldsymbol{U = n_1 n_2 + \frac{n_2(n_2+1)}{2} - \sum_{i=n_1+1}^{n_2} R_i} \qquad \textbf{(4.2.1)}$$

where n_1 = sample size 1; n_2 = sample size 2; R_i = rank of sample size; and U = Mann-Whitney test.

In order to employ the Mann-Whitney U test we consider the following dichotomic variables:

Variable	Categories	
Proponent	FEUP - Faculty of Engineering	NF (non FEUP - Faculty of Engineering)
Internationalization	National (All partners are national)	International (at least one international partner)
All partners ISFL	Yes (all the entities in the consortium are nonprofit entities)	No (when there is at least a profit purpose entity in the project consortium)
All partners large	All large (all partners are large size entities according to our previous classification)	Not all large (at least one of the partners is micro, small or medium sized)
All partners Grande Porto	Yes (all partners belong to the NUTS III classification 114 - Grande Porto)	No (exists at least one partner with another NUTS III classification)
STE/Non STE	STE (Science and Technology Engineering project)	Non STE (Theatre, social sciences, natural and exact sciences, Health sciences, agricultural science or unspecified scientific research area project)

Table 5 - Dichotomic variables

With a significance level of $\alpha=0.05$, the hypothesis tested and results using the Mann-Whitney U test are described below:

Null hypothesis	Sig.	Decision
Total Investment Amount is the same between *Proponent* (FEUP/NF).	0.000	Reject null hypothesis.
Total Investment Amount is the same between *National or International*.	0.000	Reject null hypothesis.
Total Investment Amount is the same between *All partners ISFL* (Yes/No).	0.000	Reject null hypothesis.
Total Investment Amount distribution is the same between *All partners large* (All Large/Not all large).	0.000	Reject null hypothesis.
Total Investment Amount distribution is the same between *All partners Grande Porto* categories (Yes/No).	0.000	Reject null hypothesis.
Total Investment Amount distribution is the same between *STE/Non STE* categories.	0.006	Reject null hypothesis.
Number of partners' distribution is the same between *Proponent* categories (FEUP/NF).	0.000	Reject null hypothesis.
Number of partners' distribution is the same between *National or International* categories.	0.000	Reject null hypothesis.
Number of partners' distribution is the same between *All partners ISFL* categories (Yes/No).	0.000	Reject null hypothesis.
Number of partners' distribution is the same between *All partners large* categories (All Large/Not all large).	0.000	Reject null hypothesis.
Number of partners' distribution is the same between *All partners Grande Porto* categories (Yes/No).	0.000	Reject null hypothesis.
Number of partners' distribution is the same between *STE/Non STE* categories.	0.563	Do not reject null hypothesis.
Medium size per project distribution is the same between *Proponent* categories (FEUP/NF).	0.108	Do not reject null hypothesis.
Medium size per project distribution is the same between *National or International* categories.	0.000	Reject null hypothesis.
Medium size per project distribution is the same between *All partners ISFL* categories (Yes/No).	0.212	Do not reject null hypothesis.
Medium size per project distribution is the same between *All partners Grande Porto* categories (Yes/No).	0.000	Reject null hypothesis.
Medium size per project distribution is the same between *STE/Non STE* categories.	0.645	Do not reject null hypothesis.

Table 6 - Hypothesis test: Mann-Whitney U test results

In most of the hypothesis tests, the null hypothesis is rejected.

Total Investment Amount has differences in its distribution between the categories of all grouping variables that were tested. Using *Proponent* as an example, the sum of ranks of *Total Investment Amount* when FEUP is the proponent and when FEUP is not the proponent are unequal. The same happens in the other grouping variables *National* or *International*, *All partners ISFL*, *All partners large*, *All partners Grande Porto* and *STE/Non STE*.

Number of partners does not have similar distributions between groups of all tested variables except *STE/Non STE*, which we did not reject null hypothesis with a p-value of 0.563. With this result we may conclude that there are no significant differences in the number of partners of a certain project when it is a Science and Technology Engineering project and when it is not.

The Mann-Whitney tests related to *Medium size per project* let us conclude that this variable does not have identical distributions in *National* or *International* categories, happening the same with the grouping variable *All partners located in Grande Porto*. The distribution of *Medium size per project* between *Proponent*, *All partners ISFL* and *STE/Non STE* groups may not be different between since null hypothesis is not rejected with p-values of 0.108, 0.212 and 0.645.

Kruskal-Wallis is the nonparametric alternative to ANOVA one-way and it extends the Mann-Whitney test to the problem of k independent samples, for $k > 2$. (Conover (1999)).

Each random sample is obtained from each of k possibly different populations and we test the null hypothesis that all of the populations are identical against the alternative that some of the populations tend to provide greater observed values than other populations (Conover (1999)).

Its assumptions are the same of Mann-Whitney Test. If the null hypothesis is rejected, there is a significant difference between at least two of the sample medians in the set of k medians. (Sheskin, 2007)

The Kruskal - Wallis statistic test is the following one:

$$H = \frac{12}{N(N+1)} \sum_{j=1}^{k} [\frac{(\sum R_j)^2}{n_j}] - 3(N+1) \qquad \textbf{(4.2.2)}$$

where n_j = subjects in each group; N = total number of observations; R_j = rank order assigned to each of the scores; and H = Kruskal - Wallis statistic test.

To proceed with this test, we use our previous classification of micro, small, medium and large for the variables *Total investment type*, *FEUP funding obtained type* and *Duration type*. We also created the variable *Scientific Research* with the values STE (Science and Technology Engineering), Agricultural Science, Health Sciences, Natural and exact sciences, Social Sciences, Theatre and NC (non classified).

With a significance level (alpha) of 0.05 in all tests, the results are presented in the following table:

Null hypothesis	**Sig.**	**Decision**
Total Investment Amount distribution is the same between *FEUP Funding obtained type* categories (Micro, Small, Medium & Large).	0.000	Reject null hypothesis.
Total Investment Amount distribution is the same between *Duration type* categories (Micro, Small, Medium & Large).	0.000	Reject null hypothesis.
Total Investment Amount distribution is the same between *Scientific Research* categories (Agricultural science, Health sciences, Natural and exact sciences, NC, Social Sciences, STE & Theatre).	0.064	Do not reject null hypothesis.
Number of partners distribution is the same between *Total Investment type* categories (Micro, Small, Medium & Large).	0.000	Reject null hypothesis.
Number of partners distribution is the same between *FEUP Funding obtained type* categories (Micro, Small, Medium & Large).	0.094	Do not reject null hypothesis.
Number of partners distribution is the same between *Duration type* categories (Micro, Small, Medium & Large).	0.000	Reject null hypothesis.
Number of partners distribution is the same between *Scientific Research* categories (Agricultural science, Health sciences, Natural and exact sciences, NC, Social Sciences, STE & Theatre).	0.264	Do not reject null hypothesis.

Medium size per project distribution is the same between *Total Investment type* categories (Micro, Small, Medium & Large).	0.446	Do not reject null hypothesis.
Medium size per project distribution is the same between *FEUP Funding obtained type* categories (Micro, Small, Medium & Large).	0.925	Do not reject null hypothesis.
Medium size per project distribution is the same between *Duration type* categories (Micro, Small, Medium & Large).	0.443	Do not reject null hypothesis.
Medium size per project distribution is the same between *Scientific Research* categories (Agricultural science, Health sciences, Natural and exact sciences, NC, Social Sciences, STE & Theatre).	0.306	Do not reject null hypothesis.

Table 7 - Hypothesis test: Kruskal - Wallis test results

The null hypothesis was rejected four times in the Kruskal-Wallis tests. Analysing the results that involve *Total Investment Amount*, we get p-value > α only for the grouping variable *Scientific research* (0.064 > 0.05). We conclude that there is a high likelihood of at least two of the samples (micro, small, medium and large) represent populations with different median values of *Total Investment Amount* for *FEUP Funding obtained type* and *Duration type.*

Tests related to *Number of partners* show different results. The null hypothesis is not rejected for *FEUP Funding obtained type* with a sig. of 0.094 and *Scientific research* with a sig. of 0.264. There is significant difference between at least two of the sample medians in the set of 4 medians for *Total investment type* and *Duration type*.

We do not find significant differences between the distributions of *Medium size per project* among *Total investment type*, *FEUP Funding obtained type*, *Duration type* and *Scientific research* categories, because the null hypothesis is not rejected in any of the four statistic tests.

4.3. Social network analysis

According to De Nooy et al. (2005), social network analysis (SNA) has becoming a powerful methodological tool to perform statistic analysis through different branches of social sciences. It focuses on ties among people, organizations and countries, for example.

A *graph* represents the structure of a *network.* A *network* consists of a *graph* and additional information on the *vertices* or the lines of the *graph*. A *vertex* is the smallest unit in a *network* and represents an actor. A *line* is a tie between two *vertices* and represents a social relation. A *directed graph* contains one or more *arcs* (directed lines) and all lines of an *undirected graph* are *edges* (undirected lines). Finally, a *partition* of a *network* is a clustering of vertices in the *network*. (Ibid, p. 6-7)

Pinheiro et al. (2015) suggest that social network analysis is a useful and relevant tool to understand and examine university-industry R&D links at both personal and organizational levels. The authors also state that social network analysis allows the recognition of preferential relationships between institutions, and reveals asymmetries from within the university-industry R&D network.

With the goal of finding patterns within FEUP's partnerships, we developed an extensive network analysis with Pajek64 version 4.04[2] using information from all 327 projects in which FEUP is enrolled (we exclude 132 out of 459 projects in which FEUP is the unique partner). In our case the *vertices* are entities that cooperate in these consortiums. Before any analysis we conclude that FEUP has to be the center and connects to all partners.

Table 8 shows *network* general information. The number of *vertices* is 809, which represent the number of entities. There are 9339 *lines* (or *edges*) that represent the number of connexions and 1501 multiple lines, which represents connexions between same entities that happened more than once. In network analysis, the *density* is the number of lines in a network as a proportion of the maximum possible number of lines (multiple lines are excluded). It is inversely related to network size: the larger the *network*, the lower the *density* (De Nooy et al. (2005)). In this case, density has a value of 0.0285, which means that only 2.85 % of all possible edges exist (De Nooy et al. (2005)). Because *density* depends on the network size, *degree*[3] looks at the number of lines in which each vertex is involved. In this network with multiple lines, the degree of a vertex is not equal to the number of its neighbours because multiple lines also

[2] Created by Vladimir Batagelj and Andrej Mrvar, Pajek is a free program for network analysis and visualization.
[3] The degree of a node is the number of a node' adjacent lines. (De Nooy et al., 2005)

contribute to the *degree*. The *average degree* of all vertices measures the structural cohesion of the network and has a value of 23.09 links per entity.

Number of vertices (n):	809		
		Arcs	Edges
Total number of lines		0	9339
Number of loops		0	0
Number of multiple lines		0	1501
Density 1 (loops allowed)	0.02853864		
Density 1 (no loops allowed):	0.02857396		
Average degree:	23.08776267		

Table 8 - Network general information

Figure 13 contains entities with the biggest degree extracted from the draw of the partition that groups entities with the same degree (see Appendix VI for a detailed description). It ranges from 1 to 1342 lines per node. The most frequent *degree* is four connections - happens to 50 entities, near 6% of the total. The second most frequent is having six connections - happens to 49 entities. The biggest *degree* occurs, obviously, with FEUP (a degree of 1342), followed by INESC TEC (233), Universidade de Aveiro (UA) (231), Universidade do Minho (UM) (228), Instituto Superior Técnico (IST) (193) and EFACEC (125). From this top six *degree*, we have five nonprofit purpose entities (only EFACEC is a profit purpose entity), six national entities and five different municipalities (only FEUP and INESC TEC share the municipality of Porto as location, which favours partnership between them). The international partner with the biggest degree is Linköping University from Sweden, with a *degree* of 92.

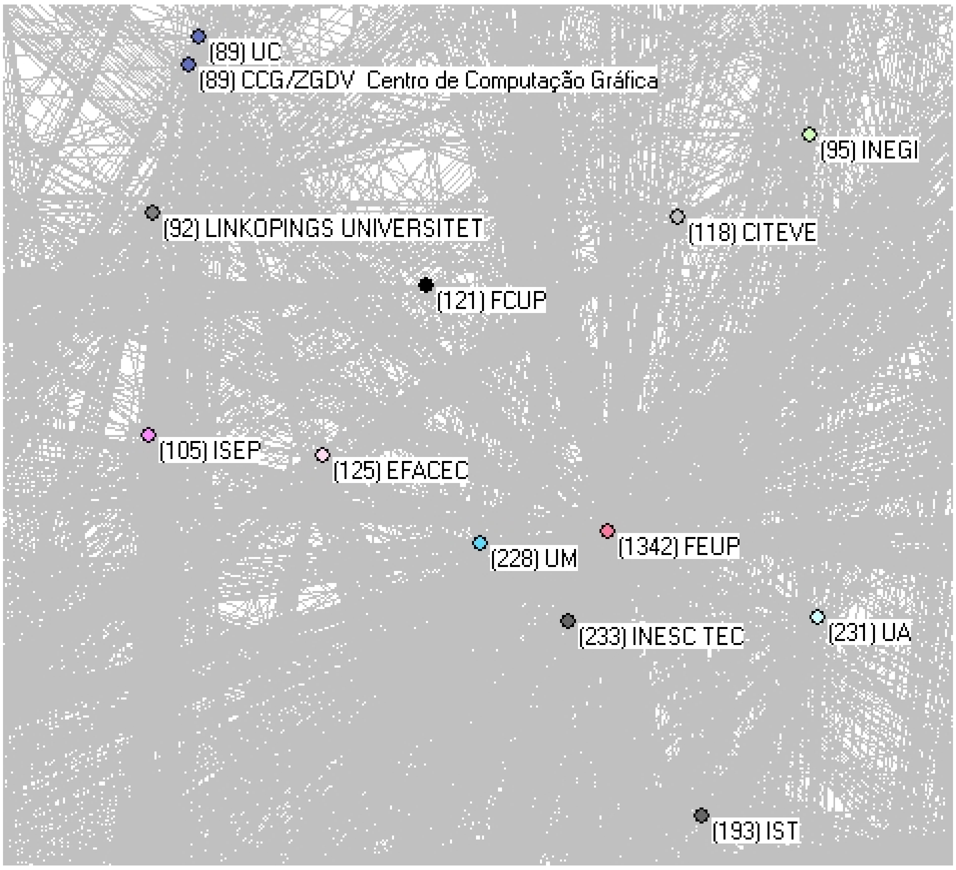

Figure 13 - FEUP's partnerships - partition with distribution of degree

To obtain more information about degree, we convert the partition to a vector (De Nooy et al. (2005)) (Table 9). The sum of the values obtained for *degree* is 18678, which doubles the number of lines, which makes sense because this analysis counts each connection between two entities as two *degrees*. The mean has a number of 23.09 connections, a median of 14 and a high standard deviation of 52.55 - influenced by the value of 1342 for FEUP. There are only 35 entities that establish one unique connection.

1. Copy of partition C1	
Dimension:	809
The lowest value	1.0000
The highest value	1342.0000
Sum (all values)	18678.0000
Arithmetic mean:	23.0878
Median:	14.0000
Standard deviation:	52.5473
2.5% Quantile	1.0000
5.0% Quantile	2.0000

95.0% Quantile	70.0000			
97.5% Quantile	72.4000			
Vector values	Frequency	Freq%	Cum. Freq.	Cum. Freq. %
(…, 1.0000]	35	4.3263	35	4.3263
(1.0000, 448.0000]	773	95.5501	808	99.8764
(448.0000, 895.0000]	0	0.0000	808	99.8764
(895.0000, 1342.0000]	1	0.1236	809	100.0000
Total	809	100.000		

Table 9 - Vector information with degree partition

Vertices with a *degree* of at least one are not isolated, although this does not mean they "are connected into a lump". Because this is an undirected *network* and FEUP establishes a line with all of the other entities, there is only one *component*[4] - the distinction between *weak* (connected by a semi-path) and *strong* (connected by a path) components does not make sense in undirected *networks*. *Degree* is also used to identify "clusters of *vertices* that are tightly connected because each vertex has a particular minimum *degree* within the cluster" (p. 70) - called *k*-core, where *k* corresponds to the *degree*. A *k*-core has the objective of identifying relatively dense subnetworks and a *vertex* in a 3-core is always part of a 2-core, while the opposite does not happen necessarily. The thirty clusters created are presented in Appendix VII and Figure 14 is a *graph* representation of the *70*-core, which is the biggest and the one that contains FEUP (followed by a 46-core):

[4] Components are the connected part of a network. (De Nooy et al. (2005))

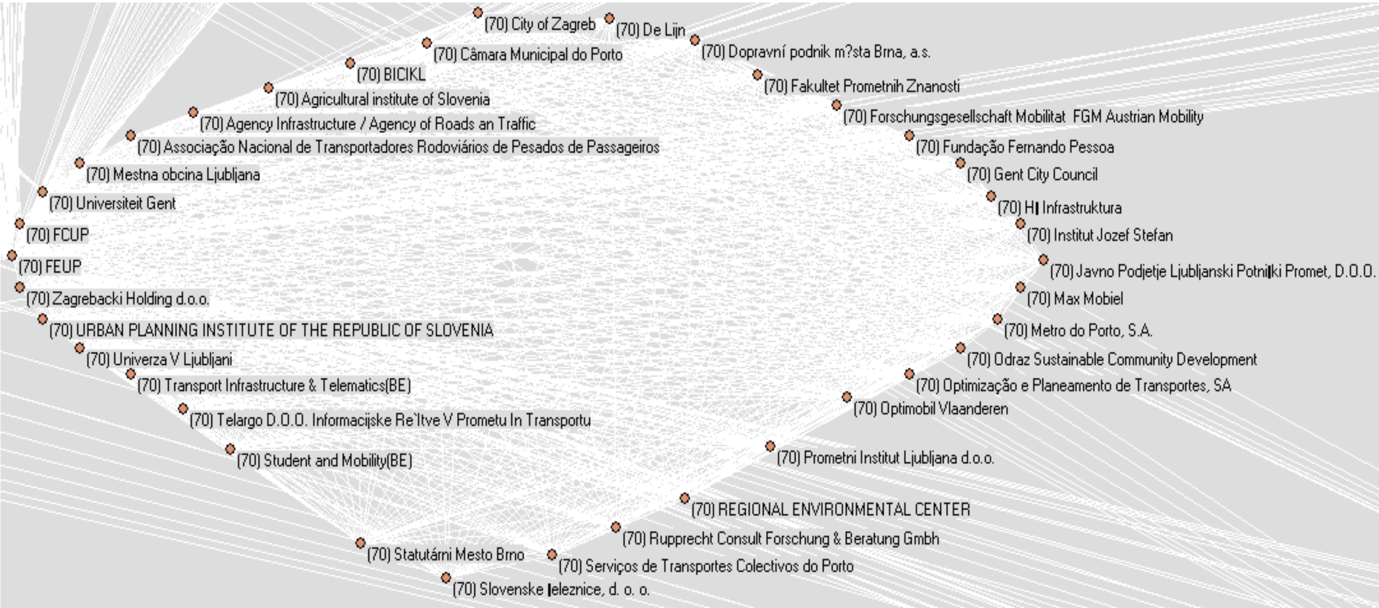

Figure 14 - 70-core including FEUP

The fact that there are only 36 entities in this 70-core can be explained by the multiple lines that exist between entities in this core. The projects where these entities participate are international, which usually have a big number of partners per project - explains the big number of links inside this cluster.

Some entities are essential for the transmission process by occupying strategic positions - now we move to the concepts of *centrality* and *centralization*. The term *centrality* refers to individual positions and has the *degree* as its simplest measure, while we use *centralization*[5] for the entire network. (De Nooy et al. (2005))

Before computing degree centrality and degree centralization we remove *multiple lines* (Appendix VIII and Table 10), where we may see that FEUP now has only 808 partners, comparing to the 1342 partners when *multiple lines* exist. Mean value falls from 23.09 to 19.38, median from 14 to 13 and standard deviation from 52.55 to 33.14. The entities with the biggest degree, besides FEUP, are now Universidade de Aveiro (UA) (168), INESC TEC (153), Universidade do Minho (UM) (142), IST (132) and CITEVE (96). INESC TEC is now the second FEUP’s partner with more connections passed by Universidade de Aveiro, which goes from a degree of

[5] Degree centralization measures local centrality by dividing the variation in the degree of vertices with the maximum degree variation that may be possible in a network of the same size and ranges from 0 to 1. (De Nooy et al. (2005))

231 to 168 while INESC TEC goes from 233 to 153. This shows that INESC TEC varies its partners less than Universidade de Aveiro and benefits more from partnerships with the same entities. Universidade do Minho comes in the third place (after INESC TEC and Universidade de Aveiro) like happened before with 228 connections with 142 different entities and IST shows 193 connections with 132 different partners. EFACEC is now replaced by CITEVE in fifth position without counting with FEUP. EFACEC (89) is the profit purpose entity with the biggest centrality and Linköping University is the international partner with the biggest number of different partners (86 entities).

Dimension:	809			
The lowest value	1.0000			
The highest value	808.0000			
Sum (all values)	15676.0000			
Arithmetic mean:	19.3770			
Median:	13.0000			
Standard deviation:	33.1400			
2.5% Quantile	1.0000			
5.0% Quantile	2.0000			
95.0% Quantile	45.0000			
97.5% Quantile	56.0000			
Vector values	Frequency	Freq%	Cum. Freq.	Cum. Freq. %
(…, 1.0000]	37	4.5735	37	4.5735
(1.0000, 270.0000]	771	95.3028	808	99.8764
(270.0000, 539.0000]	0	0.0000	808	99.8764
(539.0000, 808.0000]	1	0.1236	809	100.0000
Total	809	100.000		

Table 10 - Vector information with degree without multiple lines

In this case, all entities are *reachable*[6] and have a *geodesic*[7] because they all connect to FEUP and "information" flows through lines from any vertex to all of the others - FEUP is crucial to the transmission of information through this *network*. *Closeness centralization* is a measure of the overall closeness or distance of a *vertex* in relation to the others and has a value of 0.99 (detailed information in Appendix IX). This value takes into account variation in distances between each *vertex* and all others

[6] An entity is reachable from another entity if there is a path from the latter to the former. (De Nooy et al. (2005))
[7] A geodesic is the shortest path between two vertices. (De Nooy et al. (2005))

and also includes in the calculation maximum variation in the distances in a *network* of the same size. This high result shows that this *network* is extremely centralized because of the role of FEUP (the centre of the *network*) that shortens distances between every *nodes*: we only have to go from a *vertex* to another through FEUP.

An entity that is situated on the *geodesics* between any pair of *vertices* is crucial for the flows of information within the *network* - introducing now the concepts of *betweenness centrality*[8] and *betweenness centralization*[9].

The value of *betweenness centralization* for this network is 0.89 and it is obviously explained because of the central role played by FEUP and its most frequent partners (INESC TEC, IST, etc.) in the *geodesic* of most nodes (see Appendix X for a more detailed information).

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[8] Betweenness centrality of a vertex is the proportion of all geodesics between pairs of other vertices that include this vertex. (De Nooy et al. (2005))

[9] Betweenness centralization is the variation in the betweenness centrality of vertices divided by the maximum variation in betweenness centrality scores possible in a network of the same size. (De Nooy et al. (2005))

5. Conclusions

This internship report intended to map and characterize cooperation projects between FEUP and other entities, in what respects, in particular, their sectorial characteristics, geographical origins, scientific research area and investment amount. For that purpose, we developed a quantitative assessment of FEUP’s partnerships by using statistical descriptive analysis, statistical inference and social network analysis.

From our results, we were able to conclude that in the consortiums where FEUP belongs to, the most repeated sector of activity is "Higher Education" and "Research and natural/physical sciences development" and the core scientific research area is "Science and technology engineering". About 75.86% of partners are nonprofit purpose ones (67.73 % if we exclude FEUP). In addition, the entities' average size number of FEUP’s partnerships is 2974 employees. The average number of partners per project is 3.9 and varies between 1 unique entity in the consortium and a total of 46 entities. 386 projects (84%) have 5 or less partners, which shows that the most common project is still a project with a few members.

We also concluded that geographical proximity is relevant: Porto is the most frequent municipality, followed by Lisboa and Aveiro. The relevance of Lisboa may be explained by the fact that it is Portuguese capital and biggest city, with several universities and research centres. The percentage of international partners is 32.42%, and most frequent international ones are universities and science institutes from Germany, Spain and France. FEUP has an interesting average funding obtained of 137 853.33 € comparing to the total average investment made of 156.209.13 € (near 88.25% of average investment by FEUP is financed). The projects’ average duration is 2 years and 10 months.

Statistical inference allowed us to conclude that *Total Investment Amount* had differences in its distribution between categories of all grouping variables tested while *Number of partners* did not have similar distributions except in *STE/Non STE categories*. *Medium size per project* had no substantial differences between *Proponent*, *All partners ISFL* and *STE/Non STE* categories.

The Kruskal-Wallis test showed that *Total Investment Amount* had no differences between *Scientific research* categories, although there is a high likelihood of at least two of the four samples represent different median values for *FEUP Funding* *obtained type* and *Duration type*. There may not be differences for *FEUP Funding obtained type* and *Scientific research* in what concerns to the *Number of partners,* although the null hypothesis was rejected for *Total Investment type* and *Duration type*. The null hypothesis is not rejected in any of the tests performed to *Medium size per project* variable.

Social network analysis allowed us to map the ties between entities in these consortiums. We conclude that these partnerships involve 809 different entities and establish 9339 connections, in which 1501 of them are multiple connections - occur more than once. Taking into account the size of the network created, only 2.85 % of all possible connections exist (disregarding multiple connections). The average number of connections per entity is 23.09 with multiple lines and 19.38 excluding them.

There are 35 entities that establish only one connection and the number of connections per entity vary between 1 and 1342. We also found a core in which the 36 entities that belong to it have a number of 70 connections established with the entities within the core. The projects where these entities participate are international, which usually have a big number of partners per project

FEUP has 1342 connections with 808 entities, followed by INESC TEC (233 connections with 153 different entities), UA (231 connections with 168 entities), UM (228 links to 142 entities) and IST (193 connections with 132 entities). EFACEC and CITEVE are the profit purpose entities and Linköping University the international partner that detach.

We also concluded that *closeness centralization*, which measures overall distance of a *vertex*, has a value of 0.99 because FEUP shortens distances between every *nodes*. *Betweenness centralization* had a value of 0.89 and this can be explained by the constant presence of FEUP in the *geodesic* of most *nodes*.

In spite of the huge effort devoted both to fulfil the database on FEUP's partnerships and also to their careful statistical analysis, this research has some limitations. First, the set of variables analysed is quite restricted and for that reason, this research could be improved if we could access more information about the R&D projects developed (through interviews to the partners): how many researchers were involved and how are they characterized (gender, age, schooling, …); what were the outputs of the R&D projects under study (patents, articles, citations, …), etc.. In addition, we only studied FEUP’s partnerships, as a result of the internship and due to limitations of time. Therefore, our study could be extended to analyse other Portuguese or European research consortiums.

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Appendices

Appendix 1: Empirical studies on University-industry partnerships

Author	Research area	Main purpose/Question	Method	Main results
Ab Manan et al. (2011)	Growth.	Investigate and highlight some different university-industry-government partnership issues.	Theoretical.	University, Industry and Government (UIG) Partnership Model presented would help developing countries in preparing themselves to stay competitive and relevant.
Abramo & D'Angelo (2011)	Regional/Growth.	Examine the role of information asymmetry in the market for university-industry research collaboration.	Empirical - Statistical. Spatial and bibliometric analysis relating to scientific output in Italian university-industry collaborations.	The importance of geographic proximity in companies' choices of university partner and inefficiency in the market is revealed: private companies could have chosen more qualified research partners located closer to the place of business.
Abramo et al. (2009)	Innovation.	Investigate public-private research collaboration between Italian universities and domestic industry.	Empirical - Bibliometric analysis.	Most collaborations occur in medicine and chemistry, highest percentage of co-authored articles comes from industrial and information engineering. Research performance is better in university researchers that collaborate with private sector.
Abramo et al. (2010)	Regional.	Is it possible to compare university performance in public-private research collaboration?	Theoretical - A model to measure performance is proposed after a bibliometric approach.	For each scientific discipline and each region it is possible to measure performance of individual universities in both-regional and extra-regional collaboration.
Abramo, D'Angelo & Di Costa (2011)	Innovation.	Presentation of an econometric model which expresses university capability for collaboration with industry as a function of size, location and research quality.	Empirical - Econometric analysis.	Research quality has an higher impact than geographic distance on the capability for collaborating.
Abu-Eisheh (2004)	Innovation.	Present the methodology and the results of a study which assessed the output of local engineering education systems for an economy in transition by considering the case of engineering education in the Palestinian Territories.	Empirical - Qualitative.	Local university graduates possess overall competences and are strong in many aspects, such as theoretical and analytical abilities and computing skills. There are weaknesses in their applied skills and practical training, technical writing, scientific research capabilities and English language skills. A recommendation is increasing the interaction between the private sector and the universities and establishing university-industry partnership programs.
Ahrweiler et al. (2011)	Growth/ Innovation.	Application of a model to university-industry links by comparing innovation networks with and without university-agents.	Theoretical - Model.	University-industry links improve the conditions for innovation diffusion and enhance collaborative arrangements in innovation networks.
Ankrah et al. (2013)	Innovation.	Examine university-industry knowledge transfer in five major case studies from the UK Faraday Partnerships.	Empirical - Qualitative (Case studies).	The motives for university and industry actors correspond despite their differing work environments. Stability-seeking is a key determinant of engagement but not to seek control over others is also important.
Arundel /&	Regional.	Explore the effect of proximity on knowledge	Empirical - Econometric analysis.	Public science is among the most important sources of technical knowledge

Author	Research area	Main purpose/Question	Method	Main results
Geuna (2004)		flows from affiliated firms, suppliers, customers, joint ventures, competitors and public research organisations to innovative firms.	(ordered logit models and binary versions)	for the innovative activities of Europe's largest industrial firms. The importance of proximity increases with the quality and output of domestic public research organisations and the importance given to public science by the respondents.
Atkinson (1994)	Growth/ Innovation.	Review university-industry licensing and research collaborations by focusing on three university-affiliated venture capital funds, which represent the most direct participation by academic institutions in creating new ventures based on technologies invented by their faculty members.	Empirical - Qualitative.	Dallas Biomedical, Medical Science Partners, and Triad Investors each have made long-term contributions to their affiliated institutions by showing institutional leadership and commitment, encouraging invention dis- closures, identifying innovative research projects, attracting funding from new sources, and accelerating technology commercialization.
Baba et al. (2009)	Innovation.	Identify the effect of university-industry collaborations on the innovative performance of firms operating in the advanced materials field.	Empirical - Econometric analysis. Negative binomial regression model applied to a sample of 455 firms active in the photo catalysis in Japan.	Firms collaborations with "Star scientists" exert little impact on their innovative output.
Baba et al. (2010)	Innovation.	Identify the effect of university-industry collaborations on the innovative performance of firms operating in the advanced materials field and propose an original classification of the research organization partners.	Empirical- Qualitative.	In the advanced materials industry the most effective collaborations are driven by "core researchers", who have been involved in authoring scientific papers. These have the boundary spanning between science and technology skills. Project leaders pushed the firms' R&D towards collaboration.
Bagchi-Sen et al. (2012)	Growth.	Review literature on the extent and outcomes of academic entrepreneurship and of university-industry collaborations, with a specific focus on contradictory and inconclusive results.	Theoretical.	Evidence from a broad range and increasing volume of literature on trends and characteristics of academic entrepreneurship and university-industry collaborations shows that universities indisputably play a major role in their regions.
Barbolla et al. (2009)	Innovation.	Assessment of some of the most influential factors for success or failure in research contracts.	Empirical - Qualitative. 30 interviews are made to qualified university researchers.	There are features beyond technology ones related to the corporate partner´s strategic and functional characteristics that are decisive for success. Company's real interest and involvement during technology transfer process, capacity to assimilate new knowledge and a confident attitude towards the university research group are key elements.
Barnes (2002)	Growth/ Innovation	To identify factors that increase the probability of a collaboration being perceived as successful by both cooperators.	Theoretical - Appreciative.	The findings of six collaborative research projects are analysed.
Barnes et al. (2006)	Growth/ Innovation.	What are the management "success" factors in collaborative R&D projects?	Empirical - Qualitative. Case study research.	Develops a management tool designed to provide practical guidance on the effective management of collaborative R&D projects.
Belkhodja et al. (2007)	Innovation/ Regional.	What is the extent of the collaboration between the natural sciences and engineering researchers	Empirical - Econometric. Multivariate linear regressions are	Various factors explain the decision to collaborate or not like research budget, university localization, radicalness of research and the degree of

Author	Research area	Main purpose/Question	Method	Main results
		in Canadian universities and government agencies and industry?	done.	risk-taking culture and researcher's publications.
Bilbao-Osorio & Rodríguez-Pose (2004)	Growth.	Examine ambitious R&D European governments' policies with the aim of fostering innovation and economic growth in peripheral regions of Europe.	Empirical - Econometric.	R&D investment and higher education R&D investment in peripheral regions of the EU are positively associated with innovation.
Bishop et al. (2011)	Innovation.	Examines the methods through which firms benefit from interactions with universities.	Empirical - Econometric. Data collected from a survey of UK firms.	Benefits from interactions with universities are multifaceted. Firms R&D commitments, geographical proximity to and research quality of university partners have a distinct impact on the different types of benefits from interactions with universities.
Bjerregaard (2009)	Innovation.	Examine the collaboration strategies employed by small and medium-sized enterprises and university researchers for initiating and optimizing the process and outcome of R&D collaboration.	Empirical - Based upon a qualitative study of the total population of university departments and SMEs involved.	Different strategies like partners' previous collaborative experiences may prove successful in optimizing the outcome of university-industry collaborations.
Boardman (2009)	Growth.	Detect how different types of university research centres affect individual-level university-industry interactions.	Empirical - Statistical analysis. Uses data from a national survey of academic researchers in the US.	Independently of having ties to private companies, affiliation with centres sponsored by governments' centres programmes correlates positively with the level of industry involvement.
Boehm et al. (2013)	Innovation.	Extend industrial marketing's business-to-business model by looking at public sector participants in collaborations in order to examine the process of establishing scientific-knowledge-commercialization collaborations.	Empirical - Based on 82 interviews in 17 collaborative-research projects in both Ireland and Germany.	Retention is a catalyst for improving established collaborations to facilitate the commercialisation of scientific knowledge through repeated projects. Collaborators become loyal and committed because they are content with the overall relationship, commercialization service and quality. The study shows the importance of repeat collaborations and the development of mutual benefits which facilitate scientific knowledge commercialization.
Bruneel (2010)	Innovation	Explores the influence of different mechanisms in lowering barriers to university-industry collaborations.	Empirical – quantitative. - Poisson regression. Large-scale survey and public records from industry and academics.	Prior experience of collaboration and big levels of trust lowers barriers to university – industry collaborations.
Caloghirou et al. (2001)	Innovation	To investigate the characteristics of university-industry collaborations in a large set of research joint ventures.	Empirical - econometric analysis.	The share of university-industry RJVs is found to have gradually increased.
Calvert et al. (2003)	Regional/ Growth/ Innovation	Gathering data on the nature and extent of research collaborations between universities and industry.	Empirical – Statistical analysis of indicators of scientific publications.	Although there has been a rapid increase in the volume of university-industry collaborations since 1980s, the biggest increases were before the measures of 1990s.
Carayannis et al. (2000)	Innovation	Understanding the linkage between theory on knowledge management and strategic	Theoretical - Appreciative.	A preliminary list of key considerations and corresponding strategic management skills which firms must develop to participate in a

Author	Research area	Main purpose/Question	Method	Main results
		management, particularly those involving government, university and industry actors.		government-university-industry where every of them win.
Choi (2012)	Growth.	What is the impact of globalization and affinities between countries in international scientific collaboration?	Empirical - Quantitative.	Geographical, linguistic and economic affinities do not have a meaningful impact on the formation of co-authorship network between 'advanced' nations. Globalization was found to influence the co-authorship link between countries, but not to accelerate centralization of the network in the past 15 years.
Cohen et al. (2002a)	Innovation.	Evaluate the influence of "public" research on industrial R&D for the US manufacturing sector.	Empirical - Qualitative.	Public research is critical to industrial R&D in a small number of industries and importantly affects industrial R&D across much of the manufacturing sector. Key channels through which university research impacts industrial R&D include published papers and reports, public conferences and meetings, informal information exchange and consulting.
Counce et al. (2008)	Innovation.	Does cooperation help universities to achieve its primary missions while supports stakeholders needs?	Theoretical - Appreciative.	The value of integrating activities of the university into the broader society is demonstrated by describing several areas of collaborative activities among some US entities.
D'Este et al. (2010)	Regional/ Innovation.	The paper is focused on joint research partnerships.	Empirical - Econometric analysis.	Geographical proximity and research quality are positively associated with the frequency of these partnerships but results are not homogenous across scientific disciplines.
D'Este et al. (2013)	Regional.	What type of proximity in university-industry research collaborations does really matter?	Empirical - Statistical. Uses university-industry collaborative research grants awarded by the UK Engineering and Physical Sciences Research Council.	Geographical proximity makes university-industry research partnerships more likely. Prior joint experience in such partnerships – which we take as a measure of organizational proximity – makes partnerships more likely, but has no statistically significant effect on the importance of geographical proximity.
Devine et al. (1987)	Growth/ Innovation.	Summarizes the evolution of federal technology transfer models with particular attention to university-industry cooperative research centers.	Theoretical - Appreciative.	The large, interdisciplinary research centers can be very important to the long term health of the scientific and technological enterprise in the United States.
Elliot & Meisel (1988)	Regional.	Identify and discuss several of the methodological considerations which arise in the design of higher education commission formal studies to measure their short-term economic impact on regions.	Empirical - Qualitative. It presents new evidence regarding the effectiveness of alternative survey methods for collecting the personal expenditure data frequently used in economic impact studies.	Significant research is needed to expand the methodology of economic impact studies to meet this new challenge. Identification of program objectives and early creation of data systems to measure intermediate and long-term outcomes would greatly assist in these efforts.
Felsenstein (1996)	Regional.	Estimate some of the impacts associated with a metropolitan university.	Empirical - Case study.	These relationships can be both positive and negative and can operate in both the short and long terms. Results emphasize the magnitude of the university expenditure links with the metropolitan economy and the

Author	Research area	Main purpose/Question	Method	Main results
				importance of scale when comparing these with more localised negative effects.
Fontana et al. (2003)	Innovation.	Why did certain firms collaborate with public research organisations while others did not? What are the characteristics of the firms that might explain the different levels of co-operation with public research organisations?	Empirical - Econometric model.	These relationships are characterised by a high degree of heterogeneity. After controlling for firm size and other factors, the openness of firms to the external environment is very important in explaining their probability of collaborating with public research organisations.
Fontana et al. (2006)	Innovation	Which firms cooperated with PROs? And what are the firm's characteristics that might explain the number of R&D projects with PROs?	Empirical - quantitative analysis of the determinants of research cooperation between firms and public research organisations for a sample of innovating small and medium-sized enterprises.	The propensity to forge an agreement with an academic partner depends on the "absolut size" of the industrial partner. The openness of firms to the external environment significantly affects the development of R&D projects with PROs.
Frenken et al. (2010)	Innovation/ Regional.	Compare the citation impact of national and international research collaboration.	Empirical - Econometric analysis.	Collaborations profit from being organized at regional scale in the cases of biotechnology and organic fine chemistry. Physical proximity and successful interactions aren't positively correlated across all industries.
Fukugawa (2013)	Innovation.	Examine how university knowledge spills over into small technology-based firms in Japan.	Empirical - Econometric.	Firms with local ties have a greater advantage in improving the quality of their R&D personnel through the acquisition of complementary knowledge.
Gelijns et al. (2002)	Innovation	To review institutional patterns of innovation and draw implications for organizational and public policies.	Theoretical – appreciative: Literature review.	Universities and industry need to maximize the upsides of collaboration and minimize the downsides by changing their internal organization and by implementing new models of collaboration.
Gertner et al. (2011)	Innovation.	Explore the micro-dimensions of knowledge transfer partnerships with the aim of developing an appreciation of the personal interactions that facilitate the success of university-industry collaborations.	Empirical - Qualitative. Concerns the operation of three knowledge transfer partnerships.	The analysis highlights the significance of the boundary spanning roles of the knowledge transfer partners in facilitating the process.
Geuna et al. (2009)	Growth (Economic development)	Analyse knowledge transfer as a strategic issue.	Theoretical – Appreciative: literature review.	University knowledge transfer models are discussed and a review on the recent developments in the literature on research collaborations, intellectual property rights and spin-offs is made.
Gibson et al. (1994)	Growth.	Analyse collaboration patterns among researchers at one of US nation's oldest, largest and most complex R&D consortia, the MCC-Microelectronics and Computer Technology Corporation.	Empirical - Qualitative.	MCC researchers have collaborated more frequently with academic than with corporate researchers and more often with nonshareholder than shareholder organisations, with geographic proximity having a role in it. Universities played an important linking role between MCC and industry.
Glaser et al. (2005)	Growth/ Innovation.	Review empirical data on the attitudes of researchers toward industry involvement and financial ties in research.	Theoretical - Appreciative.	Investigators are concerned about the impact of financial ties on choice of research topic, conduct and publication. Some of them trust in disclosure as a way to manage conflicts.

Author	Research area	Main purpose/Question	Method	Main results
Gulbrandsen et al. (2011)	Innovation.	Literature review - To summarize the main findings from eight different papers.	Theoretical.- Appreciative	The paper highlights the heterogeneity of university–industry interaction, the diversity of outcomes, and the many non-linear and contingent relations they contain.
Gupta et al. (1994)	Growth.	Do an assessment about information systems educational needs based on skills needed by employers. (Taiwan)	Empirical - Qualitative.	Both general and technical skills are important. Students need to improve their communication skills and understanding of business needs. University-industry collaboration has to be enhanced in the areas of conference participation, training programmes and consulting contracts.
Hagedoorn et al. (2000)	Innovation.	Synthesizes the academic, professional and policy literature on research partnerships with an eye toward technology policy.	Empirical.	Technology policy authorities need to be aware of these reasons and accordingly be cautious when comparing the benefits with the downside effects associated with collaboration.
Hanel et al. (2006)	Regional/ Innovation	Analysis of the collaboration between manufacturing firms and universities in Canada.	Empirical - Statistical description and econometric analysis (Statistics Canada Survey of Innovation, 1999).	Collaboration with universities is frequent in knowledge based industries. Research undertaken in partnership complements R&D by collaborating firms but doesn´t replace it. Collaboration improves the performance of innovating firms.
Harman (2002)	Innovation/Growth.	Do an assessment about researcher involvement in industry-research partnerships.	Empirical - Qualitative.	40% of academics currently have industry research funding and 60% of respondents with industry funding have attracted more than $250,000 over the past three years. 20% of academics have produced research results of commercial value, most of these have been less successful in increasing their personal incomes through research commercialisation and consulting.
Heidrick et al. (2005)	Growth.	Present a case study of an university-industry partnership and identifies benefits to participating companies and to the University.	Empirical - Qualitative. Twenty-seven research and development projects at the University of Alberta's Advanced Engineering Materials Centre were evaluated.	Both university engineering researchers and engineering managers from industry can derive valuable but different benefits from the same research project. Government investment can attract other investments to the projects. These R&D projects have significant positive impact to the related companies, as well as to the university, professors and students.
Helpman (1997)	Growth.	Examine the extent to which the benefits of R&D are concentrated in the investing countries.	Empirical - Quantitative assessment of the.elasticity of total factor productivity and elasticity of total factor productivity with respect to R&D stocks.	R&D is an important activity that has a major impact on the performing countries as well as on their trade partners. There are reasons to be optimistic about recent trends towards a tighter integration of national economies.
Hemmert et al. (2008)	Innovation.	Explore and contrast the current nature and status of university-industry collaborations in Japan and Korea by focusing on factors that facilitate the development and management of such research linkages.	Empirical - Statistical.	Firms benefit from their experience with previous projects when collaborating with universities. Cultural factors appear to result in significant differences in the organization of university-industry collaborations.
Henderson et al. (2006)	Innovation/Growth.	Show how a university-industry partnership can be used to contribute to academia through the	Empirical - Qualitative. Examines a partnership between author's	Partnerships experience difficulties due to differing and incomensurate desired outcomes. Partnership activity must involve deep learning transfer.

Author	Research area	Main purpose/Question	Method	Main results
		development of research methodology and improved understanding of the subject area (total quality management) and to add to organisational learning by developing critical reflection and reflexivity.	university and a large utility organisation through four years.	This produced a range of successful outcomes for both.
Hicks (1993)	Growth.	Examine the structure and funding of universities and indicators of the performance of Japanese science.	Empirical - Bibliometric indicators, R&D managers descriptions.	The system is evolving in directions more favorable for university research excellence and there are not insuperable barriers.
Hong (2008)	Regional/ Innovation	Examine the geographic variations in university-industry collaborations in China from 1985 to 2004.	Empirical - Qualitative. The roles of different provinces and municipalities in the National Innovation System are analysed.	Less favored regions are left behind because of their shortage of local university resources and reduced extra-local knowledge support.
Hong et al. (2007)	Innovation.	Explores university-industry interactions in terms of collaborative knowledge creation and innovation, focusing on how collaborative parties are involved and motivated to work together for innovation in gaining global competitiveness.	Empirical - Case of R&D collaboration between a Finnish multinational corporation and Chinese universities.	Collaborative knowledge differs substantially from knowledge interaction in university-industry collaboration. The first requires involvement and commitment from both collaborative parties. The significance of cultural impact may accumulate with the increasing intensity of knowledge interaction. The further the cultures are from one another, the more difficult knowledge interaction is.
Hong et al. (2013)	Regional.	Provide a comprehensive analysis of formal university-industry collaborations in China by focusing on geographic distance.	Empirical- Econometric.	Geographic distance is an obstructive factor in achieving university-industry collaborations. Social proximity and university prestige could also help bring non-local academic and industrial partners together.
Howells et al. (2003)	Innovation/Growth.	Focuses on the growth of industry-academic links and in particular the growth of cross-border collaboration and funding.	Theoretical - Appreciative.	Analyses industry-higher education collaboration from an international perspective, although more detailed in a UK context. The paper concludes with a short discussion on the policy implications of the paper's findings.
Hynds (2000)	Innovation.	Examine the continual support for internship opportunities by universities as one way to create a win outcome for both universities and industry. Addresses the basic reasons for professional development/internship experience of the author, and outcomes of professional development for construction faculty members and sponsoring construction companies.	Theoretical - Appreciative.	The major factors that can contribute to a win/win outcome for the faculty member and the construction company relative to a professional development/internship opportunity are as follows: opportunities for faculty to share/learn in the real world of construction, opportunities to conduct field research projects, opportunities to stay current in area of expertise (field), i.e., current practices, opportunities to develop new research areas/topics based, promotes industry/university relationships, integration of current, best practices in the field into coursework, supplemental income for nine-month appointment faculty, opportunity for faculty to learn a new area(s) of construction
Johnson (2008)	Growth/ Innovation.	Do intermediate organizations help triple helix partnerships? How do they help?	Empirical - Qualitative. Case study of an organization called Precarn.	Collaborative intermediate organizations can facilitate successful technological adoption and commercialization across innovation networks.

Author	Research area	Main purpose/Question	Method	Main results
Kenney (1987)	Innovation.	Examines the ethical dilemmas that can occur due to university-industry cooperation.	Theoretical - Appreciative.	The goals of the university are and must remain different from those of industry for the good of the entire society.
Landry et al. (1996)	Innovation/ Growth	Instead of emphasizing motivations, mechanisms, financial costs and financial benefits of collaborative research, this paper focus on the impact of collaborative research on academic productivity.	Empirical - econometric analysis	Collaboration increases researchers' productivity.
Laursen & Salter (2004)	Innovation.	Examine the factors that influence why firms draw from universities in their innovative activities by exploring the link between universities and industrial innovation and the role of different search strategies.	Empirical - Econometric analysis.	Firms who adopt "open" search strategies and invest in "R&D" are more likely than other firms to draw from universities, highlighting the role of managerial choice.
Lee (1996)	Growth (economic development)	To evaluate the role that universities play in economic development, which specific role they may play in industrial innovations and how do they see collaborations with private industry.	Empirical – qualitative (survey to about 1000 university researchers)	There exists a decreasing federal support to university-industry collaborations; university-industry partnerships have been interfering with "academic freedom".
Lee (2000)	Growth	Examines the sustainability of the collaborative experience by focusing on its outcomes.	Empirical – qualitative: surveys conducted in 1997, one for faculty researchers and the other for innovating firms' managers.	Overwhelming majority of the participants say that in the future they would expand or at least sustain the present level of collaboration. They say that there exists significant advantages, some are expected and some are unexpected.
Lee (2011)	Growth.	After a series of reforms in Japan, universities and industries adopted a new strategic approach to form inter-organizational alliances. Based on Tokyo Institute of Technology, the paper analyses how inter-organisational alliances are managed and investigate their impact on joint R&D projects.	Empirical - Qualitative.	Inter-organisational university-industry alliances enable alliance partners to initiate more explorative research, to organize interdisciplinary projects with faculties in different research fields and establish larger-scale R&D projects.
Lee et al. (2010)		Examine the roles and effects of industry liaison offices in Japan.	Empirical - Qualitative. Case study of the Division of University Corporate Relations at the University of Tokyo.	Formal boundary spanning by industry liaison offices could facilitate the formation of 'inter-organisational' alliances between university and industry. The alliances could generate larger and overcome the limitations of traditional cooperative research projects.
Lee Yong (1998)	Growth/ Innovation.	Examines the concerns of American faculty about these collaborations and how they may impinge upon their participation in industrial innovation.	Empirical - Qualitative. Based on a questionnaire survey.	Academics are generally, but cautiously, in favor of close collaboration. They live with tension because of the instrumental need for industry funding and the intrinsic need to preserve intellectual freedom.
Li (2010)	Innovation.	Analyse factors like international investors host	Empirical - Econometric.	Contribution of local universities and research institutes to R&D

Author	Research area	Main purpose/Question	Method	Main results
		countries R&D experiences and ventures research objectives on the selection of universities or research institutes as local partners for R&D alliances.	Regression models. Data collected on 327 international R&D alliances established over 1995-2001 in China.	collaborations is abundant when investors have prior R&D experience in the host country and when the alliance has been established primarily for research rather than development purposes.
Lind et al. (2013)	Innovation.	Explore university-industry collaboration in research centres.	Empirical - Qualitative. In-depht interviews are used.	There are four forms of collaboration: distanced, translational, specified and developed collaboration. When the role of the research center is to be a forum of collaboration, the research center has to be a good mediator between the actors in order to ensure satisfaction within and between projects. If the role is to be a facilitator of collaboration, the center needs to enable the actors to learn how to interact with each other.
Lööf et al. (2008)	Innovation.	Analyse the impact of collaboration with universities on the innovative output of firms.	Empirical - Econometric analysis.	University collaboration has a positive influence on the innovative activity of large manufacturing firms. There appears to be an insignificant association between collaboration and average service firm's innovation output.
Malairaja et al. (2008)	Innovation/ Regional	Examine the effectiveness of science parks as a strategy to promote university-industry collaboration in Malaysia.	Theoretical - Appreciative.	Science parks have more links with universities than off-park firms, although the difference is not statistically significant.
Martinez Sanchez (1995)	Innovation/ Regional.	Studies university-industry links in a peripheral region of Spain.	Empirical - Qualitative.	Most links are informally established without assistance, larger firms collaborate more and percentages of collaboration were higher in medium-technology firms group.
Mohnen & Hoareau (2003)	Growth.	Uncover some of the economic factors that encourage firms to seek information from universities and government labs or to collaborate with these institutions.	Empirical - Estimation of probit models.	R&D-intensive firms and radical innovators tend to source knowledge from universities and government labs but not to cooperate with them directly. Outright collaborations is characteristic of large firms, firms that patent or those that receive government support for innovation.
Motohashi (2005)	Growth	To examine the role of new technology-based firms in university-industry collaborative activities in Japan.	Empirical - Quantitative analysis of RIETIs university-industry collaboration survey.	University-industry collaborations are gaining momentum and are likely to play a strong role in reducing the dependence of Japan innovation system to in-house R&D performed in large corporations.
Motohashi (2008)	Growth.	Examine the role of small and medium sized enterprises towards this new trend in Japanese innovation system where more and more firms are getting involved in R&D collaborations.	Empirical - Quantitative analysis.	Small and medium sized enterprises have gained high R&D productivity through university-industry collaborations. Large firms are good at collaborating activities, while small firms play an important role as partners of large firms' R&D collaborations.
Muscio et al. (2012)	Regional.	Assess the extent to which university-industry collaboration is affected by the geographic proximity of an academic institution to an Industrial District.	Empirical - Statistical.	Provides new insights into the effects of academic proximity to industrial district on university-industry collaboration by presenting robust evidence that proximity to districts promotes the establishment of collaborative agreements.
Nishimura et al. (2011)	Innovation/Gro wth.	Do an empirical study on cluster policies - examine the effects of the "Industrial Cluster	Empirical - Econometric. It is used a unique dataset of 229	Participation in the cluster project alone does not affect R&D productivity and research collaboration with a partner in the same cluster region

Author	Research area	Main purpose/Question	Method	Main results
		Project" in Japan on the R&D productivity of participants.	small firms.	decreases R&D productivity. To improve the efficiency it is also important to construct wide-range collaborative networks within and beyond the clusters.
Oladirana et al. (2011)	Innovation.	Assess teamwork, communication and conflict resolution among group members of a Global Engineering Team.	Empirical - Questionnaire-based survey of the 2008 group of Global Engineering Team.	Each group achieved the objectives of projects to the satisfaction of supervisors, assessors and funding industry partners. The GET programme shows that it is possible to deliver engineering design and sustainable manufacturing via industry/university collaboration. The programme promotes student-centred learning and facilitates multidisciplinary teamwork at an international level.
Perkmann et al. (2009)	Innovation.	Analysis of the impact of university-industry partnerships on public research.	Empirical - Quantitative. Inductive study of university-industry collaboration in engineering.	Basic projects are more likely to render academically valuable knowledge than applied projects. Applied projects show higher degrees of partner interdependence and lead to new ideas and projects.
Perkmann et al. (2011)	Innovation/Growth.	Investigate how universities research quality shapes their engagement with industry.	Empirical - Econometric analysis, using a dataset covering all UK universities.	Departmental faculty quality is positively related to industry involvement. Differentiated approaches to promoting university-industry relationships are required.
Perkmann et al. (2011b)	Innovation/Growth.	Assess the outcomes of university-industry collaborations - propose a performance measurement system and derive a success map.	Theoretical - Model.	A framework for measuring performance in university-industry alliances is proposed.
Petruzzelli et al. (2011)	Innovation/ Regional.	Investigating the role that specific technological and relational attributes may play on the relevance of R&D collaborations between universities and firms.	Empirical	Technological relatedness has an inverted U-shaped relationship with innovation value, prior collaboration ties and geographical distance are positively related to the achievement of higher innovative outcomes.
Philbin (2008a)	Innovation.	Understand university-industry research collaboration through the development of a new process model.	Empirical - Qualitative. 32 structured interviews with stakeholders, application of a model to the management of an engineering research programme.	The study finds that there is a lack of integrative frameworks for the management of research collaborations.
Philbin (2008b)	Innovation/Growth.	Investigate how to measure the performance of research and technology collaborations and to subsequently improve the management of university-industry collaborative projects.	Empirical - Qualitative. Research involving interviews with 32 relevant stakeholders.	New performance measurement tool incorporating the key findings from the literature and empirical studies.
Pinheiro et al. (2015)	Innovation.	Test the use of social network analysis as a new methodological approach to better understand university-industry relationships in the context of R&D cooperation networks for innovation.	Empirical - Apply social network analysis to data on work relationships.	Social network analysis is suggested as a useful and relevant tool to understand and examine university-industry R&D cooperation at both personal and organizational levels.
Ponds	Regional	Analyse the role of geographical proximity for	Empirical - Quantitative.	Geographical proximity is more relevant for collaboration between

Author	Research area	Main purpose/Question	Method	Main results
(2007)		collaborative scientific research in science-based technologies between universities, companies and governmental research institutes (spatial characteristics of collaboration in scientific knowledge production in Netherlands).		academic and non-academic organisations than for purely academic collaboration. It is a way of overcoming the institutional differences between organisations, which is necessary for successful collaboration.
Ponds (2010)	Regional	To analyse the effect of knowledge spillovers from academic research on regional innovation.	Empirical – quantitative: Extended knowledge production function applied to some regions in Netherlands.	The impact of academic research on regional innovation depends on geographical proximity and on networks that come from collaborations.
Porter (1986)	Growth.	Examine environmental changes that firms face today in the light of international competition.	Theoretical.	The changing pattern of international competition is creating an environment in which no competitor can afford to allow country parochialism to impede its ability to turn a worldwide position into a competitive edge.
Raine et al. (2002)	Growth.	Discuss the role of university-industry liaison offices or companies in the commercialization process. (New Zealand)	Empirical.	Recognizes the differences in culture and strategic aims of universities and industries and aims to give value to both the university and its industrial partners.
Rogers (1986)	Innovation.	Who benefits from university-industry collaborations? What are the benefits and the problems?	Theoretical - Appreciative.	Universities, private companies and federal/local/state governments seem to benefit from these relationships, but certain problems may accompany these benefits.
Rosen et al. (1985)	Regional.	Study the economic impact of the University of Wisconsin-Madison on its home community.	Empirical - Case study.	University of Wisconsin-Madison, local community and the state are interdependent.
Santoro et al. (2006)	Innovation	By studying partnerships between industrial firms and university research centers, they try to identify facilitators of knowledge transfer.	Empirical - quantitative. Random sample of one hundred and seventy-three firms from northeastern US. Multiple regression analysis.	Significant facilitators of knowledge transfer - social connectedness, trust, technology transfer-intellectual property policies, technological relatedness and technological capability.
Sequeira & Teixeira (2011)	Innovation/ Regional.	Evaluate the international scientific impact and influence of a knowledge-producing and - diffusing institution: INESC Porto.	Empirical - Standard economic studies, scientometrics and bibliometric analysis. Use of statistical tools.	Impact of backward and forward linkages are analysed as well as network patterns. As an output there is also the geography of knowledge flows and the impact of scientific output.
Sherwood et al. (2008)	Innovation.	To explore the effects of various organizational knowledge interface factors on knowledge acquisition success in university-industry alliances.	Empirical - Quantitative. Survey to 104 industry managers. Hypotheses were tested using multiple regression analysis.	Results indicate that partner trust predicts the successful acquisition of tacit knowledge but not explicit knowledge.

Author	Research area	Main purpose/Question	Method	Main results
Siegel et al. (2003)	Innovation	To analyse the technology transfer process from universities to firms and its results; Search for recommendations to improve the technology transfer process.	Empirical – qualitative (interviews to stakeholders)	Stakeholders have different perspectives about university-industry partnerships; some barriers to this technology transfer were found.
Styhre et al. (2010)	Innovation.	Study a major Scandinavian technical university.	Empirical - Qualitative.	The entrepreneurial university needs to institute a number of mechanisms and procedures that structure and guide its day-to-day work and nourish an attitude where a certain ambiguity can be tolerated.
Sun et al. (2010)	Innovation/ Regional.	Introduction of coefficients in an attempt to measure relationships among university, industry and government. Proposal of a new approach of graphic modelling.	Theoretical - Models.	Collaborations are getting weaker and members of the three sectors tend to collaborate with foreign researchers. Universities lost their role of playing the central role in the national publication system since 2000.
Swann (2002)	Innovation.	Which sorts of companies cooperate with universities and other institutions that make up the science and technology base? What do they gain from such cooperation?	Empirical - Econometric analysis.	Relatively few companies cooperate directly with universities. Companies are more likely to cooperate with universities when they are process innovators.
Tamada et al. (2006)	Innovation.	Fine-tune a search algorithm that automatically retrieves cited scientific papers and patents from the entire texts of all the Japanese papers in the used database.	Empirical - Qualitative.	The degree of dependence on scientific knowledge differs from technology to technology and different ways of collaboration are needed for different technology fields.
Temel et al. (2013)	Growth.	Study the role of innovation and university collaboration in the profit growth of short and medium-sized enterprises in emerging countries. (Turkey)	Empirical - Draws on a sample of 79 Turkish small and medium-sized enterprises.	The authors find negative direct effects of innovation-based strategy and university collaboration on the profit growth of firms. When the market competition is fierce, they find that an innovation-based strategy increases profit growth and that collaboration with universities needs to exceed a certain level before the benefits are manifested in profit growth.
Thune (2007)	Innovation.	Explore the influence of prior established networks and participants perception of the success of research collaborations.	Empirical - Qualitative study.	Successful collaborations grow out of prior established ties and these collaborations are formed in several ways depending on the availability of preexisting resources and incentives.
Thune et al. (2011)	Innovation.	Examine the increasing formalization of cross-sector collaboration between universities and industry seen in the development of public funding schemes such as collaborative research centers.	Empirical - Qualitative (case studies).	Less formal project-based collaborations often display a higher degree of institutionalization than collaborative research centers, and these last ones represent highly formal but weakly institutionalized frameworks of collaboration. This happens because centers involve several industrial partners and represent different modalities of collaboration at the same time.
Thursby et al. (2011)	Innovation.	Examine the industry interaction of faculty who participated in the nanotechnology and biotechnology revolutions, as well as faculty contribution to other areas.	Empirical - Econometric.	There are significant differences in collaborative behavior across patent types and across the major program areas.

Author	Research area	Main purpose/Question	Method	Main results
Van Dierdonck et al. (1990)	Innovation/Growth.	Examine the attitudes of Belgian academic community towards university-industry technology transfers.	Empirical- Qualitative.	No cultural barrier detected, experience affect academics attitude towards industry positively and research results don´t support the idea that a minimum level of scientific staff of funding is needed before the university can even start thinking of a partnership.
Van Looy et al. (2003)	Regional.	Demonstrate how regional economic policies to stimulate entrepreneurship and innovation can lead to success.	Empirical - Qualitative.	High-tech venturing and the development of a policy to encourage it is a complex process, implying a multitude of elements, instruments and actors.
Wen et al. (2001)	Innovation/ Regional.	The paper analyses the latest changes of collaborative R&D network and tries to provide unique empirical observations in Japan.	Empirical - Statistical analysis. It is based on 7029 projects data.	Shows the emergence and growth of different modes and provides some observations for reference to policy-makers and researchers.

Appendix II: Partners' sector of activity by Portuguese classification of economic activity: absolute frequency

Portuguese classification of economic activity		Absolute frequency	Portuguese classification of economic activity		Absolute frequency
10130	Production of meat and poultry meat products	2	33140	Repair and maintenance of electrical equipment	3
10203	Preserving of fish and fish products in olive oil and other vegetable oil and other sauces	2	33170	Repair and maintenance of other transport equipment	1
10720	Manufacture of rusks and biscuits; manufacture of preserved pastry goods and cakes	1	33200	Installation of industrial machinery and equipment	1
11050	Manufacture of beer	1	35111	Production electricity of water power origin	1
13101	Preparation and spinning of cotton-type fibres	1	35113	Production electricity of wind, geothermal, solar and other origin	1
13102	Preparation and spinning of wool type fibres	1	41200	Construction of residential and non-residential buildings	4
13103	Throwing and preparation of silk, including from noils, and throwing and texturing of synthetic or artificial filament yarns	1	42110	Construction of roads and runway for airfields	2
13201	Cotton-type weaving	5	43130	Test drilling and boring	2
13202	Wool-type weaving	1	43210	Electrical installation	1
13203	Silk and other textile weaving	1	43290	Other construction installation	1
13301	Bleaching and dyeing	1	46180	Agents specialised in the sale of other particular products	1
13303	Finishing of yarns, fabrics and textiles products, n.e.c.	1	46421	Wholesale of clothing and clothing accessories	1
13910	Manufacture of knitted and crocheted fabrics	1	46520	Wholesale of electronic and telecommunications equipment and parts	2
13942	Manufacture of nets	1	46660	Wholesale of other office machinery and equipment	4
13961	Manufacture of ornamental trimmings and narrow fabrics	1	46690	Wholesale of other machinery and equipment	3
13962	Manufacture of technical and industrial textiles, n.e.c.	2	49310	Urban and suburban passenger land transport	5
13993	Manufacture of other miscellaneous textiles, n.e.c.	1	52211	Operation of land transport infrastructure	4
14131	Manufacture of other ready-to-wear outerwear	1	52220	Supporting water transport activities	4
15111	Tanning and dressing of leather	2	58110	Book publishing	1
15201	Manufacture of footwear	5	58130	Publishing of newspapers	3
15202	Manufacture of parts of footwear	1	58290	Other software publishing	3
16211	Manufacture of wood particle boards	2	61100	Wired telecommunications activities	1
16294	Manufacture of corks of cork	2	61900	Other telecommunications activities	3
16295	Manufacture of other cork products	1	62010	Computer programming activities	39
17120	Manufacture of paper and paperboard (excluding corrugated)	2	62020	Computer consultancy activities	4
20144	Manufacture of other organic basic chemicals, n.e.c.	1	62090	Other information technology and computer service activities	16
20160	Manufacture of plastics in primary forms	5	63110	Data processing, hosting and related activities	5
20301	Manufacture of paints (except printing ink), varnishes, mastics and related products	2	64202	Management activities of non financial holding companies	2
20594	Manufacture of other miscellaneous chemical products, n.e.c.	1	65112	Others complementary activities of social security	3

Portuguese classification of economic activity		Absolute frequency	Portuguese classification of economic activity		Absolute frequency
21100	Manufacture of basic pharmaceutical products	3	65300	Pension funding and complementary occupational of social security	4
22192	Manufacture of other rubber products, n.e.c.	1	70100	Activities of head offices	1
22210	Manufacture of plastic plates, sheets, tubes and profiles	3	70220	Other business and management consultancy activities	6
22292	Manufacture of other plastic products, n.c.e.	2	71110	Architectural activities	1
23640	Manufacture of mortars	1	71120	Engineering activities and related technical consultancy	33
24420	Aluminium production	1	71200	Technical testing and analysis	6
25110	Manufacture of metal structures and parts of structures	4	72110	Research and experimental development on biotechnology	3
25610	Treatment and coating of metals	1	72190	Other research and experimental development on natural sciences and engineering	154
25734	Manufacture of metal moulds	2	72200	Research and experimental development on social sciences and humanities	2
25920	Manufacture of light metal packaging	1	74100	Specialised design activities	2
25991	Manufacture of metal household articles	1	74900	Other consultancy, scientific and technical activities n.e.c.	4
26110	Manufacture of electronic components	1	80100	Private security activities	1
26200	Manufacture of computers and peripheral equipment	7	82990	Other business support service activities n.e.c.	7
26300	Manufacture of communication equipment	5	84111	Central government	1
26512	Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, n.e.c.	1	84113	Local government	3
27110	Manufacture of electric motors, generators and transformers	2	84114	Supporting service activities for public administration	1
27320	Manufacture of other electronic and electric wires and cables	2	84122	Public administration - education activities	4
27330	Manufacture of devices and fittings for low-voltage electrical installations	1	84130	Public administration - economic activities	1
28210	Manufacture of furnaces and furnace burners	1	84220	Defence activities	5
28293	Manufacture of other general purpose miscellaneous machinery, n.e.c.	1	85310	Basic (3º stage) and general secondary education	2
28410	Manufacture of metalworking machine tools	2	85420	Higher education	696
28490	Manufacture of other machine tools	2	86100	Hospital activities	3
28940	Manufacture of machinery for textile, apparel and leather production	1	86906	Other human health activities, n.e.c.	1
28992	Manufacture of other miscellaneous special purpose machinery, n.e.c.	8	87302	Social assistance to the disabled, with accommodation	1
29100	Manufacture of motor vehicles	3	94110	Activities of business and employers membership organisations	1
29200	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers	1	94995	Other activities of associations, n.e.c.	24
29320	Manufacture of other parts and accessories for motor vehicles	4		International -	588
31010	Manufacture of office and shop furniture	1		N/A -	7
31093	Manufacture of furniture of other material for other purposes	2		**Total**	**1798**
32502	Manufacture of medical orthopaedic appliances, prostheses and medical and dental instruments	1			

Appendix III: Partners' location by municipality and NUTS III: absolute frequency

Municipality	Absolute frequency	Municipality	Absolute frequency
Açores	1	Figueira da Foz	2
Alcanena	3	Covilhã	7
Tomar	1	Espinho	1
Almada	1	Gondomar	1
Setúbal	3	Maia	49
Amadora	17	Matosinhos	20
Lisboa	127	Porto	649
Oeiras	14	Póvoa de Varzim	2
Sintra	4	Valongo	1
Arcos de Valdevez	1	Vila do Conde	2
Viana do Castelo	1	Vila Nova de Gaia	11
Vila Nova de Cerveira	2	Faro	1
Arruda dos Vinhos	2	Guarda	1
Caldas da Rainha	2	Guimarães	18
Óbidos	2	Santo Tirso	3
Torres Vedras	3	Trofa	3
Aveiro	55	Leiria	4
Estarreja	1	Marinha Grande	3
Ovar	3	Madeira	2
Barcelos	5	Odemira	1
Braga	53	Oliveira de Azeméis	2
Esposende	2	Santa Maria da Feira	8
Vila Nova de Famalicão	14	São João da Madeira	17
Beja	1	Vale de Cambra	2
Borba	1	Santarém	1
Évora	3	Vila Real	6
Vendas Novas	1	Viseu	6
Bragança	8		
Castelo de Paiva	1		
Felgueiras	1		
Paredes	3		
Coimbra	54		

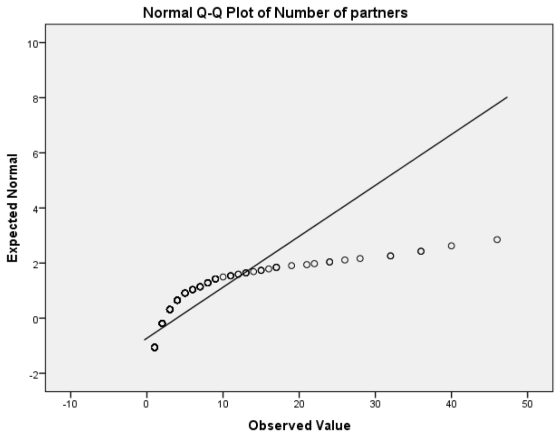
NUTS III	Absolute frequency
Região Autónoma dos Açores	1
Médio Tejo	4
Península de Setúbal	4
Grande Lisboa	162
Minho-Lima	4
Oeste	9
Baixo Vouga	59
Cávado	74
Baixo Alentejo	1
Alentejo Central	5
Alto Trás-os-Montes	8
Tâmega	5
Baixo Mondego	56
Cova da Beira	7
Grande Porto	736
Algarve	1
Beira Interior Norte	1
Ave	24
Pinhal Litoral	7
Região Autónoma da Madeira	2
Alentejo Litoral	1
Entre Douro e Vouga	29
Lezíria do Tejo	1
Douro	6
Dão-Lafões	6

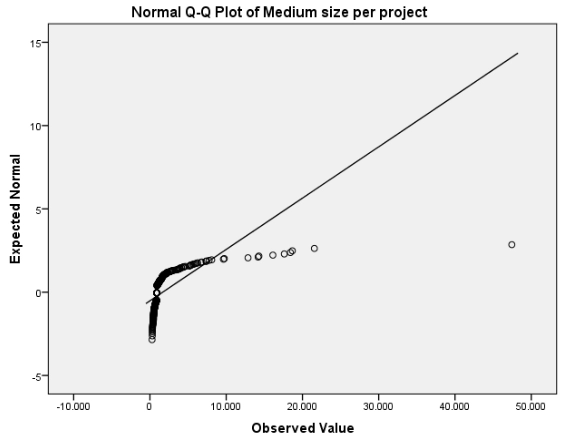
Appendix IV: Normality test

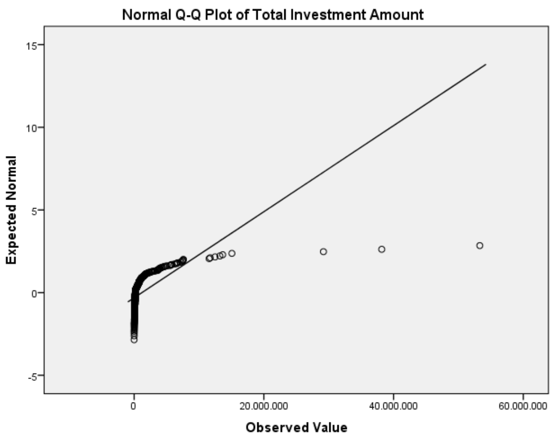
	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Number of partners	0.294	459	0.000	0.522	459	0.000
Medium size per project	0.337	459	0.000	0.320	459	0.000
Total Investment Amount	0.377	452	0.000	0.282	452	0.000
Duration	0.182	440	0.000	0.937	440	0.000

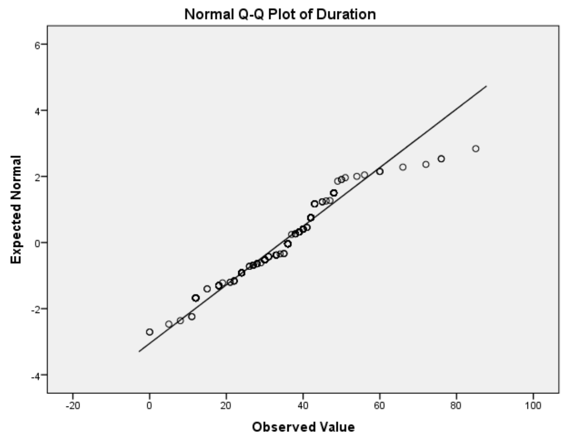
[1] Lilliefors Significance Correction

Appendix V: Dispersion diagram (variables normality)









Appendix VI: Partition degree: absolute frequency

Degree	Absolute frequency	Degree	Absolute frequency	Degree	Absolute frequency
1	35	24	6	57	8
2	30	25	20	58	4
3	43	26	1	70	33
4	50	27	20	73	1
5	23	29	1	74	1
6	49	30	3	76	2
7	38	31	38	81	2
8	35	32	2	84	1
9	11	33	2	89	2
10	25	34	2	92	1 (Linköping University)
11	17	36	2	93	1 (UBI)
12	22	38	6	95	1 (INEGI)
13	13	39	22	105	1 (ISEP)
14	36	42	1	118	1 (CITEVE)
15	15	43	1	121	1 (FCUP)
16	46	44	12	125	1 (EFACEC)
17	2	45	38	193	1 (IST)
18	6	46	2	228	1 (UM)
19	4	47	2	231	1 (UA)
20	17	48	2	233	1 (INESC TEC)
21	11	51	1	1342	1 (FEUP)
22	4	52	2		
23	22	54	3		

Appendix VII: K-core partition information[2]

Frequency distribution of cluster values:

Cluster	Freq	Freq%	CumFreq
1	35	4.3263	35
2	31	3.8319	66
3	46	5.6860	112
4	51	6.3041	163
5	28	3.4611	191
6	47	5.8096	238
7	42	5.1916	280
8	40	4.9444	320
9	7	0.8653	327
10	29	3.5847	356
11	22	2.7194	378
12	27	3.3375	405
13	12	1.4833	417
14	49	6.0569	466
15	14	1.7305	480
16	43	5.3152	523
18	7	0.8653	530
20	20	2.4722	550
21	7	0.8653	557
23	23	2.8430	580
25	19	2.3486	599
26	1	0.1236	600
27	21	2.5958	621
28	14	1.7305	635
31	53	6.5513	688
33	1	0.1236	689
39	36	4.4499	725
45	47	5.8096	772
46	1	0.1236	773
70	36	4.4499	809
Sum	809	100.0000	

[2] In this table, ***Cluster*** represents the *k* and ***Freq*** represents the number of entities in the core.

Appendix VIII: Degree centrality: absolute frequency

Degree	Absolute frequency	Degree	Absolute frequency	Degree	Absolute frequency
1	37	23	21	56	2
2	33	24	1	61	3
3	45	25	15	62	1
4	51	27	20	63	1
5	25	29	5	65	1
6	47	30	14	66	1
7	45	31	36	71	1
8	38	32	1	72	1
9	11	33	3	73	2
10	28	35	36	76	1 (CCG/ZGDV)
11	17	36	1	77	1 (UBI)
12	22	37	2	78	1 (ISEP)
13	10	38	2	86	1 (Linköping University)
14	31	39	23	89	1 (EFACEC)
15	16	40	1	96	1 (CITEVE)
16	40	42	2	132	1 (IST)
17	3	43	4	142	1 (UM)
18	8	45	45	153	1 (INESC TEC)
19	7	47	1	168	1 (UA)
20	19	49	1	808	1 (FEUP)
21	10	50	2		
22	4	54	1		

Appendix IX: Closeness centralization and vector with closeness centrality information

```
Network All Closeness Centralization = 0.98895984
----------------------------------------------------
 Time spent:  0:00:00

==============================================================================
2. All closeness centrality in N2 (809)
==============================================================================
Dimension: 809
The lowest value:                          0.5003
The highest value:                         1.0000
--------------------------------------------------------
Sum (all values):                        409.7076

Arithmetic mean:                           0.5064
Median:                                    0.5041
Standard deviation:                        0.0183
 2.5% Quantile:                            0.5003
 5.0% Quantile:                            0.5006
95.0% Quantile:                            0.5143
97.5% Quantile:                            0.5179

       Vector Values                                 Frequency       Freq%     CumFreq   CumFreq%
------------------------------------------------------------------------------------------------
 (                       ...                  0.5003]        37      4.5735          37     4.5735
 (                0.5003 ...                  0.6669]       771     95.3028         808    99.8764
 (                0.6669 ...                  0.8334]         0      0.0000         808    99.8764
 (                0.8334 ...                  1.0000]         1      0.1236         809   100.0000
------------------------------------------------------------------------------------------------
  Total                                                     809    100.0000
```

Appendix X: Betweenness centralization and vector with betweenness centrality information

```
Network Betweenness Centralization = 0.89294504
-----------------------------------------------
 Time spent:  0:00:00

==============================================================================
3. Betweenness centrality in N2 (809)
==============================================================================
Dimension: 809
The lowest value:                         0.0000
The highest value:                        0.8931
--------------------------------------------------------
Sum (all values):                         0.9784

Arithmetic mean:                          0.0012
Median:                                   0.0000
Standard deviation:                       0.0314
 2.5% Quantile:                           0.0000
 5.0% Quantile:                           0.0000
95.0% Quantile:                           0.0002
97.5% Quantile:                           0.0009

       Vector Values                                 Frequency        Freq%      CumFreq  CumFreq%
------------------------------------------------------------------------------------------------
 (                        ...             0.0000]          652      80.5933          652   80.5933
 (                0.0000 ...              0.2977]          156      19.2831          808   99.8764
 (                0.2977 ...              0.5954]            0       0.0000          808   99.8764
 (                0.5954 ...              0.8931]            1       0.1236          809  100.0000
------------------------------------------------------------------------------------------------
  Total                                                    809     100.0000
```