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Doctoral Thesis

**Assessing university performance
and strategic paths in the
presence of multiple objectives**

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“The important thing in science is not so much to obtain new facts as to discover new ways of thinking about them”.

Sir William Bragg (1862 - 1942)

PART I: INTRODUCTION

This first part serves as general background of this doctoral thesis. Here our objective is to introduce the research questions to be addressed in the context of the study, highlighting the importance of the management of universities as a topic for research.

Chapter 1: Introduction

This chapter begins with a consideration of the background concerning the importance of universities in the knowledge society, emphasising why their contribution to society has become so important, and discussing the significance to study how universities perform and manage their resources in regard to teaching, research and knowledge transfer activities. We also highlight the main challenges universities are facing nowadays and, briefly introduce the conceptual framework that holds this thesis, giving rise to a series of questions that help us to identify the existing gaps in the literature. The chapter further presents the research question and main objectives of the thesis, linking their justification with the contribution they are expected to provide. Finally, we present how the thesis has been structured.

1.1. Why study universities' performance? Background

Universities around the world are nowadays operating in a turbulent environment, where they reconsider their roles in society and evaluate their relationships with communities and stakeholders. The importance of these institutions becomes clear as they create and disseminate knowledge. This new approach to universities has modified their operations and objectives, and now these institutions are in the agendas of academics and policy-makers.

Competitiveness and excellence lies on the capacity of regions to innovate and transfer knowledge from academic institutions to society, and from now onwards the role of the triangle of education, research and innovation is critical. Indeed, the growing importance knowledge and innovation are acquiring as the basis for economic development and growth, has lead universities to expand their traditional functions (teaching and research), spreading their commitment in the contribution to economic and social welfare through their so-called third mission. This means that universities have turned into one of the most important engines for regional development (Arbo & Benneworth, 2007). They play a key role in human capital development but also in the provision of new knowledge, which is expected to have a positive impact in the innovation systems of their neighbouring regions.

Over the last decades universities have been seen as institutions that generate knowledge and transmit this knowledge to people. The contemporary university is a combination of teaching, research, entrepreneurial and scholastic interests (Etzkowitz, Webster, Gebhardt & Cantisano Terra, 2000). Nowadays universities not only provide highly qualified graduates and researchers, but they also offer innovative solutions through knowledge-transfer mechanisms that foster links with the local industry system. This means that, despite teaching and research are key actions for satisfying society’s knowledge demands, it is in the local development where this process articulates. This not only requires a high standing university, able to educate people with the latest technologies, but also a capable university to translate research results into marketable outcomes, a factor that contributes to the economic and social development of the region.

Particularly, this growing awareness of how higher education institutions¹ (HEIs) can contribute to regional innovation development, has lead governments to rethink how to maximize the benefits arising from universities, using them as principal agents for regional

¹ In this thesis, university and higher education institution are used interchangeably to designate any type of higher education centre.

development, assisting economic recovery. Collaboration with businesses, local and regional public authorities and other local actors are the traditional practices to reach this purpose, however, benefits arising from these relationships are still far from their true potential, and strongly differ from one university to another.

As a result, universities enlarge their service portfolios embracing all those economical, social, cultural and environmental issues that engage in the development and implementation of regional and urban strategies, bringing new significance to the international dimension of higher education (Goddard, 2005).

The relevance and popularity of the management of universities and their role in society is undeniable, justified amongst others by the efforts that research centres, higher education institutions and policy-makers are undertaking, as well as for the rise in the number of studies dealing exclusively with this field. At a European level, many initiatives have been carried out and many others are still in due course. The Lisbon Strategy for Growth and Jobs or the Modernisation agenda for Universities mainly focuses on this need of strengthening the knowledge triangle of research, innovation and education. Also, the EU 2020 Strategy by the European Commission and the Programme on Institutional Management in Higher Education (IMHE) launched by the Directorate for Education of the OECD support this perspective and highlight regional development as the catalyst for sustainable growth and competitiveness. In addition, an innumerable number of initiatives and networks have been established aiming to facilitate the alignment of HEIs with regional and business needs. Some examples of this nature are the European Cluster Observatory, the European Institute of Innovation and Technology, the PRO INNO Europe platform, the Enterprise Europe Network or the Business Innovation Centres tool.

Similarly, institutions with a specific focus on the management of HEIs can easily be found throughout Europe. Examples include the European Centre for Higher Education (CEPES) from UNESCO (headquartered in France); the European Centre for Strategic Management of Universities (ESMU) in Belgium; the Impact of Higher Education

Institutions on Regional Economies Initiative, the Higher Education Funding Council for England (HEFCE), or the Centre for Higher Education Studies (CHES) of the Institute of Education (University of London), all three in the UK; the Higher Education Policy Research Unit (HEPRU) at Dublin Institute of Technology (Ireland); the Centrum für Hochschulentwicklung (CHE) in Germany; the European Association for Institutional Research (EAIR) and the Centre for Higher Education Policy Studies (CHEPS) of the University of Twente, both in The Netherlands; and the Centro de Investigação de Políticas do Ensino Superior (CIPES) in Portugal. All these institutions and/or associations, attempt to study from different perspectives the functioning of universities in the current changing environment.

Differences in size, geographic location and institutional frameworks depict a complex but challenging research topic. Yet, increased competition in the higher education sector demands greater levels of quality, leadership and professionalization. This context jointly with the emergence of the aforementioned institutions led many academics to study the management of universities from multiple perspectives. Since the late 90s research addressing this issue has grown and theoretical and empirical contributions emerged. Interestingly, the bulk of research in this topic does not share a common framework, and studies have been conducted taking advantage of different research streams that can contribute to this knowledge field, including the economics of education, regional development, and the economics of technology change and innovation.

Literature on the regional engagement of universities reveals that better performance rates in regional development can be achieved through the interaction of public (government), private (industries) and academic (universities) institutional actors, broadly encompassed by the trilateral interactions that emerge between them. Known as the Triple Helix model, this approach suggests that individual goals of the different actors (wealth generation for the industry, public control for government and novelty production for academia) can be better achieved if collaborations are established. Taking as a basis the paradigm of the Triple Helix (Etzkowitz & Leydesdorff, 1997; Leydesdorff & Etzkowitz, 1996) and the

theories of Regional Innovation Systems (Freeman, 1992; Lundvall 1992), a stream of research dealing with the contribution of HEIs to the region emerged. While the Triple Helix connects the traditional categories of the innovation economy with institutional and evolutionary economics, the theory on Regional Innovation Systems allows the transformation of the classical categories into measurable elements according to their geographical dimension and emphasizing the concept of “region” (Tödting & Trippel, 2005). Nevertheless, despite reducing the level of abstraction by particularising for the region, the main concern and point of divergence presented by this body of literature relies on the measurement of the outcomes resulting from these collaborative interactions. Therefore, each partnership tends to have specific magnitudes, responding to the particular cultural, social and political context, which complicates cross-country comparisons.

It is important to highlight that universities made their entry into regional policy in the 80s, when entrepreneurship became central to local development (Van Vught, 2009). There were new incentives to create closer linkages between knowledge institutions, trade and industry, led by the likes of Silicon Valley (California), Route 128 (Boston) and some other leading high technology centres. Since then, universities have drawn new “road maps” towards dynamic local forces capable to help their cities and regions to become more innovative and globally competitive in a global economy in which deliver social well-being.

At this point, and given the relevance that active involvement of universities in regional needs has been proved to improve the economic development of the region, the main question rising is how universities link their teaching goals with the contribution to the specific regional needs? And, what mechanisms can universities utilise to enhance the shift from basic research towards applied outcomes linked to industry applications?

As for the first question, we know that universities are widening their activities and mechanisms to engage with the region. This means that universities are adopting modern approaches that allow connecting teaching activities with business links. Some examples

can be found in sponsored degrees or practicum internships that boost the diffusion of knowledge into the industry. Similar happens with research activities (second question), which through the development of collaborative R&D projects combine the expertise and knowledge generated in laboratories and offices at the university setting with their implementation into real industry situations. However, the resulting benefits from these efforts are still hard to model and quantify.

Universities are expected to meet training needs by teaching activities, establish the basis for science and technology through research functions, and contribute to the economic and social development of their territories. Therefore, universities have expanded their services, improving their management systems and adapting their organizational structures. A third question rising is whether universities allocate their internal resources and capabilities effectively to cope with all the functions and services they are expected to develop and offer.

This gives rise to the need to draw a specific framework that allows the characterisation and conceptualisation of the roles played by universities in relation to the resources they can make use. This suggests an in-depth analysis of the theory, from the perspective of the resources' management, asking for: What resources are universities using to develop their roles? Are these resources helping in the consecution of knowledge generation and dissemination? What sort of resources should be considered? Is the management and usage of these resources linked to a strategic plan?

Concerns about the metrics that effectively represent the use of resources and the outputs obtained from each role are still a recurrent source of debate. Undoubtedly, the recent trend on public consciousness for accountability jointly with the desire to perceive returns on public investments has accelerated this debate. Yet, in a global context, universities are subject to significant increased competition in areas where their influence was not relevant in the past. It is not enough for universities to define their role and missions locally. An example of this phenomenon relates to the emergence of stringent worldwide rankings and assessment processes. These methodologies evaluate certain aspects of

universities’ performance, using indicators that range from the results obtained by students or publications in top international journals, to the level of employment of graduates or the number of academic spin-offs created.

As expected, studies in this direction has led to a large amount of papers dealing with new ways and approaches to assess the performance of universities (Coates, 2007; Eccles, 2002; García-Aracil & Palomares-Montero, 2010; Grupp & Schubert, 2010; Salmi & Saroyan, 2007; Shin, Toutkoushian & Teichler, 2011), and far from converging into a unique formula, the inherent controversy of such evaluative procedures assists their diversification. Questions contributing to this debate are thus formulated as follows: What indicators are the best proxies for universities’ resources (inputs) and results (outputs)? Is it possible to obtain robust measures to assess universities’ performance? Moreover, and given the differences that exist amongst universities, does the university evaluation based on homogenous policies help them enhance their performance and achieve their goals more effectively? Or to the contrary, does the presence of prescriptive assessment tools make universities mimic others to obtain better results based on the considered parameters?

In accordance with the aforementioned interrogations, and assuming a framework where universities are compelled to redefine their missions and make an efficient use of their resources, it becomes clear that an in-depth analysis of universities’ objective function is necessary to get a better grasp on the mechanisms that shape these institutions’ performance.

1.2. Research objectives and structure of the thesis

The aforementioned research efforts have attempted to assess public universities’ operations. Yet, specific difficulties related to the theoretical framework and the empirical design may arise, and therefore we identified different drawbacks which common feature relates to the partial assessment of universities. Therefore, this thesis aims to fill this gap

by examining ‘what’ universities do, ‘why’ they do what they do, and ‘how’ they do that. To this end, we first carry out an exhaustive literature review. Second, we present a theoretical framework that leads us to model the objective function of universities, from which hypotheses emerge. In order to test them, we therefore propose a three-step empirical analysis, using 1) three different regression models (one for each mission); 2) Data Envelopment Analysis, to test the efficiency of Spanish public universities; and 3) a cluster analysis to categorise the Spanish universities according to a given set of relevant variables.

Consequently, the contribution of this thesis relies on the achievement of the following goals: 1) the definition of an objective function common to public universities; 2) the analysis of certain factors that contribute to explain the attainment of teaching, research and knowledge transfer outcomes; and 3) the identification of different behavioural pathways amongst Spanish public universities.

Therefore, the importance of this study consists in obtaining a greater insight on how public universities address their complex objective function, shedding some light on how these institutions align their internal resources and capabilities with their strategic vision. Hence, it is hope that this thesis provides an answer to these unsolved questions contributing to the existent literature by using a rigorous and innovative approach to HEIs’ missions and performance which yield in interesting findings that help both managers and policy makers to improve the performance of universities and their commitment with the region.

To attain these specific goals, this thesis has been organised as follows.

Part II presents the literature review, showing the growing attention that the field of the management of higher education institutions has experimented in the last years. In particular, Chapter 2 starts with the characterisation of universities as outstanding elements in the development of capabilities and the economic growth of regions. Based on an in-depth analysis of the most specialised literature in government-university-

industry links, these interactions are considered desirable for the economic recovery and development of territories.

In this chapter, we therefore review the main theoretical frameworks that have contributed to explain the role played by universities. The theoretical review starts with the theory of regional innovation systems (Freeman, 1992; Lundvall 1992). We then present the “mode 2” theory (Gibbons et al., 1994), and the Triple Helix model (Etzkowitz & Leydesdorff, 1997; Etzkowitz et al., 2000). Finally, we introduce the theory of the engaged university (Holland, 2001; Chatterton & Goddard, 2000). This theoretical background helps us illustrate how societies’ changing demands have to be integrated in universities’ strategic missions, re-shaping the way these institutions operate, performing tasks that go beyond the traditional teaching and research missions, but adopting a third role in regional economic development.

Given the potential impact of universities on regional development, Chapter 3 focuses its attention on how to model the production function of universities considering their three main functions: create knowledge (research), diffuse it (teaching), and translate it into the marketplace through its valorisation (knowledge transfer). A theoretical framework for the study of universities’ core missions is then suggested (Section 3.1), taking as a basis the one proposed in the EU-DRIVERS² project (Lifelong Learning Project N° 504440-LLP-1-2009-1-BE-ERASMUS-ENWS), with Josep Maria Vilalta (Catalan Association of Public Universities, ACUP) as the coordinator of the working team. The main results of this study were published in the report “Using the economic crisis as an opportunity for engaging universities in regional development. Background report”, and presented in the *First EU-DRIVERS Annual Conference*, held in Barcelona, 17 November 2010.

As any other organisation receiving public funding, universities must have a transparent and effective management of their accounts, providing relevant data about their individual

² The EU-DRIVERS project is led by the European Centre for Strategic Management of Universities (ESMU) and carried out with the support of the European Commission.

performance. Given the current importance the evaluation of universities is acquiring, Section 3.2 introduces some key issues regarding the use of different methodological approaches, the impact of such procedures, and the difficulties arising from the collection of appropriate data. A recent study co-authored with Francesc Solé (“What are we measuring when evaluating universities’ efficiency?”) and submitted to *Regional and Sectoral Economic Studies* addresses this particular topic, highlighting the uses and misuses of indicators when having to assess the performance of universities.

Once we have explored throughout the previous sections “what” universities have to do and “why” they should do what they do, we therefore wonder for “how” universities do it. Considering universities’ internal services identified in the literature review, we therefore propose a definition for the objective function of universities, from which the hypotheses that drive this thesis emerge.

Part III deals with the empirical analysis and contrasts the hypotheses emerging from Part II. We focus on the Spanish case, using data from the 47 Spanish public universities for the academic years 2006/2007 and 2008/2009, included in the reports of the Council of Rectors of Spanish Universities (Conferencia de Rectores de Universidades Españolas, CRUE) and the Network of Spanish Technology Transfer Offices (RedOTRI). A full description of the methodological approach analysis and the description of the sources of information is provided in Chapter 4. A three-step empirical analysis is then presented aiming to respond whether universities follow different patterns in the internal allocation of resources between various activities, and to what extent has the institutional context (external to the university boundaries) facilitated or hindered the development of universities’ missions. Thus, in Chapter 5 we analyse the impact that universities’ internal resources have on the consecution of teaching, research and third stream activities, proxied by the number of graduates relative to the number of students enrolled, the number of papers published in peer-review top journals, and the number of spin-offs created, respectively. To attain the research objectives proposed in Chapter 1, in Part III we run three different regression models. This way, we can scrutinise the impact that

certain factors commonly identified in the literature have over universities’ performance, and in particular, in the different activities that universities develop.

Regarding the factors that contribute to research activities a preliminary study has already been published in *The Service Industries Journal*, Vol. 31, No. 1, pp. 39-58 (2011) (“Which services support research activities at universities?”), co-authored with Francesc Solé (Universitat Politècnica de Catalunya) and Itxaso del Palacio (University College London).

As for the third stream activities, two studies examining the influence that certain internal and external factors have over knowledge transfer outputs have been published. First, a theoretical paper co-authored with Francesc Solé and presented at the *5th International Conference on Industrial Engineering and Management* held in Cartagena (September 2011). In this paper (“Caracterización del proceso de valorización de la I+D universitaria”) we identify and classify those factors that act as potential drivers or inhibitors to third stream activities. In the second paper, and together with Ferran Sabaté and Antonio Cañabate (Universitat Politècnica de Catalunya), knowledge transfer outputs (patents, spin-offs and R&D contracts) are scrutinised. This paper entitled “Brokering knowledge from universities to the marketplace: the role of Knowledge Transfer Offices” is accepted for publication in *Management Decision* (Vol. 50, No. 7).

Additionally, a paper entitled “Knowledge transfer and spin-off performance in Spanish universities” has recently been presented at the *2nd Conference of the International Network of Business and Management Journals*, held in Valencia (March 2012), which has been co-authored with the two directors of this thesis (Esteban Lafuente and Francesc Solé).

Based on the results obtained in the previous chapter, in Chapter 6 we conduct an efficiency analysis of the Spanish public higher education system by using the Data Envelopment Analysis (DEA) methodology. In this stage, we aim at to correctly assessing the overall performance of universities, and therefore outputs relate to teaching, research and knowledge transfer activities.

We are aware of the existence of potential complementarities between the different explanatory variables considered in the analysis in Chapter 5 and 6. Therefore, in Chapter 7 we run a non-hierarchical cluster analysis using a set of exogenous variables. The grouping of universities by exogenous variables not only allows us to identify different strategic patterns amongst Spanish HEIs, but also permits us to understand how these institutions behave according to their environment and internal strategies. Therefore, a better understanding about the rationale for the strategic approach adopted by universities in terms of their missions is presented.

A paper addressing all the empirical analysis carried and presented in this part has been recently submitted to the *Global Innovation and Knowledge Academy Bi-Annual Conference* (“The pursuit of knowledge transfer activities: An efficiency analysis of Spanish universities”), also co-authored with Esteban Lafuente and Francesc Solé. This work is currently under review.

Finally, Part IV summarises the main conclusions arising from both the conceptual framework and the empirical analysis. The limitations of the study and recommendations for future research are also provided in this last section.

PART II: THEORETICAL FRAMEWORK

This part develops the theoretical framework used in this thesis. It is structured in two chapters. First, in Chapter 2 we set the boundaries that shape universities' landscape, introducing the multiple challenges universities face, and how these institutions respond to stakeholders' demands. To do this so, we review various theoretical approaches conceptualising the different roles of universities. Having presented this literature, Chapter 3 introduces the specific framework for this study, modelling universities' role in society according to their three core missions. Last section of this chapter presents the conceptual approach adopted for this study and the hypotheses proposed.

Chapter 2: Setting the boundaries of the university landscape

Universities are called to play an outstanding role in the development of capabilities and in the economic growth of regions. However, their role in the society has drastically evolved from a recursive movement of re-shaping their two traditional roles, teaching and research, towards the adoption of a third role in the economic development of territories. In order to understand the underlying rationale for these changes, this chapter develops a literature review of the main theoretical bodies aiming at explaining university' strategic approaches and their links to society' demands. This framework is based on the literature on regional innovation systems (Freeman, 1992; Lundvall 1992), the “mode 2” (Gibbons, Limoges, Nowotny, Schwartzman, Scott & Trow, 1994), the Triple Helix model of university, industry, government relations (Etzkowitz & Leydesdorff, 1997; Etzkowitz et al., 2000) and the theory of the engaged university (Holland, 2001; Chatterton & Goddard, 2000). Even though the differences that exist between these theoretical approaches, their coexistence relies on the need to offer different perspectives about the driving forces shaping the relationships between universities and their beneficiaries. These theoretical bodies tend to complement each other, converging towards a concept of university where these institutions are seen as strategic catalysts for regional and economic development.

2.1. Introduction

The role of universities in knowledge-based activities is attracting growing attention from academics and policy-makers around the world. Historically universities have been considered institutions that disseminate basic knowledge and where scientists developed new theories in their laboratories. Yet, they are recently perceived as vehicles for economic progress (Shattock, 2009a). In particular its potential contribution to economic prosperity through knowledge exchange and innovation developments to the wider society is seen as highly important for the economic development and growth of regions.

This perception of HEIs concerning their potential impact on regional development has led many national and regional governments around the world to support their higher education system, establishing new policies and mechanisms that facilitate their operations (Harman, 2005). This represents a critical shift in governmental attitudes towards an education model where universities significantly contribute to increase the competitive position of the region (Kitagawa, 2004). Examples of these policies implemented by public administrations relate to the development of new ideas, products and services; and the enhancement of teaching facilities that help rise citizens' educational level. In addition, it is necessary to create networks connecting universities and the industrial fabric. These networks are expected to satisfy the demands of the latter for technological and scientific advances through the exploitation of the knowledge stock available at HEIs.

In the case of Europe, the Lisbon Strategy for Growth and Jobs as well as the Modernisation agenda for Universities go in this direction, aiming to make Europe the most competitive and dynamic knowledge-based economy in the world. This is in accordance with the EU 2020 Strategy (European Parliament, 2000), which recognises that in a fast-changing world what it makes the difference is education, research, innovation and creativity.

Thus, industry as well as science and technology policy-making have converged towards a common innovative approach, accepting the challenge of increasing competitiveness through research and knowledge-intensive institutions (Goddard & Puuka, 2008). Given that innovation emerges from knowledge based activities, the identification of elements within the region that help creating and disseminating knowledge has gained increased attention and policy-maker efforts to promote these actions have recently started (Agrawal & Cockburn, 2003; Tödting & Tripl, 2005).

From a scholastic perspective, over the past two decades theoretical developments in regional economics have led to the sprouting of numerous studies debating universities' function and their role in innovation systems. The literature on the new regionalism and the learning regions (Cooke, 2002a; 2002b; 1998; Cooke, Davis & Wilson, 2002; Florida, 1998; 1995; Lundvall & Johnson, 1994) and specially the theory on national and regional innovation systems (Freeman, 1987; Lundvall, 1992; Saxenian, 1994) have drawn a critical and significant link between the role played by universities and regional development. These provided a solid background to a large number of studies that investigate the role of universities beyond teaching and research activities. These studies aim to illustrate how HEIs can cooperate with the innovation ecosystem they belong to. The result is an extensive body of literature, represented by the theories of the “Mode 2” (Gibbons et al., 1994), the “Triple Helix” model (Etzkowitz & Leydesdorff, 1997), and the theory of the engaged university (Chatterton & Goddard, 2000; Holland, 2001).

These theories connect the traditional categories of innovation economy with evolutionary economics providing a link between the three institutional actors (public, private and academic), and capturing the reciprocal relationships derived from their interactions. The main difficulty of these connections relates to its high level of abstraction as well as to a strong sociological approach that hinders its empirical adaptation.

The literature on regional innovation systems emphasises the concept of “region”, transforming the different categories related to innovation economy into measurable

elements based on geographical dimensions (Bosco, 2007). Yet, according to Cooke (2004), the adoption of this regional dimension is essential, as only being aware of the critical dimension of the region, it is possible to mediate between global and local instances in the process of supporting knowledge creation.

These efforts has been accompanied by the deployment of a wide array of policies oriented towards innovation and technology transfer that aim at providing appropriate conditions to enhance effective university-industry partnerships that lead to the exploitation of universities' available knowledge (Mowery & Sampat, 2005).

2.2. Towards a conceptual model based on Regional Innovation Systems

The agenda for the theoretical conceptualisation of Regional Innovation Systems (RIS) has been influenced by various theories concerned about the role that universities should play in these environments. Discussions about innovation systems and how knowledge is capitalised and exploited have originated an exhaustive number of works. These studies aim to find new formulae and configurations that help territories improve their competitiveness and obtain benefits in the cultural, social, and economical spheres.

The theoretical development around innovation was first proposed by Schumpeter (1934), and his linear model expresses the relation between market-driven push and pull forces and innovation. However, this approach is insufficient to induce knowledge transfer mechanisms and new theoretical approaches were developed in order to capture the evolutionary essence and the non-linear process in which agents communicate and interact in innovative systems (Edquist, 2005). Innovation does not consist of discrete steps from discovery and invention to commercialisation and diffusion, but in an iterative process with many feedback loops (Kline & Rosenberg, 1986).

One of the earliest conceptualisations of an innovation system is the *input/output analysis* by Leontief (1941), which addresses the flows of goods and services amongst different sectors in the economy. However, the modern version for the characterisation of

innovation systems was introduced in the mid 80s, and it appeared in a booklet on the user-producer interaction and product innovation (Lundvall, 1985).

Freeman (1988) utilises this concept to describe and interpret Japan’s performance during the post-war period. Contributions by Dosi, Freeman, Nelson, Silverberg & Soete (1988), Lundvall (1992; 1988), Nelson (1993; 1988) and Edquist (1993) brought this concept to the international audience, and this led to define what is known as the theory of the *national innovation systems* (NIS), based on the *national system of political economy* by List (1841). The term “national” reflects the states’ formation historical process, “innovation” relates to the “*process by which firms master and puts into practice product designs and manufacturing processes that are new to them*” (Nelson & Rosenberg, 1993:4), and “system” denotes a set of institutions.

Research based on this new approach emerged, and the theory of NIS gained adept. This theory states that innovations reflect a process where knowledge-creators and knowledge-users merge and get mutual feedback based on powder, trusty and loyalty relationships (Lundvall, 1985). According to Freeman (1992:169) a national innovation system specifically refers to “*the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies*”. Lundvall (1992) stressed the nature of the agents inside a NIS.

The *system* is defined by a set of interrelated *components*. On the one hand, the operational agents, which generate and disseminate knowledge (knowledge-suppliers). On the other hand, knowledge-users with specific *attributes* exploit this knowledge and create *relationships* between themselves in order to work towards a common objective. These relationships are based on feedback (interactions), and this process makes the system dynamic (Carlsson, Jacobsson, Holmen & Rikne; 2002; Carlsson & Stankiewicz, 1991). That is, the greater the interactions between components the greater the system’s dynamics. It is important to note that due to this dynamism, change is an intrinsic characteristic of any system. This way and strictly related to the system dynamics, it is possible that the system

borders should be enlarged (or narrowed) leading to a change in its components, establishing new relationships, or requiring the inclusion of new attributes.

The components are linked to each other in such a way that their individual attributes vary when they are integrated into a system (Hughes, 1987). Each component in the system behaves according to the others' behavioural patterns. Given the interdependence that exists between these actors, the system's performance is more than just the sum of its parts (Blanchard & Fabrycky, 1990), limited or fostered by external factors (normative and instrumental policies).

Although the concept of an innovation system suggests a coordinated action, interactions tend to be unplanned and spontaneously driven rather than deliberated (Bergek, Jacobsson, Carlsson, Lindmark & Rickne, 2008).

From the NIS approach, different conceptualisations on innovation systems have been put forward in the literature. For instance, Niosi, Saviotti, Bellon & Crow (1993) offer a critical perspective of the concept. Carlsson & Stankiewicz (1991), Carlsson (1994), and Carlsson & Jacobsson (1997) introduce the term *technological systems* to refer to those systems with a particular technology, knowledge area or industry, and these authors argue that systemic interrelationships are only applicable in a technological field.

Malerba & Orsenigo (1993) and Breschi & Malerba (1997) introduce the term *sector innovation systems* based on the notion that sectors operate under different technological regimes characterised by a particular combination of opportunities and technological knowledge-based, and these determine their development. Likewise, Taddei & Coriat (1993) work with a concept similar to national innovation systems, but using a perspective more focused on the characteristics of the national manufacturing sector, particularising their observations and results for the French case.

Further developments are the *local industrial systems* (Saxenian, 1994), which emerges from the study of the Silicon Valley in California and the Route 128 in Massachusetts. In this

case, the system is mainly defined by its geographical location and the culture and competitive behaviour condition its performance. These are known as *socio-technical systems* (Bijker, 1995; Geels, 2004). Other contributions come from the *evolutionary economics* (Nelson & Winter, 1982), the *network theory* (Hakansson, 1987), the *institutional economics* approach (North, 1990; 2005), the *new regional economics* (Storper, 1993), the *economics of learning* (Foray & Lundvall, 1996), and the *economics of innovation* (Dosi et al., 1998). Despite these approaches deal with technology innovativeness, their contribution and empirical application remain limited given the complex nature of innovation (Doloreux, 2002).

Since the nineties the term “national” has been spatially bounded, resulting in the emergence of the theory on *regional innovation systems* (Acs, 2000; Asheim & Isaksen, 1997; Autio, 1998; Braczyk, Cooke & Heidenreich, 1998; Cooke, Boeckholt & Tödting, 2000; De la Mothe & Paquet, 1998; Doloreux, 2002; Fornahl & Brenner, 2003; Howells, 1999).

According to Bosco (2007) and Doloreux & Parto (2005) the popularity reached by the theory of regional innovation systems (RIS) responds to several factors. RIS emerges from an international competition atmosphere, where regions struggle to consolidate their position, balancing local and global interests. On the one hand, and driven by a globalised and dynamic economy, regions are competing for attracting talent and retain investments, asking for both knowledge capital and financial resources that help them engage locally and compete globally. On the other hand, from a local perspective, there is increased a stronger demand for decentralised regional policies. This is due to regional policies represent territorial perspectives that alert national governments about the local economic and social conditions. The apparent shortcomings of the traditional centralised policies, together with the success of industrial and business clusters in various regions have contributed to the discussions about NIS when confronting it with the literature on regional science.

Consistent with Niosi (2000) any definition of a RIS should first present a clear concept of “region”. Cooke (2001) and Cooke & Schienstock (2000) highlight two considerations that characterise a “region”. First, a region is a geographical and administrative area

defined by a set of agreements, innovation networks and institutions that operate under common goals. Second, the definition of region should emphasise its cultural, social and internal cohesion regardless of its political or administrative boundaries. It is possible to find in the literature different conceptualisations of the term “region”, and this term is freely used to refer to territories, jurisdictions or countries (Table 2.1).

Table 2.1. Units of analysis in the study of RIS.

Unit of analysis	Authors
Cities	Crevoisier & Camagni (2001); Simmie (2001; 2003)
Metropolitan area	Brouwer, Budil-Nadvornikova & Kleinknecht (1999); Diez (2000); Feldman & Audretsch (1999); Isaksen (2004)
Districts inside metropolitan areas	Asheim & Isaksen (2002); Asheim, Isaksen, Nauwelaers & Tötödling (2003); Enright (2001); Porter (1998); Saxenian (1994); Voyer (1998)
NUTS ³ II (Eurostat)	Evangelista, Ianmarino, Mastrostefano & Silvani (2002; 2001)
Supra-regional / sub-national scale	Capron & Cinera (1998); Gertler & Wolfe (1998); Latouche (1998)
Countries	Maskell (1998)

Source: Self-devised, based on Doloreux & Parto (2005), and Rip (2002).

Etzkowitz (2002) points out that, irrespective of the unit of analysis, the fundamental requirement for the characterisation of a region is its critical potential dimension. Thus, a region is a complex setting where a set of political, industrial and academic institutions interact, by design or unintended consequence, and work to improve the local innovative conditions which is expected to contribute to its endogenous development. Yet, RIS must show particular identity features, such as culture, a distinctive educational system or a specific knowledge transfer policy, which shape the development of the region and determine its own learning capabilities (Doloreux, 2002).

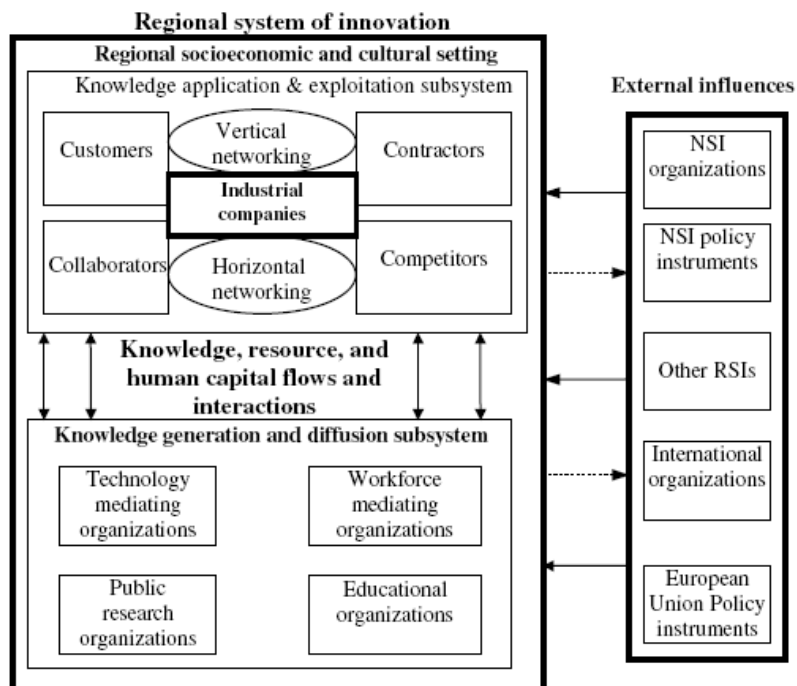
³ The Nomenclature of Units for Territorial Statistics (NUTS) is a geocode standard for referencing the subdivisions of countries for statistical purpose, that do not necessarily correspond to administrative divisions within the country. This standard is developed and regulated by the European Union, only covering the member states of the EU in detail. For each country, a hierarchy of three NUTS levels is established by Eurostat.

Nevertheless, the distinction between NIS and RIS is difficult to ascertain. There are academics that clearly separate them (Asheim & Isaksen, 1997; Autio, 1998), whereas others consider RIS as a particular type of NIS (Archibugi & Michie, 1997; Buesa, Martínez, Heijs & Baumert, 2002; Doloreux, 2002; Wiig, 1999). Despite the discrepancies in the definition of RIS and the breadth the term “region” entails, academics agree that the definition of region has to be flexible enough to be applicable to multiple types of regions and reflect the territorially embedded system from which it emerges, where the generation and diffusion of knowledge plays a crucial role (Cooke, Roper & Wylie, 2003).

Following Doloreux’s (2002) components categorisation, it is possible to distinguish institutions that influence in the creation, development, transmission and usage of new knowledge developments (i.e. universities and research centres), from the economic agents responsible for demanding and using knowledge (i.e. firms). This is also highlighted by Autio (1998) (Figure 2.1). Here, the RIS is divided in two main subsystems. On the one hand, a subsystem integrated by knowledge-supplier institutions (universities and public research centres/institutes) and knowledge-broker organisations (knowledge transfer offices). On the other hand, a subsystem guided by industrial companies that interact in an ecosystem of customers, contractors, collaborators and competitors through the establishment of vertical and horizontal networks (knowledge-users).

The performance and reproduction of such a system strongly not only depends on the capabilities of knowledge-suppliers and knowledge-users, but also on the normative framework that regulate the interactions amongst them. In order to account for these policy dimensions, Tödting & Trippel (2005) added this dimension into Autio’s model, and they consider multiple regulation levels (local, regional, national, and supra-national). This implies that policy-makers can play a powerful role at a local or regional level as they provide the sufficient autonomy to formulate and implement innovation enhancing policies (Cooke et al., 2000; Cooke & Memedovic, 2003), however, these policies might be somehow subject to supra-regional agents.

Figure 2.1. Structure of a regional innovation system (RIS).



Source: Autio (1998).

Literature on RIS has generated further analyses on the relationships between the agents involved and how the innovation process is linked with other constructs such as proximity, social integration, learning capabilities, and economic performance. This has led to the emergence of new concepts in the innovation field and regional science such as *learning regions* (Morgan, 1997; Florida, 1995), *innovative regions* and *milieux* (Camagni, Maillat & Matteaccioli, 2004; Crevoisier & Camagni, 2001), *industrial districts* (Beccatinni, 1992), *local productive systems* (Courlet, 1994), *high-tech areas* (Keeble & Wilkinson, 2000; 1999), *clusters of knowledge based industries* (Cooke, 2002b), or *knowledge spillovers* (Audretsch & Feldman, 1996; Bottazzi & Peri, 2003).

2.3. Regional innovation systems and the role played by universities

Most recent research on regional development processes stresses the role played by knowledge and networking strategies between the system's components. If correctly managed, they can help regions revitalise their industry and develop economically, and

thus, maximise the economic benefits (Cooke et al., 2003). In this context, the theory of RIS depicts a promising descriptive framework for the understanding of innovation knowledge processes that take place at the regional level.

Gibbons et al. (1994) argue that the role of science in society has changed, becoming central to the generation of welfare. Whereas science has always spoken to society providing new ways of conceptualising the physical and social world, the contemporary society speaks back to science, putting into manifest the transformation from an industrial society to a knowledge-based one. Yet, the emergence of a knowledge-society has increased the number of social and economic activities that need to be included by research components in their day-to-day operation. The industry, and in particular high-tech companies and management consultancies, are increasingly dependent upon knowledge systems to the point that knowledge itself is nowadays becoming a commodity (Nilsson, 2005).

Knowledge production becomes part of a larger process in which discover, application and use are closely integrated (Nilsson, 2005). According to Freeman (1995), the role of knowledge and by extension that of institutions involved in its generation are often raised to an overwhelming importance relative to more conventional factors such as labour and capital (Morgan, 2004).

In this setting, the role of academic research in “post-modern” industrial societies led to the “Mode 2” concept of knowledge production identified by Gibbons et al. (1994). According to these authors, the shift from Mode 1 to Mode 2 of knowledge production is due to the changing nature of knowledge production in universities and elsewhere. Mode 1 implies the production of knowledge, mainly by universities and research centres in specific disciplines with little direct connection to societal needs. To the contrary, Mode 2 involves the generation of knowledge in an applied context embracing a much broader range of perspectives and embodied in multiple and trans-disciplinary environments. Therefore, research is associated with a more interdisciplinary, pluralistic, “networked” innovation system, with a blurring of the boundaries between the traditional sectors

reflecting the increased scale and diversity of knowledge inputs required for scientific research (Gibbons, 2000; Mowery & Sampat, 2005; Nowotny, Scott & Gibbons, 2003).

This framework claims that the sources of knowledge within modern innovation systems have become more diverse and indispensable (Mowery & Sampat, 2005), emphasising the role of universities as fundamental research centres. Consequently, knowledge institutions, such as universities, play a key role as resource endowments within the region for its own development.

In this sense, a relevant concern relates to how universities can contribute to stimulate wealth creation, support sustainable development, and become active participants in the construction of regional economic and competitive advantage (Chatterton & Goddard, 2000; Keane & Allison, 1999). Thus, most HEIs' agenda has shifted from a desire to increase the general education level of the population and the output of scientific research (Hazelkorn, 2005) towards an intensification of their engagement with regional development issues and the regional development community (Shattock, 2003). Universities have been recognised as providers of graduates through teaching activities, that is, future professionals that capitalise their knowledge stock available at universities (van der Ploeg & Veugelers, 2008). Through research activities, universities extend the horizons of knowledge for industrial innovation (Guston, 2000; Hart, 1988; Smith, 1990).

The emerging regional development agenda has led many universities to intensify their engagement in regional development issues, recognising a “third role” that must not only be sat alongside but fully integrated with mainstream teaching and research activities (CEC, 2003). Consequently, as the requirements for regional engagement embrace many facets, meeting a wide diversification of needs, the contribution of universities to society goes beyond economic and technical advancement. Universities sustain the knowledge production and knowledge transfer processes that underpin the success of regions in attracting and retaining high value-added activities in the form of capital and talent or through processes of endogenous development (Shattock, 2003). Yet, the regional availability of knowledge and human capital is as important as the physical infrastructure

(CEC, 2003). As a result, regionally-engaged universities are key assets for regional innovation systems.

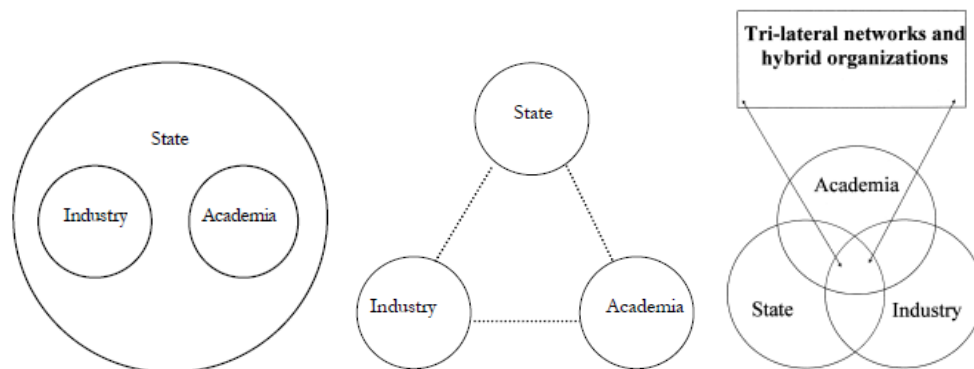
This engagement is occurring in a context characterised by a broader set of changes in which universities must compete (Charles, 2006). Concerning the role of universities in any regional innovation system, there are two dominant approaches to conceptualisation (Gunasekara, 2006): the Triple Helix model of university, industry, and government relations, and the literature on the engaged university. Even though both theoretical approaches overlap when highlighting the links between universities and the region where they are located, they differ in the assumptions made regarding institutional norms and behavioural paths.

The Triple Helix model emerged from a workshop on *Evolutionary Economics and Chaos Theory: New Directions in Technology Studies* (Leydesdorff & Van den Besselaar, 1994) organised with the intention of crossing the boundaries between institutional analysis of the knowledge infrastructure and the evolutionary analysis of the knowledge base of an economy (Leydesdorff & Meyer, 2006). Theorised later by Leydesdorff & Etzkowitz (1996), it suggests that in a knowledge-based society the boundaries between public and private sector, science and technology, university and industry are increasingly fading, giving rise to a system of overlapping interactions which did not previously exist (Ughetto, 2007). The main difference between the Triple Helix theory and previous models, such as the national systems of innovation approach (Lundvall, 1988, 1992; Nelson, 1993) or the “Triangle” model of Sabato (1975), is that under the Triple Helix approach universities acknowledge a leading role in innovation, complementing (and not just supporting) the two traditional starting points of science and technology policy (government and industry).

This model allows identifying different configurations (Figure 2.2) depending on the interaction and the level of commitment in regional development of universities, industry and governments. In fact, these three spheres, characterised by rigid and strong boundaries in the past, are considered to be softening their horizons, leading to configure

a flexible and overlapping system, where each one takes the role of the other. This potential for movement and reorientation of the spheres and the adoption of new relative positions generates different configurations: a *statist regime*, a *laissez-faire policy* or a *balanced approach*.

Figure 2.2. Main configurations of the Triple Helix model (*statist regime* on the left, *laissez-faire* in the centre, and *balanced* on the right).



Source: Etzkowitz & Leydesdorff (2000).

In a *statist regime* the national state is encompassed by academia and industry, driving their mutual relations (Etzkowitz & Leydesdorff, 2000). However, this configuration either expressed in terms of “market pull” or “technology push” is insufficient to induce knowledge and technology transfer because there is too little room for “bottom up” initiatives and innovation. Although the state loses part of his authoritarian role, in the *laissez-faire* configuration the institutional borders of the spheres are tightened up, making difficult the establishment of potential relationships, and industry acts as the driving force whereas the other two spheres act as ancillary support structures. Despite its lack of autonomy, this configuration is used as a way to reduce the role of the state, especially in those countries where it has an excessive control over the remaining spheres. The last configuration, the *balanced model*, clearly draws an overlapping framework in three dimensions that fosters knowledge generation and diffusion through the promotion of hybrid organizations that emerge from the interferences amongst the spheres. Universities gain prominence and they interact with the industry which leads to the establishment of joint initiatives (Etzkowitz & Ranga, 2010). Simultaneously, government encourages, but

not controls, these relationships through the normative laws and reforms, financial assistance or via new actors. Finally, industries benefit from their positioning in this type of environment as it is easier to establish collaborative R&D projects with knowledge-based institutions (having the opportunity to share scientists’ expertise and academic infrastructures), and have legal facilities and tax breaks.

Although the Triple Helix model depicts a rather static scheme, the overlapping movements between the three spheres indicate a dynamic process. Yet, each sphere (or helix) has an internal core and an external field space, drawing two parallel dimensions that expand simultaneously (Etzkowitz & Zhou, 2007). First, the vertical dimension developed by each helix evolves according to the helixes’ mission or strategy. These spheres experience internal changes that are independent with respect to the rest of helixes. Second a horizontal dimension, where spheres form an interactive circulatory system with the others in terms of exchanges of goods, services and functions. The interrelations resulting from these movements provide an innovative environment where knowledge flows in all directions. Therefore, the Triple Helix model is conceived as a spiral pattern of innovation that mirrors the complexity of activities and the multiple reciprocal relationships that take place at different points of the process of knowledge capitalization in the science/technology vector.⁴

Based on the assumption that universities require new resources and forms of management to meet more effectively the demands of various regional stakeholders and make a dynamic contribution to the development of the region, the approach of the engaged university arose (Chatterton & Goddard, 2000; Holland, 2001; OECD, 1999).

⁴ In the paper presented at the *XXI Congreso Nacional de ACEDE* “Estrategias para la competitividad regional: Evidencias practicas del modelo de la Triple Hélice” (Bergal & Martín, 2011) we report the analysis of various Triple Helix Spanish partnership examples, leading to a series of experiences on how universities, governments and the business sector can contribute to enhance dynamic and successful innovation systems.

This theory underlines the adaptive responses that universities have to adopt, embedding a stronger regional focus in their core functions (teaching, research and knowledge transfer) broadening their spectrum. On the one hand, universities need to possess a highly-skilled workforce, where researchers are seen as important as knowledge itself. On the other hand, focusing on capacity building, institutional learning and regional networking, universities have to become the centre where learning economies and the regionalisation of production meet.

The main challenge rising from this theory relates to the universities' commitment with the region (from faculty and staff to students and visitors) at all its levels and processes (skills enhancement, technological development and innovation, cultural awareness, etc.). Consequently, universities through their resource base, skills and knowledge, play a significant role in regional networking and institutional capacity building (Gunasekara, 2006).

It should be noted that this engaged role gives academics the opportunity to fulfil their functions in society, meeting the criticism that universities take public support but ignore the interests and concerns of the community (Mayfield, 2001).

Both the Triple Helix model and the engaged university literature identify a set of explanatory factors that shape the role of universities in the development of regional innovation systems. As reported by Chatterton & Goddard (2000) and Gunasekara (2006) these factors, which may vary amongst institutions, include historic university-region linkages; university orientation; course' demands that are not exactly consistent with the region needs; the matching of the attributes of graduates and the skills required by local employers; the academic promotion systems and the influence of accreditation bodies; the political and economic policies and conditions and their implementations; start up costs for collaborative projects; and the availability of regional seed funds. This means that countries with higher education systems and cultures respond differently to changes and demands coming from the environment.

2.4. The knowledge-based society and the economic impact of HEIs

The aforementioned theoretical frameworks cannot be neither understood as the result of individual and isolated changes nor conceived as static trends. They are part of a global transformation which is increasingly strict and ambitious. They arose from a knowledge-based society which asks for the production of new knowledge, its transmission through education and training, its dissemination, and its usage through new industrial processes or services (CEC, 2003). Due to their key role in regional innovation systems, universities are therefore called to adapt to all these new needs and take an active part in global competition process (Coenen, 2007; Kitagawa, 2004; Wolfe & Bramwell, 2008).

The literature on the HEIs' engagement with society has significantly grown in the last two decades, in parallel with a restructuring wave that has impacted their management. Therefore, as society demands more from HEIs (Hazelkorn, 2005), universities moved towards a redefinition process that require the introduction of new formulae that attempt to engage more efficiently into society's demands, make a better allocation of resources, and become more attractive for professors, researchers and students (Van Vught, 2009). In order to efficiently cope with all these challenges, universities have adopted flexible structures that allow them to quickly adapt to this changing environment regulated by market demands.⁵

These new demands include a claim for increased higher education, and if predictions are not misleading, this trend will continue in the years ahead motivated by the objective of certain countries of increasing the number of population with a higher education degree (CEC, 2003). This situation may lead to further intensify capacity saturation in universities, moving from elite to mass higher education (Delanty, 2001). Although society has to ensure broad, fair and democratic access, it is important to strengthen the

⁵ For an exhaustive review of the evolution of universities' structure see the paper presented at the *XX Congreso Nacional de ACEDE* (Berbegal, Solé & Llorens, 2010).

excellence of teaching, without compromising the quality offered. But the main problem behind this overcrowding in higher education is limited by the availability of human resources and the financial capacity of universities.

Universities are also intensifying their international partnerships, resulting in a more active involvement in student's exchange programmes, as well as in a more profound academic mobility. The result is a competitive environment amongst universities at regional but also at national and international level. Universities are an element of the regional institutional system and they struggle to attract and keep excellent professors and researchers as well as the most talented students (Shattock, 2003). Students go abroad to pursue their higher education degree, and give more visibility and credibility to their curriculum. Likewise, scholars who wish to remain in the elite of scientific research are required to visit foreign universities and remain there for several months or years. In Europe, the European Higher Education Area (EHEA) was designed following this criterion, aiming at facilitating the mobility of students and faculty by converging very diverse higher education structures in Europe and bringing them in line with international standards. One of the top priorities of EHEA relates to the cross-border readability and comparability of qualifications, in order to promote the most widespread mobility, making workload equivalent across countries (European Commission, 2010).

Based on the proliferation of places where knowledge is produced, there is a natural tendency of the business sector to outsource their research activities to universities. Thus, from a competitiveness perspective the cooperation between universities and industry is highly desirable. The knowledge flow from the academia to businesses and society has to be intensified as it is seen as an effective way to improve the industrial fabric of the region. Despite geographic proximity is a desired condition, location is no longer the main basis for selecting a partner given the access to improved communication technologies and information. Global competition is served.

This way, businesses seek to select the best universities and shorten the time span between discoveries and their application. Hence, universities pursue the promotion of

effective university-industry relationships, eliminating barriers that inhibit the exploitation and commercialisation of research outcomes. Several mechanisms facilitate these interactions. Amongst many others, the two most frequently reported procedures through which knowledge and academic expertise can flow to industry are the licensing of university intellectual property, and the creation of spin-offs and start-up companies (European Commission, 2010).

The expansion of the knowledge-based society also forces universities to be more closely involved in community life (European Commission, 2010).

Thus, and together with their fundamental teaching mission, universities have to take into consideration new educational needs. These include the provision of both horizontal and specific skills according to labour market demands as well as the support to graduates to facilitate their access to the labour market (Washer, 2007). Also, universities should match their training programmes to business needs, or diversify their range of training provision in terms of target groups, content and methods widening the conditions of access to higher education (Boulton & Lucas, 2011; Cepic & Krstovic, 2011; Gunasekara, 2004).

Finally, regarding the sources of income, universities' economic sustainability relies on a diversified financial structure. As a result, it is necessary to introduce changes in the funding regime of universities as states seek to control the education budget and exert a closer oversight over universities' activities (Shattock, 2003). Universities receive financial backing from public and private institutions, and the knowledge they generate has an undeniable impact on the economy. Thus, universities are called to demonstrate that they do a responsible management of their financial resources. This translates in saying that the local administration and other stakeholders demand more transparency in the governance of public institutions, and that universities have to find an adequate balance between their core missions and the management and allocation of financial resources.

The increased pressure over universities at the demographic, economic, technological, social, and political spheres positions universities as active vehicles for economic progress.

Nevertheless, these demands give rise to certain questions that are worth noting: how can universities better contribute to local and regional needs? What mechanisms help establishing a closer link between universities and the business community to ensure knowledge's dissemination and exploitation? What structure improves universities' resources management? To sum up, how universities should perform to meet society's demands?

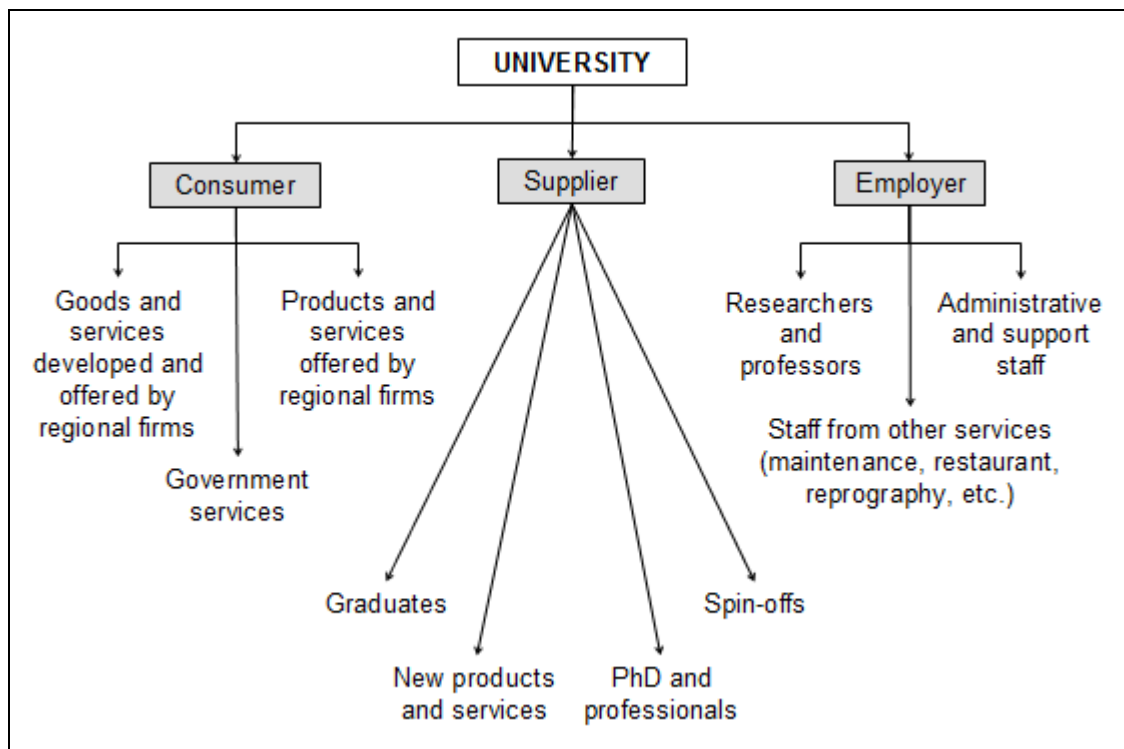
A perspective that could help answer these questions and explain the role that universities may play in regional innovation systems comes from the analysis of the economic role that they have (Shattock, 2003; Vilalta, De la Rubia, Ortis, Martín, Berbegal & Betts, 2010). On the one hand, universities are employers. They create job opportunities not only for researchers and professors but also for administrative and support staff. On the other hand, they are also suppliers, providing a highly skilled workforce and technological know-how in form of human capital, products, services or even new ventures that enter into the marketplace. Finally, they can also be considered as consumers, as they need resources and services to effectively achieve their core activities. The result is a mixture of complementary roles that are performed simultaneously. Figure 2.3 summarises this framework.

From the *consumers'* point of view, universities make use of a set of resources that allow them to carry out their activities. They also purchase a wide variety of products and services which are generally hired from regional suppliers. Acting as regular customers of the regional industry, universities contribute to the economic development by creating demand and increasing regions' economic activity.

Concerning the provision of human resources, universities are facing highly complex institutions that require specialised staff able to undertake a wide range of tasks related to teaching, research, knowledge transfer, management and administrative support (e.g. administrative and service staff, librarians, laboratory personnel) as well as to services addressed to the whole community (e.g. maintenance, infrastructures, ITC networks, reprographics, catering). Given that universities represent the cornerstone of research

activities, education and innovation, they are in many respects considered amongst the largest *employers* in their regions. Thus, governmental and regional development agencies consider universities as a key component for the economic regeneration and growth of territories (Kelly, McLellan & McNicoll, 2006). From this perspective, universities are institutions that employ a large number of people with different profiles. According to the CEC’s (2003) report, universities employ 34% of the total number of researchers in Europe. Moreover, new social demands, technologies and innovation processes that require and imminent response give rise to the creation of new job opportunities.

Figure 2.3. Economic role of universities.⁶



Source: Self-devised.

Finally, as *suppliers*, universities provide human capital (graduates, postgraduates and PhDs) that aim at satisfying market demands for a qualified workforce. Likewise, research

⁶ This conceptual framework for the economic role of universities results from the research carried under the project of EU-DRIVERS. The main conclusions of the study were reported in Vilalta et al. (2010).

disclosures turn out into new products and services that may result in the creation of new ventures. In addition, incubation and advisory services are other types of value-added services that position universities as seedbeds for new technology based firms and business hubs.

From this individual analysis, it is particularly noticeable the economic impact that universities have on regional economies. They generate jobs; contribute to the creation of a more flexible and adaptable workforce; produce research outputs that are marketable, and export earnings. Thus, the strength of the higher education sector and its effectiveness in generating economic activity becomes especially relevant in a context characterised by an economic downturn where businesses in most sectors are contracting (Kelly, McLellan & McNicoll, 2010). A successful engagement of universities in the regional social and economic system cannot be achieved without the consideration of all these functions.

Chapter 3: Modelling universities' objectives

This chapter reviews universities' missions individually (Section 3.1). Section 3.2 follows with the dilemma of how to assess universities performance in relation to its objectives. Concerns about different benchmarking practices are discussed. Finally, Section 3.3 defines the objective function of universities, and presents the conceptual model for the analysis of the three core universities' missions that will be employed in the empirical part to explore 'what' universities do, 'why' they do what they do, and 'how' they do what they do. Finally, we present the hypotheses resulting from the theoretical framework.

3.1. University missions

Universities' movement from a teaching and research format to an entrepreneurial one has been studied in different academic systems such as US, Asia or Latin America. Notwithstanding, the European case has generated a worldwide debate, and this is mainly consequence of the Bologna process and the convergence to a European Higher Education Area (EHEA).

Universities are evolving institutions (Vorley & Nelles, 2008). In its origins, the primary role of the medieval university was the diffusion of knowledge rather than the advancement of science *per se*. Universities as teaching institutions existed until the mid 19th century when an alternative model emerged. The specific teaching mission was linked to knowledge creation processes by conducting teaching and research activities. This paradigmatic shift is to what Etzkowitz et al. (2000) refers to the first academic revolution, that is, the introduction of research activities as a core function alongside with the dissemination of knowledge through teaching tasks.

Social and economic changes occurred, as well as a massive incorporation of students into the higher education system. Thus, universities evolved from a vertical conception to an open matrix one (Solé-Parellada, Coll-Bertran & Navarro-Hernández, 2001). Research

activities expanded and new figures appeared, turning different professional tasks related to research activities. Thus, universities moved towards a type of institution where teaching and researching developed simultaneously; constituting a shift that Etzkowitz et al. (2000) frame in terms of a second academic revolution. This revolution refers to the transformation of universities from ivory towers to more socio-economically engaged institutions that are nowadays still on-going in many educational systems (Etzkowitz & Leydesdorff, 1997). Although tensions coexist between these activities, this configuration has proven to be more productive and cost effective.

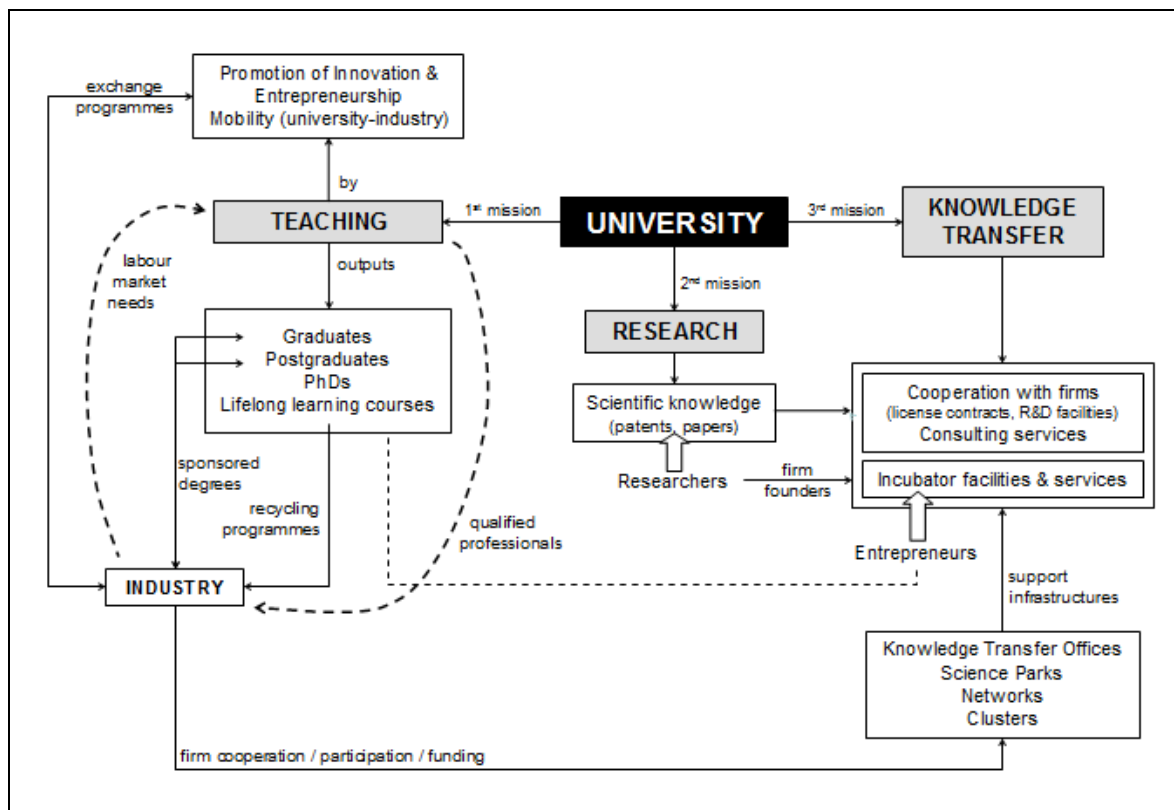
The entrepreneurial university (Clark, 1998) followed the matrix one, where the research function was organised into different units, its valuation was generalised and advanced services were created to support research activities (Solé-Parellada et al., 2001). This approach assumes that the market is a driving force that encourages external collaborations between the academic world and the industry, and this strengthens universities' performance and facilitates the access to additional non-public funding and resources. In this context, universities can be defined as entrepreneurial, being unafraid of maximising their research developments' potential through their commercialisation, as these efforts have no damaging effect over traditional academic values (Clark, 1998).

This is the so-called “third mission” scenario, which results from the combination of the two previous (teaching and research). Here, the basic research outcome is expected to turn out into applied research with some economic and social repercussions that go beyond its production (research) and transmission (teaching and publication).

According to Tuunainen (2005), the universities' third mission encompasses a wide array of activities including the generation, use, application, and exploitation of knowledge and other university capabilities outside academic environments. Therefore, it is evident that the adoption of this new paradigm implies that universities are considered knowledge-based engines in the economy, which materialise different forms of engagement and at different geographical scales (Vorley & Nelles, 2008).

From the above, it is clear that universities are powerful drivers for regional development. However, university’s role cannot be fully understood without an individual analysis of its specific missions. Aiming to explore ‘what’ universities do, ‘why’ they do what they do, and ‘how’ they do what they do, this section presents a theoretical framework that comes from the literature review presented in Chapter 2. As illustrated in Figure 2.4, it is structured upon the universities’ three core missions (teaching, research and knowledge transfer), and it will present and explain to what extend each mission contributes to regional development.

Figure 2.4. Theoretical framework for the university engagement with the regions included in the three missions’ perspective.⁷



Source: Self-devised.

⁷ First published in Vilalta et al. (2010).

Contributions of higher education institutions from the teaching or first mission have been traditionally measured through the outputs produced, namely, graduates, postgraduates and PhDs. Universities recognise that during economic downturns, many people enrol in universities as a way of becoming more competent and qualified to find a job. Although the majority of education courses and curricula in most European countries are still dictated by regulatory frameworks and ministerial orders with little freedom of action for universities, there is an emerging trend (mainly promoted by the EHEA) that takes into consideration labour market needs when designing academic degrees.

On the one hand, this strategy clearly aims at generating a top-level workforce with the right profiles and skills according to labour market demands matching university's training with employer's needs. On the other hand, it helps graduates to find employment more easily. But, to accomplish the teaching mission universities and businesses have to create close collaborations. Some forms of cooperation can be achieved by introducing sponsored degrees, offering facilities or boost international mobility. From a teaching perspective, an entrepreneurial culture is strictly related to the awareness of the market's *status quo*, questioning why things happen. Students must be trained and encouraged to provide new ideas, explore new ways of doing things, and face new roles and challenges.

Universities are also extending their teaching capabilities shaping firms' demands. This embodies lifelong learning courses offered to specific demands of particular firms (recycling programmes), or in university extension courses. These courses are primarily addressed to unemployed population, attempting to facilitate their reintegration into the workforce, or even to current workers that need to improve competences, skills or upgrade their knowledge. Further, new technologies are gaining increased importance in education, defining hybrid ways. Examples of teaching modalities that benefited from technological advances are blended courses, part-time modules (that can be undertaken when working) or distance learning programmes looking to offer bespoke training that fits companies and learners' needs.

There is a large amount of empirical evidence on the contribution of university teaching to economic development (Aghion, Dewatripont, Hoxby, Mas-Colell & Sapir, 2007; Jacobs & van der Ploeg, 2006). These studies corroborate the existence of a positive economy-wide educational spillover effect, with substantial social returns that justify the public and economic support that higher education institutions receive.

Based on the notion that economies richer in human capital have a higher rate of innovation, an increase in the level of human capital is shown to have a positive effect on the growth rate of productivity (Sianesi & van Reenen, 2003). In addition, these social returns manifest in the form of a higher probability of finding better-paid jobs and in increasing lifetime earnings. Educational externalities are also found to yield additional indirect benefits to growth by stimulating physical capital investments and technological development and adoption (van der Ploeg & Veugelers, 2008). Finally, as universities provide a continuous flow of trained personnel to the industry, the general level of familiarity with science and technology throughout society rises.

As knowledge-creators, universities are responsible for 80% of the fundamental research pursued in Europe (CEC, 2003). The research or second mission is by its nature competitive, and many international league tables are using research outputs as their main influential indicators (Shattock, 2009a). Universities are likely to desire a good positioning in these rankings, as it could signal universities' capacity to create cutting-edge research. But, why research? Research is crucial to universities existence. Research stimulates the creation of a learning environment, it helps attracting and retaining qualified faculty and students, and it maintains a cutting-edge curriculum of the institution (Hazelkorn, 2005).

But, for research to be meaningful within universities, it must respond to regional needs, providing economically useful knowledge and skills with industrial relevance, and being able to align academic activities with economic development.

Activities emerging from this mission may include both traditional academic investigation and university-industry collaborative partnerships. Outputs can be seen in terms of the

scientific results obtained by research groups, departments, research centres or institutes, and these outcomes are linked to publications in scientific journals or conference proceedings or any other kind of intangible. However, if knowledge is not efficiently disseminated its returns would be poor or nonexistent. Thus, both universities and firms must identify common interests in pursuit of the establishment of alliances and cooperation that can take benefit from the scientific knowledge stock (Cockburn & Henderson, 2000; Hall, Link & Scott, 2000; Veugelers & Cassiman, 2005). These collaborative research schemes together with licensing arrangements of patented university inventions are the most commonly found channels from which research results transfer to industry (van der Ploeg & Veugelers, 2008).

As for the economic impact of research activities on regional and economic growth, many studies provide a coherent body of theoretical and empirical evidence addressing this topic (Adams, 1990; Henderson, Jaffe & Trajtenberg, 1998; Mansfield, 1995). University-industry collaborative research, for instance, has received substantial attention in recent years, and the intensification of these interactions has grown over time (Barnes, Pashby & Gibbons, 2002; Hall et al., 2000; Lee, 2000; Mora, Detmer & Vieira, 2010; Motohashi, 2005; Perkmann & Walsh, 2007; Ramos-Vielba, Fernández-Esquinas & Espinosa-de-los-Monteros, 2010).

In particular, the links between research results and industries are clearly explicit in some classical science-based sectors such as the case of high-tech, chemistry, pharmaceuticals or biotechnology industries, which heavily rely on research discoveries (Levin, Klevorich, Nelson, Winter, Gilbert & Griliches, 1987).

Universities are important sources of knowledge and scientific discoveries, thus both academics and policy makers are interested in how these institutions can develop their third stream function (Etzkowitz, 2003) to become more adept at exploiting their knowledge-base and transfer it to the private sector (Lockett & Wright, 2005), going beyond the confines of the academic community. Beginning at the US with the Bayh-Dole Act of 1980 but then expanding to the rest of the countries, a growing interest in

knowledge transfer activities, the commercialisation of university research and academic entrepreneurship have emerged. The convergence of three main axes (entrepreneurship, innovation and social commitment) has facilitated the development of the third mission amongst universities, and this helped respond to the social pressure over universities. Third mission represents a concept that was first used in the UK to describe a funding stream to universities that aimed to support the technology/knowledge transfer process. Today, the use of this term has broadened denoting activities primarily designed to support regional engagement and regional economic growth more generally (Shattock, 2009b).

Despite many empirical studies have focused their attention in quantifying different forms of knowledge transfers from academic research (e.g. Anderson, Daim & Lavoie, 2007; Carlsson & Fridh, 2002; Lockett & Wright, 2005; O’Shea, Allen, Chevalier & Roche, 2005; Wright, Clarysse, Lockett & Knockaert, 2008), two main ways are primarily envisioned when talking about third mission activities: placing products and services in the marketplace directly (through the creation of spin-offs) or indirectly (by interacting with firms).

In the case of spin-offs, they represent the entrepreneurial route to commercialise public research (Rasmussen, 2008). As the creation of university spin-offs entails an entrepreneurial orientation, spin-offs can be defined in terms of the identification and exploitation of an opportunity carried out by individuals with a particular commitment in starting up a business in the university context. Thus, universities give birth to the dual academic career. Beyond the traditional seeking scientist, there is the “entrepreneurial scientist” who is able to interface knowledge and innovation (Viale & Etzkowitz, 2005). Scientific knowledge can be turned into the starting point of a business idea, and by extension, the birth of new a company. Universities are natural firm-founders, and through incubator facilities, the development of support structures spin-offs formation increases, enhancing the local gateways to the market. Nevertheless, it is important to highlight that the commercialisation process of spin-offs is initiated inside the university

setting, and these firms may be affected by the university operations, which can occasionally turned into stimulating processes but also into inhibiting ones (Rasmussen, 2008).

In the second case, possible ways of engagement with firms are, amongst others, cooperation agreements (licenses, R&D agreements, projects, etc.), consulting services, incubator facilities or assessment for start-ups. At first glance, universities’ motivations to engage in this type of activity mainly relates to the opportunity to access to new sources of funding for the development of new activities in which they currently do not investigate, mainly due to the lack of resources. But, working side by side with the industry can improve the state of the art and get new ideas which can be the basis for new fundamental research. Also, in periods of economic downturn, we found that businesses of all sizes, but small and medium enterprises (SMEs) in particular, may have problems to carry out R&D activities, as it usually requires complex infrastructures and advanced services for product development.

Focusing on SMEs it is easier to understand what drives firms to establish links with universities. Not only universities are offering a broad spectrum of expertise, they are also helping firms in the identification of technology opportunities, giving assessment and guidance in pre-competitive stages of product development, and providing access to a non-ending source of human capital, training and knowledge. Another common practice for SMEs is to use universities’ research infrastructures as a way to save money and take advantage of their expertise and setting. To this extend, SMEs use universities’ laboratories as R&D labs. Nevertheless, although this may be seen as a beneficial practice, the controversy relies on the fact that SMEs are indirectly transferring part of their costs to the state, which provides a large part of university funding (Slaughter & Leslie, 1997). Other forms of university-firm partnerships may include consultancy services or innovation networks. What is interesting from all these ways of engagement is that both universities and industry are brought together, emphasising their physically closeness and narrowing their distant mentality.

The benefits derived from third stream activities have been widely documented in the literature, including the improvement of regional economies through the implementation of mechanisms that facilitate the knowledge flow from the academia to the industry's front-line (Markman, Gianiodis, Phan & Balkin, 2004; Mowery & Shane 2002; Wright, Birley & Mosey, 2004), and the introduction of new formulae that help reducing the time needed to transform research outcomes into commercial products and services. It could be said that the commercialisation of university-based knowledge offers technological innovation, which is likely to improve the prosperity and competitiveness of the region (Chang, Yang & Chen, 2009; Chang & Yang, 2008; Lockett & Wright, 2005; O'Shea et al., 2005; Wright et al., 2008).

To cope with the challenges of adopting this third role, universities have developed new strategies and policies as well as new infrastructures to foster university-industry partnerships. Whereas the former may include the establishment of regulatory frameworks for the devolution of intellectual property rights, patents or licenses, the later considers the creation of knowledge transfer offices (KTO) or business incubator centres. Complementary factors such as how organisational structures are managed (Siegel, Waldman & Link, 2003; Thursby & Kemp, 2002), the promotion of initiatives to enhance commercialisation of university knowledge (McAdam, Keogh, Galbraith & Laurie, 2005; Rasmussen, Moen & Gulbrandsen, 2006), the creation of business skills and managerial capabilities through technology transfer offices (Chapple, Lockett, Siegel & Wright, 2005), and a favourable environment for creativity and innovation can help achieve third stream activities.

Although all universities are expected to undertake third mission activities, regardless its size, academic spread or research interests, the location and economic factors of the region would shape the character of the university and the kind of third stream activities it engages in (Shattock, 2009b). Nevertheless, for this role takes place effectively, the academic community must have the time, the freedom, and the motivation to produce the knowledge that can be transferred (Shattock, 2009b).

Finally, universities also contribute to some other objectives related to social community engagement, employment or the improvement of the general level of education. Examples of activities addressing these values are the organisation of conferences, meetings, exhibitions, open-doors journeys, value-added services or the development of international cooperation projects. These social actions reflect university's values and social orientation.

Despite these activities are part of universities' third mission, they are excluded from the third stream analysis, as they refer to other social engagement activities rather than the commercialization of academic knowledge. In modern societies, social commitment and cohesion activities must ensure access and social inclusion. Therefore, results are two folded. First, the social function of universities gets reinforced as they offer public services that contribute to the welfare of the society and its culture. Second, the existing gap between university research and the real needs of society narrows.

The implementation of all these missions leads to the concept of contemporary universities, that is, an amalgam of teaching, research, entrepreneurial and scholastic interests that not only provide qualified graduates and researchers, but also a university that offers innovative solutions to the industry, meeting regional needs.

3.2. The need for HEIs' accountability

Higher education institutions represent an inexorable source of knowledge and technology capacities, becoming the ideal partner for multiple stakeholders, including both enterprises and public agencies. But as any organization that part of its budget comes from public funding, transparency and accountability is needed. Perhaps the reason why the management of HEIs has become such a meaningful topic amongst academics and policy makers is due to the never-ending expansion of the media and the rise of the evaluative state. One of the consequences of the enhanced institutional autonomy universities have in their own management has translated into a greater

accountability as well as into a more stringent and detailed procedures to assess their quality. Subsequently, universities are immersed in a process, looking for new ways in which to inform their stakeholders about their performances (Mora & Vieira, 2009).

Reports measuring universities' performance and their rankings are available in abundance, adopting a public accountancy role. Yet, funding agencies want to be assured that funding is being spent in areas that are consistent with national efficiency and equity priorities, therefore, quality outcomes are important (Garlick & Langworthy, 2008). In this sense, league tables (using the British nomenclature) or rankings (in an American terminology), parametric and non-parametric approaches, composite indexes or other econometric procedures satisfy this public demand for transparency and information that institutions and governments have not been able to meet on their own up to date.⁸ These methodologies measure universities' activities by using a wide range of indicators in pursuit of an order in which universities can be ranked according to their performance. It has just been since the turn of the century that their impact on the media and subsequent public discussions has been exceptional (Bonaccorsi & Daraio, 2005), becoming a central issue for government thinking, marketing campaigns and universities' development.

However, in the literature we find that it is difficult to converge into a single way of assessing performance and it is even more difficult to find one that is universally agreed upon. While problems might lie in the interpretations of terms such as *quality* or *efficiency*,⁹

⁸ Two recent studies (Bebegal & Llorens, 2011a; 2011b) have been presented at the *VIII Foro de Evaluación de la Calidad de la Investigación y de la Educación Superior* (FECIES) held in Santander, 31st May - 3rd June 2011, addressing different practices of benchmarking. A first one, offering a comprehensive overview of different methodologies used to assess universities' performance (“Diferencias metodológicas en la evaluación de la eficiencia de las instituciones de educación superior”); and a second one, focussing on how to measure technical efficiency (“La eficiencia técnica de las universidades: Una revisión de los indicadores más comúnmente utilizados en la literatura”).

⁹ From an in-depth analysis of the literature, García-Aracil & Palomares-Montero (2010) provide a definition of quality, equity, effectiveness, efficiency and efficacy of the higher education system. In terms of evaluation, “quality” refers to the resources available at universities; “equity” stands for the egalitarian distribution of resources within the university system; “effectiveness” reflects the degree of achievement of university forecast results in relation to actual results; “efficiency” refers to the best use of resources; while “efficacy” designate the price of the results obtained.

highly influenced by the social, cultural, political and economic contexts of each region, the inherent controversy of these methodologies give rise to some points of disagreement, being sometimes criticised for not conducive to a fair and equal analysis. Main criticisms come from the selection of inputs and outputs, the reliability of the data, the inability to distinguish environmental factors, the unequal applicability to all branches of knowledge or the lack of actuality of the indicators used (indicators are measuring past activities or the results of past strategic planning instead of reflecting the current situation).

Nevertheless, the fact is that these assessment tools are undoubtedly influencing the strategy of HEIs, the rationalisation of institutions and the professionalization of services, transforming the way they liaise and collaborate with each other (Hazelkorn, 2009). Therefore, consensus has emerged on the need to investigate them (Marginson & van der Wende, 2007). Thus, both academics and policy makers around the world have shown, in one way or another, their interest in such procedures, developing complementary ways to assess the performance of their HEIs that have turned into potential benchmarking tools.

While most past studies have focused on suggesting new ways to assess the performance of HEIs, little has been done in trying to understand and categorise the nature of the variables employed (Palomares-Montoro & García-Aracil, 2011). In a recent work we have tackled this problem.¹⁰ In this study, we analyse the consistency of the indicators used in the literature to represent universities' resources (inputs) and outputs. To this end, we carried out an exhaustive literature review from 2000 to 2010 measuring HEIs' performance. Our classification emphasises the nature of indicators, resulting in six categories: funding and expenditure, resources, teaching, research, third mission and overall perception.

¹⁰ Berbegal-Mirabent, J. & Solé, F. “What are we measuring when evaluating universities' efficiency?”. Submitted to the *Regional and Sectoral Economic Studies* (March 2011).

These evaluative methodologies are conceived to stimulate and improve the internal assessment of universities for the benefit of both the university and the region (Charles & Benneworth, 2002), nevertheless, some questions arise about their appropriateness and legitimacy. Are these procedures really helping universities to set strategic goals and improve their quality and performance? Or are they just encouraging universities to refocus their activities and resource allocation in order to gain a better rank and become what is measured? Are we converging to more homogenous measurement approaches? What is the real impact of these measures?

Models tested in the literature usually address the overall performance of HEIs. As universities are responsible for developing a wide range of activities getting multiple outputs from a set of inputs, by carrying general models, multitask challenges are considered where activities are sometimes substitutive but others complementary. However, an individual approach focusing on each mission independently is also needed. Additionally, critical issues in the ways of comparing institutions emerge: Is it fair to compare entire universities? Does really one size fit all? Only after analysing disciplines, fields or missions attaining specific dimensions, can a global balance of HEIs make complete sense.

Another problem arising from indicator systems relates to the opportunity cost of obtaining the necessary data to appropriately represent it, and in many cases this is unfeasible. Thus, data usually come from governmental statistical agencies that far from being collected on an annual, standardised and systematic basis tend to be underscored by political forces (Salerno, 2004). To this extent, studies evaluating the performance of HEIs heavily depend on data availability and reliability, as the vast majority of the desired data do not exist, or they are not publicly available. Additionally, available data tends to be aggregated (not individualised by institutions or areas of knowledge), country-specific (making cross-country comparisons difficult) and hardly registering third mission activities.

Concerning these assessment procedures and their impact over potential consumers, we find that consumers range from students and their families, universities, different stakeholders (sponsors, governmental agencies, industry, and partners) to the general audience.

Regarding students, assessment tools are used to facilitate their choice about what university to enrol in, even though some research (Hazelkorn, 2009) confirms that such decision may also be influenced by partnership and family ties. On the university side, rankings and efficiency studies somehow stress institutions to improve their performance according to the criteria used to create this comparative performance index. This pressure can be internal, based on the desires for prestige and high quality teaching and research, but it can also come from outside as a performance requirement imposed by governmental agencies to lift the university’s overall position. Therefore, these mechanisms help HEIs in identifying their strengths and weaknesses, and they also can be used by HEIs to set up specific goals aiming at improving their position in these rankings instead of matching the university’s strategy. Finally, governments’ attitude against these assessment methodologies is perhaps the most unexplored of the three. For instance, governments tend to expropriate the merits achieved by universities if they are well ranked or deemed as efficient, but they generally receive partial support. The current debate at this level is now focused in whether it is better to have a one-class or a world-class university.¹¹

¹¹ According to Hazelkorn (2009), having “few world-class universities” (also called as the neo-liberal model) consists in create greater vertical (reputational) and horizontal (functional) differentiation. That is, few centres of excellence. Examples of countries adopting this perspective are China, France, Germany, Japan and Korea. On the other hand, a “world-class system” (the social-democratic model) means to create diverse set of high performing globally focused universities (mission or functional), promoting excellence wherever it exists. Some examples of countries following this second approach are Australia, Norway or Spain.

3.3. Defining the universities’ objective function

Based on the literature review we note that in recent decades, universities have faced many changes in both their internal and external environment, and they continuously responded to the new challenges society is demanding. Universities tend to operate in a highly competitive sphere where there is strong competition for the best students, for attracting outstanding research staff and to capture research funds. Universities are required to give immediate responses to industry needs. Likewise, they have to provide the marketplace with new knowledge, experience and technology solutions, and connect more efficiently with society through third mission activities that are associated with the economic regeneration of the region (Schattock, 2009a).

This situation has forced universities to remain at the cutting-edge of research, requiring highly skilled human capital and the appropriate mechanisms and infrastructures to accelerate the valorisation process of knowledge. Therefore, universities have to acquire new responsibilities, often influenced by governments and funding agencies (Taylor & Miroiu, 2002) that have led to significant organisational changes within these institutions. These changes manifest themselves depending on the strategic vision of each university, drawing different ways to address HEIs’ multiple objective function. In parallel, previous evidence shows that this process has taken place at different rates and intensities (Shattock, 2009a). As a result, universities assume different roles that can be more oriented towards teaching, research or third stream activities.

Having explored in Chapters 2 and 3 “what” universities do and “why” they do what they do it is necessary to question “how” universities allocate their resources internally between their various activities in order to tackle their different missions. In particular, and given the resource constraints faced by universities and their vulnerability with respect to environmental changes and uncertainty, a better understanding of the factors that explain their performance stands as a key issue for academics and policy makers. Hence, there is an increasing interest in identifying the main characteristics that differentiate universities that perform well from those that do not. On the one hand, it is

important to know more about the way that universities use their scarce resources, and on the other hand, increasing our knowledge about those factors that make universities more efficient in the achievement of their goals is a relevant issue to the appropriate design and application of more selective support policies. Thus, in order to explore the ways universities balance teaching and the demands for basic research and knowledge transfer, we thus have to identify these components, which in general terms respond to technology, capital and other productive factors.

During the last decades, an extensive body of literature has been developed in order to explain universities' performance. Universities have valuable tangible and intangible resources such as faculty, administrative staff, libraries, meeting rooms, laboratories and other facilities as well as knowledge, technology and research expertise which all contribute to the development of universities' operations. Empirical evidence focuses on organisational capabilities, internal resources or services that support universities' activities. Different research streams in this particular field have been identified. Following Del-Palacio, Solé & Berbegal (2011), we consider universities' internal services as inputs, measured as organisational assets, financial resources, and human capital where experience and knowledge accumulation are considered relevant determinants.

The theoretical framework based on the Human Capital Theory (Becker, 1975) seems to be appropriate for the study of the impact that individuals' knowledge and internal capabilities have on university performance. Human capital comprises amongst others individual's attributes as formal education and previous experience. This type of capital is considered unique since knowledge cannot be taken away from the individual as tangible assets and financial capital can. Becker (1975) remarks that the presence of high levels of human capital influence the quality of business behaviour. This is especially relevant in the case of universities as this type of business heavily rely on individual's capacities to achieve their teaching and basic research objectives. Consequently, human capital (knowledge, abilities and capabilities) provided by individuals constitutes a key determinant to ensure corporate success.

For the purposes of this thesis, the first dimension of human capital considered refers to the staff engaged in research and teaching activities (faculty), and the personnel involved in specific support tasks such as administrative or service oriented activities (non-academic staff) (Kusku, 2003). It is worth noting that individuals working at the university constitute unique resources embedded in their human capital, so therefore these resources (academics, researchers, students, and administrative staff) are critical for the university's strategic design (Feng, Chen, Wang & Chiang, 2011). As it was previously indicated, the adoption of this approach implies that human capital represents knowledge and intellectual capital that universities use to attain some of their objectives.

The second dimension of human capital considered in this thesis relates to knowledge accumulation or the knowledge stock available at the university. This knowledge represents the ultimate consequence arising from any activity carried out at the university, which may be used or turned into another tangible output with a different use and nature (Anderson et al., 2007).

In the specific case of universities, this accumulated knowledge can be expressed in terms of didactic material, dissertations, papers published in scientific journals, patents granted, license contracts, spin-offs, amongst others. In this study, we assume that knowledge accumulation represents the basis for further developments within the university. That is, the effective implementation of this knowledge creates other outputs. Also, the presence of a considerable knowledge stock can help HEIs in obtaining new outputs and reducing time spans necessary to develop new activities strictly related to their objectives.

The third human capital component analysed relates to knowledge accumulation processes, and it represents the experience or background that a HEI has in a specific field. Previous experience gives to people working at the university the specific knowledge and capabilities which can help them develop more successful strategies leading to both a more efficient resource allocation and higher output rates. Through this construct we aim at capturing the dynamic knowledge spillovers derived from past experience in teaching activities, paper publishing, and academic spin-off creation, as prior experience is

suggested to help in creating a more fertile setting for the development of new activities. One way to account for this experience background is measuring how actively the university has been involved in producing the desired outputs during the last years. Those universities with seniority are expected to have developed appropriate policies, managerial capabilities, infrastructures and services to facilitate the production of the desired outputs in the present. Thus, expertise can be considered as a catalyst for the achievement of HEIs’ outputs. Given all these considerations, it becomes clear that human capital is critical for universities when it comes to achieve their objectives. Therefore, we hypothesise that:

Hypothesis 1: *There is a positive relation between human capital components and the achievement of university’s objectives.*

Another important aspect that has to be taken into account relates to those spaces and infrastructures that support universities’ activities. These include specific areas such as buildings, fixed capital equipment and the area specifically used for teaching, research or promotion of knowledge transfer results (Nan-bin & Jing 2009; OMB, 2008; Qingyun, Ya & Keqiang 2010). For instance, teaching and research infrastructures may include the total lecture-rooms, laboratories and libraries (Powell, 1992). Knowledge transfer space is represented by existing incubators that enhance the allocation of entrepreneurs with a formal or an in-progress idea that is expected to evolve and become a real business (Cooper, 1985; Grimaldi & Grandi, 2005). This way, our second hypothesis emerges:

Hypothesis 2: *The presence of specific infrastructures and knowledge transfer centres offering advanced services positively contribute to achieve universities’ objectives.*

Regarding the availability of financial resources, many studies have emphasised that there is a positive relation between access to finance and knowledge transfer activities (De Coster & Butler, 2005; Landry, Amara & Ouimet, 2007). Financial resources include

possible sources of fundraising for the day-to-day operations of HEIs, such as the amount of external research funding coming from governmental agencies, different sponsors, research grants (McMillan & Chan 2006; Abramo, d’Angelo & Pugini, 2008), and revenues from tuition and fees (Kongar, Pallis & Sobh, 2010). Yet, income from R&D activities may be considered a better proxy for university’s financial resources as it represents the income coming from the exploitation of research results, which is closely related to the quality of the research activities performed by a HEI (Cohn, Sherrie, Rhine & Santos, 1989). In this thesis, we stress on the impact that universities’ income from R&D activities is having over their activities. This R&D income may be seen as that derived from specific fundraising activities (such as public grants), private contracts (universities-firms contracts, licensing agreements), or that coming from the commercialisation of specific research results (patents). Given that financial resources are critical for developing R&D activities, we hypothesise that:

Hypothesis 3: *There is a positive relationship between universities’ income from R&D activities and the achievement of third stream objectives.*

We also consider the academic spread of the university. This variable captures the degrees offered and the nature of the research engaged. Spanish universities offer different degrees which can be catalogued in five groups: humanities studies (average proportion of degrees offered by the Spanish universities considered in the final sample: 14.06%), social sciences (39.13%), experimental sciences (9.62%), medical sciences (6%), and engineering studies (31.18%). It has been widely recognised that universities with medical studies or those universities more oriented towards engineering studies and chemistry are more likely to be engaged in knowledge transfer activities than those in social science or humanities (Carlsson & Fridh, 2002). In terms of publications, a similar behaviour is observed as in some knowledge fields it is easier for academics to develop their research activities and publish in scientific journals (engineering and medical sciences) than in other fields (arts and humanities). Based on this rationale we hypothesise that:

Hypothesis 4 (a): *There is a positive relation between academic diversity of HEIs and their teaching outputs.*

Hypothesis 4 (b): *There is a positive relation between academic specialisation and HEIs research and knowledge transfer performance.*

Finally, we include in the analysis two variables linked to the university’s profile. First, we consider university age as a variable capturing the institutional experience. According to Gueno (1998) and Merton (1998) old universities can have both a halo and a Mathew effect based on historic interactions of expertise and prestige. This translates in saying that old universities may have established a working environment and a certain way of doing things that can have a positive influence over their capacity to catch up and host highly talented faculty and the most significant research; creating an outstanding intellectual community and producing top trained students. Second, we consider university size. This variable is measured as thousands of square meters and it proxies the scale possibilities of the university (Johnes & Yu, 2008; Kao & Hung, 2008).

As one of the main objectives of this thesis is to corroborate whether the aforementioned factors impact university’s performance, the model specification used to test our hypotheses is expressed as follows:

$$\begin{aligned}
 f_{\text{HEI}}(T,R,KT)_i &= \alpha_0 + \beta_1 \text{Human Capital}_i + \beta_2 \text{Infrastructure}_i \\
 &+ \beta_3 \text{Financial Resources}_i + \beta_4 \text{Academic Spread}_i \quad [1] \\
 &+ \beta_5 \text{University Size}_i + \beta_6 \text{University Age}_i + \varepsilon_i
 \end{aligned}$$

Equation [1] implies that the objective function of the *ith* university comprises teaching activities (*T*), research (*R*), and a third stream objective linked to the knowledge transfer activities (*KT*). Also, it should be noted that in equation [1] human capital includes the variables linked to faculty, knowledge accumulation and the record of previous activities related to research and knowledge transfer tasks. As previous experience refers to

research results obtained in the past, the variables used to characterise this factor will be introduced as lagged terms.

Taking into account data availability it should be noted that some aspects of universities performance are unquantifiable and consequently not included in the modelling of universities’ objective function. As for university’s missions, Table 2.2 depicts the general vector of factors that we consider relevant to explain these objectives, and how these explanatory factors are measured. The Table considers factors that exert an impact over the three university objectives as well as specific components linked to each mission.

Table 2.2. Variable definition proposed to assess university performance.

Factor		University objectives		
		Teaching	Research	Third stream
		Graduates / Students	Papers	Spin-offs
Human capital	Faculty	Students / Total faculty	PhD Faculty / Total faculty	Proportion of faculty working on knowledge transfer activities relative to total faculty
	Knowledge accumulation	-	Number of thesis dissertations	Number of patents granted
	Experience	-	Papers published in the last 3 years / Total faculty	Number of spin-offs created in the last 2 years
Specific infrastructures		Area dedicated to teaching relative to total size	Area dedicated to research relative to total size	Incubator
Financial resources		-	-	Total R&D income
University’s profile		Educational diversity		
		University size (square meters)		
		University age		

In terms of the main output related to each mission, we observe in Table 2.2 that the teaching mission is proxied through the net flow of students, expressed as the number of graduates per students enrolled. We believe that this approach is appropriate as the main objective of this first mission is to graduate students. In addition, while accounting for this flow of customers we also avoid scale size effects.

Concerning research activities, we find that traditional academic research includes publications in peer-reviewed journals, books and book chapters, conference proceedings and research projects. Given the particularities of the Spanish higher education system, we selected publications counts. On the one hand, it reflects both the quantity and quality of the research carried, as we only include those papers published in top journals indexed in the Scopus database. On the other hand, publication counts is the factor with the highest weight in the researchers’ evaluation processes for internal promotion purposes.

Finally, the third stream objective is measured by the number of spin-offs created. We are aware that the development of the third mission includes more activities than the creation of spin-offs, however, the entrepreneurial culture (which is a desired attribute for the modern university), is clearly reflected in the emergence of new ventures with an academic basis. Moreover, Spanish universities have an exploitation of the entrepreneurial culture that is far from its true potential. Therefore, the number of spin-offs would help us identify those universities that are really committed with transferring academic discoveries to the market from those that still lack resources and an entrepreneurial culture.

As for the variables related to human capital, specific infrastructure, financial resources, and university’s profile factors, their definition emerges from the theoretical framework used to develop the hypotheses proposed. Detailed information about the different model specifications shown in Table 2.2, as well as a description of the variables included in the different analysis stages are presented in Chapter 5.

PART III: PERFORMANCE ASSESSMENT OF SPANISH PUBLIC UNIVERSITIES

The previous chapters presented a conceptual framework where we identified the different roles played by universities and how they meet the social demands. In order to answer the research questions and test the hypotheses proposed in Part II, this part describes and analyses the empirical research followed, discussing the findings obtained. To this end this part is structured in 5 chapters. First in Chapter 4 we introduce the methodological approach and the description of the sources of data. Then, Chapter 5 test the influence of the different factors identified for each academic mission. Aiming to have an overall perspective, Chapter 6 follows with an efficiency analysis of the public higher education system. Finally, Chapter 7 proposes an innovative approach, based on a cluster analysis, for the study of the different pathways Spanish public universities are following in relation to the strategy adopted to address the objective function of universities. This part ends with Chapter 8, where the main findings and implications are discussed.

Chapter 4: Methodological approach

This chapter briefly describes the methodological strategy adopted in this thesis (three-stage empirical analysis), the sources of information, and the software used.

4.1. Structure of the empirical study

From the theoretical deductions presented in the previous part of this thesis it is clear that a more in-depth analysis of universities' management is necessary to correctly understand their functioning. Following the research objectives of this thesis, we present a quantitative analysis that aims at providing empirical evidence that helps test the hypotheses proposed and give answers to the research questions stated in the introduction part.

As it has been discussed throughout this thesis, one of the major limitations of the management-based analysis of higher education institutions relates to the lack of studies that transform theoretical developments into quantitative work that validates them, avoiding the temptation to become merely figures where universities, despite their heterogeneity, are sorted according to a homogeneous criterion.

We are aware that universities face multi-dimensional objectives. Hence, this empirical study is divided in three stages which explore, individually and from a joint perspective, different aspects that are hypothesised to explain universities’ performance. The attractiveness of this study heavily relies on the analysis of Spanish public universities’ performance from a much broader view, aiming to determine the strategies chosen to achieve their social and economic objectives, as well as to identify the repercussions that certain regional policies are having on their performance.

Chapter 5 analyses the impact that universities’ internal resources have on the achievement of their core objectives: teaching, research and third stream activities. To this end, and after a careful selection of the variables, we run three regression models, one for each mission, and test the hypotheses proposed in Chapter 3. Based on these results, in Chapter 6 we assess the overall efficiency of Spanish universities by carrying out a multidimensional analysis using the Data Envelopment Analysis (DEA) methodology.

Finally, and based on the findings obtained in the two previous chapters, in Chapter 7 we carry out a non-hierarchical cluster analysis. This not only allows us to look at the similarities and differences amongst Spanish public universities, but also helps get a better grasp on these institutions’ behaviour. This is expected to shed some light about the strategic approaches adopted by universities in terms of their different missions.

Chapter 8 summarises the main findings linking the empirical results with the theoretical framework presented in Part II.

4.2. Sources of information and software tools

This dissertation has required from two different methodologies, as described below: an in-depth literature review, which analysed and consisted in the identification and assimilation of the literature of reference; and the conduction of various quantitative analysis employing different statistical techniques in order to verify the hypotheses and give an answer to the proposed research questions. Similarly, through this period of research, several meetings were held with experts from different universities and institutions in order to externally validate the consistency of the preliminary results. As it has been mentioned in the introductory section, some of the results have also been presented in conferences and published in scientific journals, ensuring the consistency and quality of the research through their acceptance and public diffusion.

4.2.1. Literature review

For the characterisation of the models that have been tested, it is necessary to develop a comprehensive literature review on the role of universities in the knowledge-based society. Also, it is relevant to identify the procedures and methodologies used to assess universities' performance and to examine what environmental features may influence their operations. To this end and based on their quality, reputation and ease of use, the most relevant bibliographic sources in this area have been consulted (Web of Knowledge, Scopus). In addition, we collected information from specific sources comprising detailed data about the units of analysis (Spanish universities). All this information has been processed and managed using bibliometric tools, particularly RefWorks and Sitkis.

4.2.2. Quantitative analysis

The information to carry out the empirical analysis comes from two main sources. First, we used the data published in the biannual report elaborated by the Council of Rectors of Spanish Universities (Conferencia de Rectores de Universidades Españolas, CRUE). Since

1998, six issues of this report have been published. The most recent issues include data of public and private universities, informing about their nature and educational and research inputs and outputs. The information on the report is provided directly by Spanish public and private universities themselves. Internal resources, organisational data as well as information regarding the composition of the pool of academic degrees offered by Spanish universities were obtained (CRUE, 2010; 2008; 2006). Second, we used the annual reports available from the Spanish Network of Knowledge Transfer Offices (Red de Oficinas de Transferencia de Resultados de Investigación, RedOTRI) to obtain information related to knowledge transfer activities, such as the presence of business incubators, the portfolio of patents or the number of spin-offs created in the Spanish academic setting (RedOTRI, 2009; 2008; 2007; 2006).

To our knowledge, these two aforementioned reports are the most comprehensive ones for national source of data on the higher education system and knowledge transfer activity; however data presented some missing observations. Aiming at completing these data, the use of additional sources was necessary. To this end, manual searches for annual reports of each HEI as well as direct contact with some of them were also required. Although the majority of the data were successfully completed, some missing values remained unaffordable.

Additional information regarding specific variables was obtained through the Scopus database and from the Spanish National Institute of Statistics (Instituto Nacional de Estadística, INE) website.¹²

The original database comprises information for 47 Spanish public universities and data were collected for the academic years 2004/2005, 2006/2007 and 2008/2009.

¹² www.ine.es

The statistical treatment of data has been performed using STATA statistical package (version 10). Likewise, to calculate the efficiency scores, the OnFront software in its version 2.0 was used.

Chapter 5: Individual analysis of HEIs’ missions

The objective of this first empirical section is to analyse the impact that universities’ internal resources have on the achievement of universities’ main objectives: teaching, research and third stream activities. There is a wide array of outputs that can be used to measure universities’ performance. Nevertheless, and given the scope of this empirical analysis, we assess each university objective individually. Consistent with the literature, the selected output variables refer to critical objectives that universities try to achieve: the number of graduates in relation to the number of enrolments (as a proxy for teaching activities), papers published in scientific journals indexed at Scopus database (for basic research), and the number of spin-offs created (to proxy the most commonly used third stream HEIs’ output).

To do this so, in this chapter we first review the hypotheses that emerged at the end of Part II and briefly review the theoretical framework proposed, highlighting a number of factors (human capital, specific infrastructures, financial resources and university’s profile) that are expected to help explain universities’ performance. In order to test our hypotheses, we carry out different regression models to verify the explanatory power of the previously identified factors. For each regression the results obtained and the validation of the hypotheses is discussed.

5.1. Hypotheses development

Throughout this thesis it has been noted that there is a growing interest in identifying the factors and mechanisms that help explain differences in universities’ performance. Thus, in this chapter we explore the extent to which factors commonly identified in the literature (Part II, Chapter III) influence the achievement of teaching, research and third stream objectives. Before starting the analyses we summarise the hypotheses proposed which emerge from the literature review. As explained in Section 3.3 (Chapter 3), we proxy these factors through human capital components, organisational assets, financial resources and university’ features. The hypotheses formulated follow:

Hypothesis 1: *There is a positive relation between human capital components and the achievement of university's objectives.*

Hypothesis 2: *The presence of specific infrastructures and knowledge transfer centres offering advanced services positively contribute to achieve universities' objectives.*

Hypothesis 3: *There is a positive relationship between universities' income from R&D activities and the achievement of third stream objectives.*

Hypothesis 4 (a): *There is a positive relation between academic diversity of HEIs and their teaching outputs.*

Hypothesis 4 (b): *There is a positive relation between academic specialisation and HEIs research and knowledge transfer performance.*

These hypotheses emerge from our conceptual model, and Table 3.1 presents the vector of factors that we consider relevant to explain these objectives and how these explanatory factors are measured. Both general and specific factors in regard to universities' missions are considered. Detailed information about the dependent and independent variables chosen as well for the model specification for the different university's objectives are discussed in the following sections.

Based on Table 3.1 the model specification used to test our hypotheses is expressed in equation [1]:

$$\begin{aligned} f_{\text{HEI}}(\text{T,R,KT})_i = & \alpha_0 + \beta_1 \text{Human Capital}_i + \beta_2 \text{Infrastructure}_i \\ & + \beta_3 \text{Financial Resources}_i + \beta_4 \text{Academic Spread}_i \quad [1] \\ & + \beta_5 \text{University Size}_i + \beta_6 \text{University Age}_i + \varepsilon_i \end{aligned}$$

Table 3.1. Variable definition proposed to assess university performance.

Factor		University objectives		
		Teaching	Research	Third stream
		Graduates / Students	Papers	Spin-offs
Human capital	Faculty	Students / Total faculty	PhD Faculty / Total faculty	Proportion of faculty working on knowledge transfer activities relative to total faculty
	Knowledge accumulation	-	Number of thesis dissertations	Number of patents granted
	Experience	-	Papers published in the last 3 years / Total faculty	Number of spin-offs created in the last 2 years
Specific infrastructures		Area dedicated to teaching relative to total size	Area dedicated to research relative to total size	Incubator
Financial resources		-	-	Total R&D income
University's profile		Educational diversity		
		University size (square meters)		
		University age		

Equation [1] implies that the objective function of the *itb* university comprises teaching activities (*T*), research (*R*), and a third stream objective linked to the creation of spin-offs (*KI*). Human capital includes variables linked to faculty, knowledge accumulation and the record of previous publication experience and the creation of spin-offs. These two latter variables are introduced as lagged terms, and in the case of research (papers published) it is measured as the annual average number of papers published per faculty during the last three years, whereas spin-off experience is the number of spin-offs created in the last two years. Concerning the variables related to infrastructure, financial resources, academic spread and university age, their definition follows the framework presented in Table 3.1. Descriptive statistics for the selected variables included in the different model specifications are summarised in Table 3.2.

Table 3.2. Descriptive statistics for the selected variables.

Variable	Obs.	Mean	Std. Dev.	Min	Max
Endogenous variables					
Graduates / Students	47	0.1485	0.0240	0.0756	0.1942
Number of papers published	47	6.5700	0.7304	4.9345	8.0821
Number of spin-offs	44	2.5909	3.0827	0	14
Explanatory variables					
Human capital components					
<i>1. Faculty</i>					
Students / Total faculty	47	10.8363	1.8469	7.7148	14.3636
PhD Faculty (%)	47	0.6234	0.0934	0.3978	0.8276
Faculty involved in knowledge transfer (KT) activities (%)	45	0.2382	0.1347	0.0665	0.6606
<i>2. Knowledge accumulation</i>					
Number of thesis dissertations	47	156.0213	142.9347	19	668
Number of patents granted	46	10.8913	9.0437	0	39
<i>3. Experience</i>					
Publishing: Papers published in the last 3 years / Total faculty	47	1.1668	0.3838	0.5918	2.2460
Spin-offs: Number of spin-offs created in the last 2 years	47	4.8936	6.5549	0	31
Specific infrastructure					
Teaching area relative to total size	46	0.3026	0.0881	0.1259	0.5196
Research area relative to total size	46	0.1584	0.0573	0.0359	0.3048
Incubator (dummy)	47	0.6383	0.4857	0	1
Financial resources					
Total R&D income (thousands of euro)	47	31,607.22	26,482.78	2,399.75	118,627.94
University's profile					
Education diversity (Herfindahl index)	47	3.1671	0.8005	1.1011	4.2368
Total size (square meters)	47	282,378.20	172,166.80	88,93	911,74
University age (years)	47	133.62	220.94	11	791

The following sections describe the selected methodological approach to model each university's objective, discuss the appropriateness of the selected variables and present the results of the analyses.

5.2. The teaching mission

Teaching can be considered a multidimensional construct that comprises qualitative and quantitative aspects related to graduates and the quality of teaching as well (Dilts, Haber

& Bialik, 1994). Thus, it is not surprising that little agreement exists concerning the definition of teaching outputs by academics, even though teaching activities can be considered easier to operationalise than research or knowledge transfer outcomes (Sarrico, Rosa, Teixeira & Cardoso, 2010). Here, technical problems associated with the use of quantitative but meaningless measures reflecting qualitative aspects of teaching (perhaps more easy to quantify but less related to teaching performance) dominate the research landscape. The lack of reliable and detailed data concerning teaching, together with the intangible and unquantifiable nature of some teaching activities probably explain the existing conceptual disagreement, leading to biased assessments of teaching outcomes.

Studies evaluating the teaching mission mainly focus on achieving students' success. However this success, far from being easily quantifiable, reflects the ambiguity inherent in the term. Feasible data that allow incorporating appropriate variables are difficult to obtain, mainly because information from universities usually cannot reflect the university's teaching capacity but rather the students' performance. Measures that aim to proxy learning processes suffer from a similar problem. Indicators such as number of degrees awarded (per levels or globally) and PhD completions have been widely used (Emrouznejad & Thanassoulis, 2005), however, they do not capture the essence of the teaching activity (i.e., differences related to the time that students need to obtain diplomas are not computed). Students' grades before entering HEIs are also a commonly used indicator (Celik & Ecer, 2009). However, it lacks the quality dimension of teaching that some universities may pursue, and this variable only measures the extent to which students advance in their academic process. Measures like students' progress rates (Avkiran, 2001) or the attrition rate (Kongar et al., 2010) have been used to better tackle this problem. Alternative approaches include the paper by Tóth (2008) who, using the data envelopment analysis method, studied the efficiency of 19 European countries and the author proposes as an output the employment rate of graduates to proxy teaching quality. This author justifies the use of this variable on the fact that it captures the capacity of the HEI to graduate students with a higher probability of being employed in the market. Employment rates can be considered as an important dimension of the

teaching mission as it is linked to the returns of studying. Yet, it should be noted that this variable not only captures teaching quality, but also includes the reputational effect of universities. Also, employment rates amongst graduates can be affected by unobservable factors related to specific skills that students develop during their learning process. These skills clearly vary amongst students and the students' capacity to acquire these skills can be affected by the quality of teaching and student's specific factors (for instance, previous labour experience). Therefore, the use of graduate's employment rates to assess universities' teaching performance could potentially lead to obtain upward biased estimators due to the presence of unobservable factors linked to reputation, and to unobservable factors related to the students analysed.

More recently new approaches have been developed where composite indicators that weight qualitative and quantitative aspects of teaching are considered (Giménez & Martínez, 2006; Turner, 2005). Once more, the lack of data complicates the use of these indexes.

5.2.1. Variables

From a university's perspective, teaching is a broad mission where quality and graduating students are key elements of this objective. Traditionally, the total number of graduates has been used to measure teaching (Johnes, 2006; Johnes, 1996; Johnes & Taylor, 1990; Smith & Naylor, 2001). However, in absolute terms universities with hard-science schools produce fewer graduates than universities with faculties in humanities and social sciences. Thus, using the number of graduates to measure teaching would lead to inconsistent results as this variable does not consider the capacity of any given university to graduate students. Therefore, we stress that the inclusion of the total number of students enrolled in the university is necessary to correctly assess teaching outputs.

As a result, and in order to avoid potentially biased results, we assess the teaching mission from an university's perspective, and we measure this objective as the number of

graduates during the academic year 2008/09 relative to the total number of students enrolled in the same academic year. This ratio is calculated at the university level, and the components of this variable only include students and graduates in undergraduates programs as information for postgraduate or master degrees was not uniform and available for all the universities.

As it was discussed above, to the best of our knowledge this approach to teaching has not been widely used in previous studies. However, we believe that it is an appropriate proxy for the capacity of HEIs to graduate students, because it avoids scale size effects. In addition, this variable proxies the net flow of students, as it includes a term accounting for the inflow of student in the university, that is, total number of students enrolled (both new students and students with university background), and a term that reflects the number of students that successfully finished their studies. From an university's perspective, teaching refers to graduating students, and also to ensure a flow of customers (inflow and outflow) that guarantees stable revenues from tuition as well as an efficient use of resources available (for instance, faculty, lecture rooms, libraries, etc.). This way, through this variable we control for size differences and for differences in the inflow and outflow of students amongst universities, which can be attributed to different factors (Katharaki & Katharakis, 2010). For instance, entry rates are affected by entry cohorts and by the presence of students who decide not to continue their academic formation.

From Table 3.2 it can be noticed that for the academic period 2008/09 the outflow of students represented 14.85% of the students enrolled in Spanish universities, being the highest figure shown by the Universidad Carlos III de Madrid (16,454 students enrolled and 3,151 graduates in 2008/09), whereas the lowest change in the flow of students is observed in the Universidad de Las Palmas de Gran Canaria (21,161 students enrolled but only 1,599 graduates).

Concerning the explanatory variables, it is important to correctly represent the effort and/or the availability of human capital in teaching activities. Variables such as credit

hours or teaching load (Kao & Hung, 2008) as well as average size group (Caballero, Galache, Gómez, Molina & Torrico, 2004) respond to this need.

Thus, for the purposes of this study, human capital is measured through a proxy variable that captures the academic load per lecturer in terms of students per class, that is, the average number of students to be attended per faculty member. Similar to Abbott & Doucouliagos (2003) and Taylor & Harris, (2004), this independent variable is expressed as the average of physical headcount of total number of enrolments in undergraduate degrees during the academic year 2008/09 per academic staff in the same year. We are aware that students' enrolments are sometimes conditioned by the different types of studies that students can enrol in (undergraduate, postgraduate and PhD) or by the knowledge field (Johnes, Johnes, Thanassoulis, Lenton & Emrouznejad, 2005; Thanassoulis, Kortelainen, Johnes & Johnes, 2009). However, and due to lack of data availability, for this study we only account for undergraduate students. A similar interpretation can be done in the case of the potential involvement of students in teaching activities. Students are potential grant holders, so that they can undertake teaching tasks as a result of collaborative scholarships. Nevertheless, data on students with academic grants for the development of teaching tasks were not available. Therefore, we cannot incorporate this concept in our definition of teaching performance. From Table 3.2 it can be observed that, on average, there are 10.84 students per faculty member, being the Universidad de Zaragoza the institution with the lowest rate (7.71 students per faculty member), whereas the Universidad de Jaén exhibits the highest rate of students per faculty (14.36 students).

At this point, it should be noted that we are aware that other dimensions of human capital should be taken into consideration when it comes to explain teaching performance. For instance, McLean & Blackwell (1997), McLean & Bullard (2000) and Prieto & Altmaier (1994) introduce in their analysis previous experience of faculty members and highlight the importance of teaching courses for those novice teachers in order to improve their performance. Other potential dimensions that would have been interesting to be tested

given their relation to students’ learning success is lecturers’ quality (Giménez & Martínez, 2006) and the coherence of their curricula throughout the entire academic offer. Unfortunately, we lack information concerning this type of human capital, or other human capital dimensions, and the incorporation of a greater number of human capital variables is a concern that should be tackled in future research.

Specific infrastructures devoted to teaching activities are mainly those spaces where students attend their lessons (lecture rooms); have access to bibliographic resources and complement their learning process (libraries); and apply the knowledge acquired into practical situations requiring the use of adapted infrastructures where to carry the appropriate experiments (laboratories). Consistent with previous studies using similar variables (Agasisti & Dal Bianco, 2009; Duh & Kuo, 2006; Gamble, 1989; Lewis & Moulder, 2008), we proxy academic space through a variable that accounts for the area (measured in square meters) devoted to teaching activities (classrooms, laboratories and libraries) relative to the total size of the university (measured in square meters). From Table 3.2 it can be seen that, amongst Spanish universities, 30.26% of their total size is used for teaching activities.

To account for the academic spread of the university, we assumed this diversity in terms of the education degrees offered by the different Spanish universities. Thus, following the works of McMillan & Chan (2006) and McMillan & Datta (1998), we used a Herfindahl index (HHI) to assess the degree of diversification amongst the sampled universities in terms of degrees. The Herfindahl index is calculated as $HHI = \sum_{j=1}^J s_j^2$, where s is the proportion of degrees offered by the university in the j th disciplinary category. The degrees considered for each university are those offered during the academic year 2008/09, and as it was previously indicated, they are grouped into the following categories (j): humanities studies (average proportion of degrees offered by Spanish universities considered in the final sample: 14.06%), social sciences (39.13%), experimental sciences (9.62%), medical sciences (6%), and engineering studies (31.18%).

To facilitate the interpretation of the results for this variable, we use the inverse value of this factor throughout our analyses. Table 3.2 shows that Spanish universities have on average studies in 3.1683 disciplinary categories (mainly in social sciences, engineering and humanities as indicated above).

In addition to the set of explanatory variables used in this study, we included in the different model specifications two control variables commonly found in previous research and that will be used in all the three models as they are not specific to any particular mission, but to the overall performance of the university (Qingyun, Ya & Keqiang, 2010): university size (measured as thousand square meters) (Johnes & Yu, 2008; Kao & Hung, 2008), and university's age (expressed in years).

5.2.2. Model specifications

Despite the representativeness of the sample, we observe that it is rather small (47 universities), and as shown in the descriptive statistics in Table 3.2 one university was dropped out from the final sample because information for the different variables used was not available (Universidad de Valladolid).

As a result, the final sample size is 46 universities for this first analysis. An in-depth analysis of the sample reveals that old universities are also the larger ones (Universitat de Barcelona, Universidad de Sevilla, Universidad de Granada, Universitat de València and Universidad Complutense de Madrid). This explains the significantly positive correlation found between university size and age (Table 3.3).

Table 3.3. Correlation matrix of variables for the teaching mission.

	(1)	(2)	(3)	(4)	(5)	(6)
1. Graduates/Students	1					
2. Size	-0.1836 (0.217)	1				
3. Age	-0.0276 (0.854)	0.6403 (0.000)	1			
4. Educational diversity	0.1833 (0.217)	0.2162 (0.144)	0.3886 (0.007)	1		
5. Students / Total faculty	-0.4326 (0.002)	0.0312 (0.835)	-0.0242 (0.872)	0.1333 (0.372)	1	
6. Teaching size	0.2669 (0.073)	-0.3406 (0.021)	-0.1908 (0.204)	-0.0400 (0.792)	-0.0199 (0.896)	1

Significance level is presented in brackets.

To assess the determinants of the teaching objective, we run a regression to examine the explanatory power that each of the exogenous variables considered has individually. In this case, the linear regression is the econometric technique chosen, and the full model to be estimated follows (equation [2]):

$$\begin{aligned}
 f_{HEI}(\text{T=Graduates/Students})_i = & \alpha_0 + \beta_1 \text{Students / Faculty}_i + \beta_2 \text{Teaching Area}_i \\
 & + \beta_3 \text{Education Diversity}_i + \beta_4 \text{University Size}_i \quad [2] \\
 & + \beta_5 \text{University Age}_i + \varepsilon_i
 \end{aligned}$$

As for the hypotheses to be tested, we expect a positive and statistically significant result in the parameter estimates for the variables linked to human capital. It is worth noting that in the case of the variable used in the model to proxy human capital (proportion of students per faculty member), we expect a negative and significant result in the coefficient, meaning that better teaching results are achieved when lecturers have smaller groups (H1: $\beta_1 < 0$). We expect a positive result for the parameter estimate related to the specific infrastructures (H2: $\beta_2 > 0$) and academic diversification (H4a: $\beta_3 > 0$). University size and age are introduced as control variables. The consistency in the effect that each variable has over the dependent variable will be tested in a full model.

5.2.3. Results

The results of the different applications of the linear regression to the ratio of graduates per students, as a proxy of the teaching mission of universities, are presented in this subsection (Table 3.4).

Before to comment the results it is important to note that we tested whether disturbances emerging from the different model specifications are normally distributed. To do this so we use normal probability plots of the residuals. Through this procedure it is possible to plot the fractions of the error's distribution versus the fractions of a normal distribution having the same mean and variance. If the distribution is normal, the points on this plot should fall close to the diagonal line. A bow-shaped pattern of deviations from the diagonal indicates that the residuals have excessive skewness (i.e. they are not symmetrically distributed, with too many large errors in the same direction). An S-shaped pattern of deviations indicates that the residuals have excessive kurtosis (i.e. there are either too many or too few large errors in both directions). As it can be seen in Appendix A (Figure A.1), the plots obtained for the different regressions support the normality assumption of disturbance terms, so therefore our approach to the teaching mission is appropriate.

As for the key results of this analysis, empirical findings reveal that the human capital factor considered in the teaching model is critical when it comes to explain differences in the achievement of the teaching mission. The parameter estimate is statistically significant and it has the expected sign ($\beta_1 < 0$), confirming that a lower ratio of students per faculty helps achieve better teaching results in terms of the proportion of graduates relative to the total number of enrolments (Table 3.4). This result suggests that students may have a more personalised training process if class groups are smaller, recording more useful interactions amongst students and with professors. In other words, if each lecturer has small groups of students, an individualised and personalised teaching method would prevail, and given that their teaching load is distributed amongst fewer students the

faculty can efficiently respond to students’ demands and inquiries. This finding is in accordance with one of the postulates of Bologna’s framework, where reductions in the number of students per class, as well as the enhancement of individualised learning processes are promoted. As a result, we confirm our hypothesis **H1** that states that, for this mission, human capital positively impacts the achievement of teaching objectives.

Table 3.4. Linear regression results: Determinants of the teaching mission.

	(1)	(2)	(3)	(4)	(5)
Size	-0.0106 * (0.0059)	-0.0094 (0.0057)	-0.0072 (0.0056)	-0.0102 * (0.0051)	-0.0055 (0.0050)
Age	0.0027 (0.0028)	0.0021 (0.0023)	0.0020 (0.0027)	0.0011 (0.0029)	-0.0004 (0.0028)
Students/Faculty		-0.0055 *** (0.0018)			-0.0060 *** (0.0019)
Teaching area			0.0613 * (0.0359)		0.0592 * (0.0321)
Educational diversity				0.0065 (0.0044)	0.0088 ** (0.0043)
Intercept	0.2698 *** (0.0663)	0.3156 *** (0.0686)	0.2114 *** (0.0683)	0.2495 *** (6.3049)	0.2377 *** (0.0700)
F – test	1.67	4.19 **	2.25*	4.11 **	5.78 ***
R squared	0.0474	0.2247	0.091	0.0878	0.3357
RMSE	0.0234	0.0218	0.0239	0.0237	0.0209
Observations	47	47	46	47	46

Robust standard errors adjusted by heteroskedasticity are presented in brackets. *, **, *** indicate significance at the 10%, 5%, and 1%, respectively.

Concerning the availability of specific areas for teaching activities, Table 3.4 shows that those universities that have a higher proportion of their total size devoted to teaching spaces (lecture rooms, libraries and laboratories) exhibit a higher rate of graduates relative to the total number of enrolments ($\beta_2 > 0$). This is consistent with our hypothesis **H2** about the presence of a positive relationship between the presence of specific infrastructures with the facilities that students need to further develop their learning process and the proportion of graduates relative to the number of students enrolled. As it can be seen in model specification three, the influence that this variable exerts over the endogenous variable remains significant in the full model (specification five). These results reinforce the idea that what really matters for universities is to have specific infrastructures, in this case, for teaching activities.

As for the degree of educational diversification, results in model specifications four and five of Table 3.4 show that, when controlling for the average group size and the proportion devoted to teaching area, diversification in terms of academic degrees exerts a positive impact over the proportion of graduates ($\beta_3 > 0$). This means that the higher the academic spread, the greater the proportion of graduates relative to the number of students enrolled. This finding suggests that a university with a greater number of degrees in different knowledge fields may have a higher graduation rate. However, this result should be taken with a grain of salt. Even though the result is statistically significant in the full model (specification five), in the individual model (specification four) the impact of this variable dilutes. From Table 3.3 it can be observed that the variable capturing the education diversity is only correlated to university age (at the 1% level). In our interpretation, the observed positive effect of education diversity in the full model could signal the need to control for group size when examining the variables affecting the rate of graduates relative to the number of enrolments.

To further examine this result we introduced dummy variables accounting for the potential effect that polytechnic universities have over the flow of students. Results are not shown but they are not statistically significant, revealing that universities' flow of students follows a similar path, regardless the type of university. Moreover, we further explore this by assessing the students' flow in polytechnic universities and universities with medical schools. Results of the *t-test* (p -value=0.0486) confirm our intuition that universities with a more concentrated academic offer, in our case polytechnic universities, have a statistically significant lower flow of graduates per enrolments (0.1260) than that shown by generalist universities (0.1506). Nevertheless, based on our results and despite these aforementioned appreciations, we can conclude that **H4a** is partially supported.

Finally, concerning university size and age, our results show that these variables do not exert a statistically significant effect over the rate of graduates per student enrolled. In the case of university age, this means that university's seniority does not have a critical influence on teaching results, and it seems more important that universities have the

appropriate infrastructures, a critical mass of human capital, and a more diversified set of degrees. A similar interpretation could emerge for university size. Even though it is suggested that the influence of size over students' flow is negative, our results signal the importance to differentiate those spaces specifically used for teaching activities from the whole area of the university.

5.3. The research mission

The relationship between research metrics and research quality is an endless source of debate. The most commonly used indicators tend to be linked to the use of bibliometric data (Sarrico et al., 2010). This is mainly because this information is widely available and it facilitates the use of measures related to the number of papers published in scientific journals (in particular those published in academic journals indexed in the Science Citation Index, the Social Science Citation Index or similar), and citations counts that reflect both the quantity and quality of the research activity (Abramo et al., 2008; Cole & Cole, 1967; Golden & Carstensen, 1992). However, these variables are usually criticised because they are considered vague and incomplete, and because they do not fully represent the universities' research productivity (Collins, 1999; Hicks, 1999; Van Raan, 2005). On the one hand, an article would be considered as a research output only if it is published in an indexed journal, and this is detrimental to those research documents that were published in journals with some reputation, regardless their indexing. On the other hand, other types of publications such as conference proceedings (Coccia, 2008), books and book chapters (Daghbashyan, 2009) or reports are underscored. Despite it is widely accepted that these latter types of publication denote less quality than the former, it becomes clear that measuring basic research outputs through traditional variables linked to indexes may lead to biased estimations of research outputs. A similar argument holds for the number of citations. Although it is seen as an indicator of the quality of an article, its appropriateness as a research output is questionable because this variable do not reflect the type of citation (academic journal, book, working paper, amongst others), and it can

be influenced by self-citation and friend-citation practices (Toutkoushian, Porter, Danielson & Hollis, 2003).

“Scientific quality indexes” including weighted measures of different research results (both quantitative and qualitative) using *a priori* value judgments of the relevance of each research outcome can also be found (Daghbashyan, 2009; Turner, 2005; Tyagi, Yadav & Singh, 2009). While some academics suggest that aggregate dimensions can be obviated for introducing biases (weights are not objective) and not being a substantive basis in the literature for making such judgments (Johnes & Johnes, 1995; Johnes et al., 2005; Salerno, 2004), other authors argue that only a qualitative indicator like this can really reflect research quality (Tyagi et al., 2009).

According to O’Shea et al. (2005), these indicators based on bibliometric analysis do not consider other research outputs apart from scientific publications, whereas university’s research outputs are shown to be directly correlated to industry income. In order to include both types of research, we will differentiate between basic and applied research by considering as applied research those activities oriented towards HEIs’ third mission (see Section 5.4 of this chapter).

Following the same methodology as the one used for the teaching mission, a regression analysis with the results obtained is presented below, aiming to shed some light on those factors that enhance basic research productivity at Spanish HEIs.

5.3.1. Variable definition and hypotheses

The dependent variable chosen is the number of publications. Although we have previously pointed out some concerns about the appropriateness of this type of indicator, our selection responds to the following criteria. First, and according to Kao & Hung (2008), this indicator not only reflects quantity but also quality aspects of research. This is so because papers have been submitted to journals with a blind-peer review system, and they are published following the quality standards accepted by academics. Second,

researcher’s publication count is the most important factor considered for governmental quality agencies in Spain, especially when evaluating the academic merits of any professor for internal promotion purposes. For instance, according to the Spanish ANECA (National Agency of Quality Assessment and Accreditation Trust), the most valued criterion for being designated for any of the different types of academic positions is papers published. Papers published in scientific journals have a weight ranging between 26 and 35 points out of 100, depending on the knowledge field (higher for art and humanities or social and legal sciences, and lower for engineering and architecture). Third, the information about the number of papers published in a year per university is reliable and well documented, thus, final results do not suffer from missing or unreliable data.

As a result, we decided to use the number of academic papers published during the year 2009 in the journals included in the Scopus database. We prefer this database because it is less restrictive in the selection of journals than the ISI-Web of Knowledge, and this makes possible to find all indexed journals as well as articles published in conference proceedings and other second-level sources.

Analogously to the teaching model, we considered the same factors as before (human capital, infrastructures, experience and academic spread) and due to the particularities of research activities we added a variable that accounts for the knowledge accumulation factor. Detailed description of the variables is provided as follows, and descriptive statistics are summarised in Table 3.2.

Similar to Martín’s (2006), human capital is measured as the proportion of faculty that holds a PhD. Through this variable we aim at incorporating a quality criterion (holding a PhD) linked to a greater academic productivity in terms of publications counts. It is expected that those universities that have a higher proportion of scholars with a PhD will exhibit a more research-oriented faculty. Consequently, faculty with a greater level of human capital is expected to develop a more active research career, because internal promotion policies at Spanish universities are strictly linked to higher rate of publications.

Publications are the main observable outcome of many types of research efforts. Under normal operations at the university level, it could be assumed that the most commonly recognised sources of publications relate to the researcher’s involvement and commitment, PhD dissertations, and research projects (be they granted or not). In the case of the former, researchers put into practice their capacities to create the research document with the logical expectation of publishing. For PhD dissertations, the resources used are generally provided by individual students, firms or universities’ infrastructures, mainly because in this case financial resources tend to be scarce in Spain. For the latter, papers resulting from non-granted research projects usually come from third parties. This additional funding is used by researchers to give support to activities related to their corresponding research field, and this includes the purchase of specific material, other tangible or intangible assets, as well as the appointment of research members. Papers emerging from these projects have no additional cost for the university, as financial resources usually come from external sources and the cost of using HEIs’ infrastructures is offset by the income that the project generates. On-going research based on non-granted research projects could potentially benefit from the use of both internal services and human capital available in the department/university, and this leads to avoid additional expenditures.

As we are interested in these internal resources and capabilities, we decided that variables related to financial aspects are not relevant because they only capture the capacity to continue to support the current organisational structure or the potential access to new resources. Consequently, and similar to Carayol & Matt (2004) we include in the different model specifications the number of thesis dissertations in the previous year and research contracts as proxies for the knowledge accumulation factor. However, information concerning research contracts is ambiguous, and due to a lack of reliable data we only accounted for PhD dissertations.

Past experience is an important factor commonly used by academics to explain research performance. Previous experience in any field, together with the development of a

particular set of tasks constitutes a human capital component, and this is expected to contribute to the creation of specific capabilities that facilitate the achievement of the objective set by the researcher or the university. Previous experience in this case is proxied through the number of articles published in academic journals. At this point it should be noted that the total number of publications only reflects the amount of papers that the university published. Yet, this number is clearly affected by the size of the faculty, irrespective of whether researchers are full time or not. In addition, the number of previous publication periods chosen aims at capturing the nature of publication activities. Scientific journals not only show distinctive characteristics in terms of formatting, but also exhibit heterogeneous and dissimilar review processes and acceptance time spans, and this could complicate the evaluation of previous publication experience in the short run. Therefore, in this study we measure publication experience as the number of publications in the last three years relative to the total faculty working at the university during the last academic year. As it was indicated above, this variable controls for size differences in terms of faculty. Also, it indirectly incorporates the presence of organisational designs related to research groups within the university, which gradually can establish synergies, exploit externalities and create cooperative work patterns amongst the group members.

Research infrastructures are represented by libraries and laboratories facilities. Libraries represent areas where knowledge is available (for instance, books and journals), and laboratories are those areas where it is possible to conduct experiments, create knowledge and make discoveries, and these aspects are related to research activities (Del-Palacio et al., 2011; Gamble, 1989; Johnes, 1988; Lewis & Moulder, 2008; Powell, 1992). In order to control for size differences, we consider the proportion of the total university's area devoted to research facilities, that is, we measure research infrastructure as the ratio of the total square meters assigned to libraries and laboratories divided by total size (square meters). At this point, an important consideration is also in order. The estimation of the research area does not include the departments' size because this space only represents the area where faculty members are located at the university. However, this space is not

exclusively used for research activities. Faculty can use offices for both teaching and researching, and faculty members can visit other universities, which leads to conclude that this space may have alternative uses.

Looking at the correlation matrix we find a highly significant correlation between the number of thesis dissertations and journal articles (Table 3.5). This is in consonance with the intuition that PhD dissertations are an important source of publications as they represent a key source of knowledge in the process to be disseminated on the academic community (as publications in academic journals). Consequently, we expect a positive influence of this variable over the number of publications.

Table 3.5. Correlation matrix of variables for the research mission.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1. Papers	1							
2. Size	0.7876 (0.000)	1						
3. Age	0.6057 (0.000)	0.6403 (0.000)	1					
4. Education diversity	0.0835 (0.577)	0.2162 (0.1443)	0.3886 (0.007)	1				
5. Papers 3-years/ Academic staff	0.3282 (0.0243)	0.221 (0.1354)	0.0296 (0.8435)	0.1277 (0.3922)	1			
6. PhD faculty (%)	0.3759 (0.0092)	0.4608 (0.0011)	0.458 (0.0012)	0.4054 (0.0047)	0.0501 (0.7379)	1		
7. Research area	-0.2724 (0.067)	-0.4061 (0.0051)	-0.3667 (0.0122)	-0.2357 (0.1148)	-0.0196 (0.8972)	0.0096 (0.9494)	1	
8. Thesis dissertations	0.8477 (0.000)	0.6312 (0.000)	0.6503 (0.000)	0.2202 (0.1369)	0.3416 (0.0188)	0.454 (0.0013)	-0.2768 (0.0626)	1

Significance level is presented in brackets.

Concerning the education orientation of the faculty, an important factor that could help explain research performance is linked to academic specialisation (McMillan & Chan, 2006; McMillan & Datta, 1998). It has been argued that universities having a more concentrated pool of studies and a more specialised faculty are more prone to develop their research more intensively. The rationale behind this lies in the existence of a much more potent critical research mass that boosts the establishment of synergies amongst researchers, becoming a recurrent practice. This translates in saying that highly specialised

universities may have a greater capacity to accumulate knowledge in any specific knowledge field, and this facilitates researcher’s activity in terms of publishing. Following this argument, we introduce the education diversity index (Herfindahl index) to account for the potential benefits that researchers may obtain from working at universities with a more specific academic orientation. Therefore, this variable is included to control for the benefits that specialisation may have over publishing outcomes.

In addition to the set of explanatory variables abovementioned, as in the case of the model that assesses teaching (Section 5.2), we introduce university size (measured as thousand square meters), and university’s age (expressed in years) in the different model specifications as control variables.

5.3.2. Model specifications

Similar to the case of the analysis of the teaching mission, we first examine the explanatory power that each exogenous variable has over the research output variable (publication counts) in an individual fashion. Second, we run a full model where all the independent variables are included in the model specification. The resulting model is expressed in equation [3]:

$$\begin{aligned}
 f_{\text{HEI}}(\text{R=Papers})_i = & \alpha_0 + \beta_1 \text{Papers / Faculty}_i + \beta_2 \text{Proportion of PhD Faculty}_i + \beta_3 \text{Theses}_i \\
 & + \beta_4 \text{Research Area}_i + \beta_5 \text{Education Diversity}_i + \beta_6 \text{University Size}_i \quad [3] \\
 & + \beta_7 \text{University Age}_i + \varepsilon_i
 \end{aligned}$$

In terms of the hypotheses to be tested, we expect that $\beta_1 > 0$, $\beta_2 > 0$ and $\beta_3 > 0$, meaning that human capital components positively impact the number of publications (**H1**). We also expect that $\beta_4 > 0$, indicating that universities with a greater proportion of infrastructures oriented towards research activities have higher number of publications (**H2**). As for the hypothesis **H4b**, we expect that the parameter estimate for the variable linked to academic spread to be negative ($\beta_5 < 0$), indicating that universities with a more

concentrated research scope can develop both internal capabilities and externalities that are expected to help academics to publish more.

5.3.3. Results

This sub-section presents the results for the different model specifications (Table 3.6). As in the case of the section assessing teaching performance, we used normal probability plots of residuals to test whether errors resulting from the different model specifications follow a normal distribution. Plots presented in Appendix A (Figure A.2) indicate that the errors obtained for the different regression models are normally distributed, confirming that the empirical results presented in Table 3.6 are reliable.

Concerning the findings of this analysis, results in specification two and seven do not give support to the argument that a greater proportion of highly qualified faculty (holding a PhD) positively influences academic publications.

Table 3.6. Linear regression results: Determinants of the research mission.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Size	0.7782 *** (0.1109)	0.7848 *** (0.1080)	0.7899 *** (0.1118)	0.5198 *** (0.1000)	0.7049 *** (0.1135)	0.7685 *** (0.1008)	0.5658 *** (0.0853)
Age	0.0921 (0.0606)	0.0951 (0.0667)	0.1348 ** (0.0596)	-0.0460 (0.0337)	0.1111 * (0.0559)	0.1269 * (0.0634)	0.0272 (0.0498)
PhD Faculty (%)		-0.1582 (0.8905)					-0.7859 (0.7093)
Research area			1.1830 (0.9956)				1.0386 (1.0340)
Thesis				0.0032 *** (0.0007)			0.0030 *** (0.0008)
Papers 3-years / Faculty					0.3547 ** (0.1636)		0.0565 (0.1683)
Educational diversity						-0.1398 * (0.0724)	-0.1032 * (0.0516)
Intercept	-3.4086 *** (1.2510)	-3.4029 ** (1.2727)	-3.8841 (1.3086)	-0.1811 (1.1926)	-2.9867 ** (1.2631)	-2.9772 ** (1.1394)	-0.4082 (1.0743)
F – test	56.87 ***	38.96 ***	44.17 ***	28.04 ***	39.73 ***	43.25 ***	34.94 ***
R squared	0.6377	0.6380	0.6687	0.8282	0.6700	0.6576	0.8562
RMSE	0.4495	0.4545	0.4399	0.3131	0.4339	0.4420	0.3048
Observations	47	47	46	47	47	47	46

Robust standard errors adjusted by heteroskedasticity are presented in brackets. *, **, *** indicate significance at the 10%, 5%, and 1%, respectively.

To the contrary, the only human capital dimension that exerts a positive and significant effect over the number of publications relates to the number of thesis dissertations ($\beta_3 > 0$). This result could corroborate that dissertations represent, on the one hand, a highly valued source of knowledge. On the other hand, doctoral theses can also be considered a cornerstone for future publications, as faculty members convey their knowledge to PhD students, who ultimately put all this knowledge in his/her dissertation with publishing purposes.

Even though the results reported for the proportion of the faculty holding a PhD and research area may look counterintuitive, we believe that the lack of significance in these variables can be explained by the conditions that dominate the research context in Spain.

In the Spanish public university sector, internal promotion policies are strictly conditioned to an accreditation system where governmental agencies play a key role. As it was previously indicated, and according to the existing set of regulations, papers published in academic journals is the most important criterion valued by the different governmental agencies to accredit professors. The weight of scientific publications in the final evaluation varies according to the knowledge filed, and it ranges between 26% and 35%. A positive evaluation makes them valid candidates for potential internal promotions in their corresponding universities. Given the weight that scientific publications have in the evaluation system, it becomes clear that for young academics to carve out an academic career is a long-distance race conditioned, to a great extent, to their capacity to publish their research. To the contrary, full professors have no exogenous incentives to publish, and their only motivation is endogenously determined by their own interest in conducting research in their knowledge fields. Research by full professors may be motivated by knowledge dissemination objectives, the enhancement or consolidation of research projects, or by reputational factors.

As a result, and under some mild conditions, internal promotion policies and the evaluation system in Spain help distinguish academics with publishing potential from those with less potential. Therefore, and assuming that academics play in a competitive

context and that universities want to minimise adverse selection when contracting new professors; academics who are in a weaker position (in terms of contractual relations) are pushed towards publishing their research in scientific journals to signal their research capacities to the market of academics. PhD students not only seek a PhD degree that could represent a relevant key to success in a hypothetical academic career, but they also try to publish their research to help minimise the information asymmetries that shape universities' contracting preferences. Thus, it is not surprising that the variable related to the number of thesis dissertations is the only human capital component that significantly explains differences in the number of publications amongst Spanish universities. PhD students are, by far, one of the most productive groups in terms of papers, jointly with those academics who aim at improving their contractual relation.

To sum up, in our interpretation the Spanish publishing incentive system is designed in such a way that the existing evaluation tool allows universities to use the publishing record of candidates to minimising information asymmetries and improve their contracting processes. Also, young academics, PhD students as well as professors in a weaker contractual position have stronger incentives to publish in order to create reputational signals that are expected to increase their probability to be appointed by universities. Finally, it could be said that incentives to publish diminish as academics consolidate their careers.

The past experience factor measured as previous publishing activity, that is, the number of publications in the period 2006-2008 per faculty, shows as statistically significant in the individual model (specification five), however, the explanatory power of this variable dilutes in the full model. In line with our argument, the lack of significance of this variable in the full model may result from the fact that the full models controls for the PhD students' involvement in basic research activities. This could imply that universities with a greater number of thesis dissertations and on-going theses publish more. In fact, additional descriptives for the Spanish data corroborate that there is a positive and

statistically significant correlation between the number of PhD students and the number of papers published (73.84%, p -value $<1\%$).

Consequently, we partially support our first hypothesis that states that human capital components positively affect publication performance (**H1**), as the number of thesis dissertations is the only variable that consistently explains the number of publications in Spanish universities.

The parameter estimate for the research area variable is not statistically significant, revealing that this factor does not explain differences in the number of publications amongst Spanish universities. This leads to reject our hypothesis **H2** that positively relates research areas and the number of papers published in academic journals.

Our results confirm the positive effect that specialisation in terms of academic degrees has over the number of papers published, thus, our hypothesis **H4b** is confirmed. More specifically, this result suggests that universities benefit from a more concentrated set of academic degrees, and this could be related to the presence of some disciplines that are more likely to generate publishing outcomes or are boosted to do so according to the framework drawn by quality accreditation agencies.

We further explore this, and in the case of Spain we compare the academic production of polytechnic universities relative to that of generalist universities. Also, we compare the number of papers published between universities that have a medical school and universities that do not. Results for the *t-test* reveal that academic production of polytechnic universities in 2009 (on average 1,367 papers) is significantly higher than generalist universities (on average 879.72 papers) at the 5% level (p -value=0.0168). To the contrary, the average number of papers in universities with a medical school in 2009 (933.76) is not significantly different to that figure obtained by universities with no medical studies (868.11) (*t-test* p -value=0.1969).

Concerning the control variables, university’s seniority (age) is inconsistently significant along the different model specifications. Conversely, university size is found to be statistically significant in all model specifications. This result suggests that large universities have a greater capacity to produce research outputs, measured in terms of scientific publications. This result is not surprising because small universities have more difficulties in accessing research resources, and in creating economies of scale in the development of research projects and its further diffusion.

5.4. Third stream activities

A knowledge transfer mechanism that has attracted increased interest in the economic and management literature is the creation of university spin-offs, that is, new ventures that are dependent upon licensing or assignment of the university’s intellectual property for initiation (Association of University Technology Managers in the US, AUTM).

Strictly defined, a university spin-off is an outcome of an entrepreneurial process initiated in a university setting and based on the exploitation of a university development (Rasmussen, 2008). Spin-offs are conceived from a push view of the demand, where the technology or the invention developed is looking for a place in the market. Although a few of them really serve national markets or create new ones (Markman, Siegel & Wright, 2008) they undoubtedly represent an important mechanism that contributes and stimulates economies.

Spin-offs are usually pursued for the direct financial gain of the university but they also have an important role outside universities’ doors (Wright et al., 2008). From a government’s perspective, spin-offs are seen as mechanisms with the capacity to regenerate economic activity within the region through the exploitation of the most up-to-dated technology available at universities. This links particularly well with the difficulties of established firms in bringing new technologies to the market (Utterback,

1994). Therefore, universities as natural source of high-tech developments are called to play this role, turning this substrate into applicable products and services.

The stimulation of academic entrepreneurship has become a critical issue for both universities and governments. The rise in the number of academic spin-offs, especially in European countries (Mustar, Renault, Colombo, Piva, Fontes, Lockett, Wright, Clarysse & Moray, 2006) seems to be accelerated by a combination of circumstances: 1) a social pressure over public universities to commercialise research in order to generate a new revenue stream that helps foster regional economic growth (Clarysse, Wright, Lockett, Mustar & Knockaert, 2007); 2) the availability of public funds aimed at narrowing the so-called financial and knowledge gaps (Wright, Clarysse, Lockett & Binks, 2006); 3) the introduction of policies that stimulate the creation and development of spin-offs at universities; and 4) the creation of institutional programs, measures, and schemes offering business support and low cost facilities (Jacob, Lundqvist & Hellsmark, 2003). The rationale for all these policies and initiatives reflects the desire to generate high growth technological firms (Dosi, Llerena & Sylos Labini, 2006), comparable with those in the US.

Literature on university spin-off activity has rapidly grown in the last years (Mustar et al., 2006) and different streams of research in the field of academic ventures have been identified. Based on Rasmussen's (2008) premise, spin-offs are initiated inside the university and these firms can be affected by university's operations, which can occasionally turn into stimulating processes or inhibiting ones. As a result, our analysis for the HEIs' third mission focuses on the institutional and organisational assets that, according to the literature, are expected to influence the number of spin-offs created at the university level.

5.4.1. Variables

Concerning the dependent variable used in this paper, we use the number of spin-offs created by each university in the year 2009. From the descriptives presented in Table 3.2 we observe that, on average, Spanish universities created 2.59 spin-offs in 2009, being the Universidad Politécnica de Cartagena and the Universidad de Granada the institutions that reported the greatest number of spin-offs created in this year (14 and 10, respectively).

Knowledge transfer activities require an important stock of human resources (Clarysse, Wright, Lockett, Van de Velde & Vohora, 2005; Lockett, Wright & Franklin, 2003). Spinning off not only relates to the link between scientific research that translates into the settlement of a new firm, but it also represents an activity that needs coaching, as well as an appropriate assessment and stimulation of entrepreneurial spirit. In our approach, human capital for spin-off purposes refers to those academics engaged in research activities in the past (year 2008), relative to the total number of faculty members. From Table 3.2 it can be observed that on average 23.82% of faculty members in Spanish universities are aligned to R&D activities. The greater the proportion of faculty actively involved in knowledge transfer activities, the greater the university's capacity to create an entrepreneurial activity (Feldman, Feller, Bercovitz & Burton, 2002) and introduce new lecturers in technology transfer activities.

University spin-offs emerge from academic research processes. Examining the creation process we can distinguish two ways through which spin-offs are created. On one hand, researchers first apply for a patent, and once granted, they start working on the business plan and the search for venture capital, ending with the formalisation of the spin-off. This procedure is especially attractive due to cost reductions (Clarysse et al., 2007), and even though patenting does not guarantee the future marketability of the technology, it represents a key tool for safeguarding its potential (Powers & McDougall, 2005). On the other hand, the technology developed may have the potential to be commercialised directly through a venture, which prevents the individual(s) involved in the process to

disclose the invention or apply for a patent. The risk associated with the latter procedure is higher than in the former, so the creation process (and especially in high-tech sectors) tends to follow the first description (DiGregorio & Shane, 2003). Moreover, some studies (Deeds, Decarolis & Coombs, 1999; Zahra & Bogner, 1999) indicate that patents are predictive of firm performance, that university patenting stimulates future patent activity and consequently the creation of more spin-offs (Mowery, Sampat & Ziedonis, 2002). Given all these considerations, we take the number of patents awarded by the Spanish Office of Patents and Trade Marks (OEPM) in the last two years (2008 and 2009) as the proxy for the knowledge accumulation factor. From Table 3.2 it can be noticed that Spanish universities issued on average 10.89 patents, in 2008 and 2009, being the highest figures shown by the Universitat Politècnica de Catalunya (39 patents) and by the Universidad de Málaga (30 patents).

It has been recognised that universities with tradition in spinning out technology-based companies are more likely to generate a greater number of academic spin-offs (Lockett & Wright, 2005; O’Shea et al., 2005). The underlying argument supporting this relies on the fact that universities with spin-out experience are more likely to develop the appropriate policies, managerial capabilities, as well as the infrastructures and services necessary to facilitate the creation process of new academic ventures. As a result, accumulated experience leads to the creation of knowledge spillovers that are expected to boost the creation of new spin-offs within the institution. One way to account for this experience is measuring how actively involved has the university been in knowledge transfer activities, and in particular, we proxy this through the number of spin-offs created during the last two years (2007 and 2008). The descriptives (Table 3.2) show that Spanish universities created on average 10.53 spin-off businesses during the period 2007-2008. In this case, the Universidad Autónoma de Madrid reported the highest number of spin-offs created in the previous two years (31), whereas eight universities did not create any spin-off firm in the same period.

Another important aspect that should be taken into account relates to incubators affiliated to the university. Incubators are spaces with advanced services and facilities devoted to allocating entrepreneurs with a formal or an in-progress idea that is expected to evolve and become into a real business. Advantages from incubators have been widely documented in the literature (Cooper, 1985; Grimaldi & Grandi, 2005), and these are related to the proximity to researchers and its experience, the presence of a creative atmosphere, the access to a skilled labour force (for instance, students) and infrastructure facilities. Thus, incubators are seen as an accelerating element for the creation of new ventures (O’Shea, Chugh & Allen, 2008). This way, we expect a positive relation between the presence of a university-affiliated incubator and the number of spin-offs created within the university. To represent the availability of such infrastructures, we included a dummy variable taking the value of one if the university supports the spin-off creation process by providing its infrastructure through the presence of a business incubator, and zero otherwise. Descriptive statistics in Table 3.2 show that in our sample 30 universities (63.83%) had an affiliated incubator in 2008.

Regarding the availability of financial resources, many studies have focused on the relationship between the different sources of finance and the spin-off activity (De Coster & Butler, 2005; Landry et al., 2007). In addition, Lockett & Wright (2005) and Powers & McDougall (2005) report a positive and statistically significant relationship between annual university R&D expenditure and the number of spin-offs created. Our analysis stresses on the impact of universities’ income from R&D activities over in the creation of spin-offs. Financial resources emerging from R&D may be understood as those derived from specific fundraising activities (such as public grants or private contracts), therefore, they represent ‘own funds’. As financial resources are critical for developing and commercialising research, a positive relationship is expected between universities’ income from R&D activities and the creation of academic spin-offs. To account for the financial resources available for R&D activities, we use the total income from R&D reported by each university in 2008 which is, on average, nearly 10.02€ million. This measure helps us

denote the possibility to self-finance the creation of new ventures through the incomes generated by R&D activities.

The nature of the research engaged is another important factor affecting the level of spin-off activity (Fontes, 2003; O’Shea et al., 2008). It has been widely recognised that universities with a medical school or those universities more oriented towards engineering studies and chemistry are more likely to be engaged in knowledge transfer activities than those in social science or humanities (Carlsson & Fridh, 2002). For instance, O’Shea et al. (2005) find that universities with a computer science faculty, or biology and chemistry disciplines have higher spin-off formation rates; whereas Landry et al. (2007) report that researchers in engineering are significantly more involved in spinning off than researcher in other fields. In order to test if the number of spin-offs created within universities is positively related to the presence of hard-science schools, we also use the Herfindahl index as a proxy of the academic spread.

To this list of independent variables we also added the two control variables (size and age) used in the previous models tested.

5.4.2. Model specifications

The lack of information about the number of spin-offs created and certain explanatory variables lead us to drop from the final sample the University of Las Palmas de Gran Canaria, the Universidad de León, the Universidad de Valladolid and the Universidad Politécnica de Cartagena, so that the final sample used in this sub-section consists of 43 Spanish public universities.

To correctly identify the differentiating characteristics that affect the creation of spin-offs firms amongst Spanish universities we have to tackle two problems related to the dependent variable and the sample. On the one hand, our dependent variable is the count number of spin-offs created in 2009. We also know that the distribution of this variable is highly skewed: 10 universities (23.26%) did not report the creation of a spin-off, whereas

11 universities created one spin-off firm. On the other hand and despite its representativeness, we observe that our sample is rather small (43 universities) so that we have to compensate the characteristics of the sample and the large number of independent variables introduced in the analysis.

Following the methodology employed in the two previous analyses we also conduct a two-steps analysis. First, and using a negative binomial regression technique, we assess the explanatory power that each of the exogenous variables has over the number of spin-offs created in 2009 in an individual fashion. Second, we use a negative binomial regression in a full model (equation [4]). Negative binomial regression is the econometric technique chosen as this method best fits to the characteristics of the dependent variable (a count variable exhibiting a highly skewed distribution) (Greene, 2008; 2003). Individual correlations between variables are presented in Table 3.7.

$$\begin{aligned}
 f_{\text{HEI}}(\text{KT=Spin-offs})_i = & \alpha_0 + \beta_1 \text{Proportion of Faculty in KT activities}_i + \beta_2 \text{Patents granted}_i \\
 & + \beta_3 \text{Spin-offs created in the last two years}_i + \beta_4 \text{Incubator}_i \\
 & + \beta_5 \text{R\&D Income}_i + \beta_6 \text{Education Diversity}_i + \beta_7 \text{University Size}_i \\
 & + \beta_8 \text{University Age}_i + \varepsilon_i
 \end{aligned}
 \tag{4}$$

Concerning the hypotheses to be tested, in this case we expect that $\beta_1 > 0$, $\beta_2 > 0$ and $\beta_3 > 0$, indicating that human capital components exert a positive and statistically significant effect over the capacity of universities to create spin-offs (**H1**). We also expect that $\beta_4 > 0$, indicating that universities with an affiliated incubator create more academic spin-offs (**H2**). As for the hypothesis **H3**, we expect that the coefficient of the R&D income to be positive and statistically significant ($\beta_5 > 0$). For the variable linked to academic diversification, a negative result in this parameter estimate ($\beta_6 < 0$) would corroborate that universities with a more concentrated set of academic degrees are those that create a higher number of spin-offs (**H4b**).

Table 3.7. Correlation matrix of variables for third stream activities.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1. Spin-offs	1								
2. Size	-0.0903 (0.5599)	1							
3. Age	0.0808 (0.6021)	0.6403 (0.000)	1						
4. Educational diversity	-0.228 (0.1365)	0.2162 (0.1443)	0.3886 (0.0070)	1					
5. Spin-offs 2-years	0.4778 (0.001)	0.2981 (0.0418)	0.1459 (0.3278)	-0.1839 (0.2158)	1				
6. Patents	0.4059 (0.0063)	0.3654 (0.0136)	0.4237 (0.0037)	-0.0483 (0.7528)	0.2164 (0.1533)	1			
7. Incubator	-0.2381 (0.1195)	0.138 (0.355)	0.0124 (0.9339)	0.1805 (0.2248)	-0.026 (0.8622)	-0.0743 (0.6277)	1		
8. Total R&D income	0.1408 (0.3620)	0.7564 (0.000)	0.5072 (0.0003)	-0.0323 (0.8294)	0.4735 (0.0008)	0.5439 (0.0001)	0.1371 (0.3580)	1	
9. Faculty involved in KT activities (%)	0.2498 (0.1019)	-0.3059 (0.0365)	0.0211 (0.8878)	0.3092 (0.0344)	-0.0037 (0.9805)	-0.1928 (0.2045)	-0.1634 (0.2725)	-0.2069 (0.1629)	1

Significance level is presented in brackets.

5.4.3. Results

The results of the different applications of the negative binomial regression to the number of spin-offs created by Spanish universities in 2009 are presented in Table 3.8.

Our findings concerning the role played by faculty members show that a higher proportion of faculty involved in knowledge transfer activities does not help in creating more spin-offs. To the contrary, it exerts a negative influence over spin-off creation. This is in contrast to our hypothesis about the positive effect that the active involvement of faculty in knowledge transfer activities has on spin-off creation. This behaviour is also observed in the individual model (specification 2) although the influence is not statistically significant. Regarding the correlation matrix we find a positive but weak and not statistically significant relationship (24.98%) between the proportion of faculty members aligned to knowledge transfer activities and spin-off firms. We can interpret these results as a signal that the quality and the capacities of the faculty members are more important

than the number of faculty members involved in knowledge transfer activities. Also an entrepreneurial culture is required, without which it is impossible to disseminate and translate knowledge discoveries into the marketplace through the establishment of new ventures (Clark, 1998; Stankiewicz, 1994).

Table 3.8. Negative binomial regression: Determinants of the knowledge transfer mission.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Size	-0.4093 (0.3896)	-0.0505 (0.3404)	-0.3429 (0.3604)	-0.5756 (0.1488)	-0.703 * (0.3667)	-1.1696 *** (0.4000)	-0.3436 (0.3366)	-0.9728 *** (0.3288)
Age	0.1964 (0.1559)	0.1488 (0.1515)	0.2022 (0.1468)	0.1256 (0.1488)	0.2076 (0.1301)	0.1318 (0.1338)	0.2933 * (0.1549)	-0.0334 (0.1226)
Faculty on KT (%)		-1.5536 (1.1834)						-2.3052 ** (0.9858)
Incubator			-0.5411 (0.3390)					-0.1511 (0.2683)
Patents				0.0616 *** (0.0135)				0.0457 *** (0.1367)
Spin-offs 2-years					0.0839 *** (0.0237)			0.0583 *** (0.0161)
Total R&D income						0.8361 *** (0.2773)		0.4682 ** (0.2268)
Educational diversity							-0.3913 * (0.2215)	0.3770 * (0.1906)
Intercept	5.2537 (4.4663)	1.2354 (3.8991)	4.7348 (4.1493)	6.7335 (4.2974)	8.2683 * (4.2342)	6.4032 * (3.8835)	5.2711 (3.7703)	6.6631 * (3.6621)
Log likelihood	-92.5589	-85.7336	-91.3718	-86.4966	-86.2952	-89.5645	-90.9088	-80.8249
Pseudo R2	0.0095	0.0171	0.0222	0.0744	0.0765	0.0415	0.0271	0.1627
Wald chi2	1.66	4.38	3.57	21.00 ***	15.87 ***	12.68 ***	5.24	109.69 ***
Observations	44	43	44	44	44	44	44	43

Robust standard errors adjusted by heteroskedasticity are presented in brackets. *, **, *** indicate significance at the 10%, 5%, and 1%, respectively.

The results also reveal that universities are obtaining important gains from knowledge accumulation processes. Looking at the impact of the number of patents issued from 2008 to 2009, our results indicate that this variable is highly influential when it comes to explain the number of spin-offs created in 2009 ($\beta_2 > 0$). This finding is in accordance with previous studies examining this relationship (Clarysse et al., 2007; Mowery et al., 2002), and it could indicate that academics have a strong preference for safeguarding their knowledge, and they get involved in entrepreneurial activities only if the patent they applied for is granted. Therefore, we confirm our hypothesis which states that there is a

positive relationship between the number of patents awarded and the number of spin-offs created.

The coefficient for the variable reflecting the number of spin-offs created in the past two years is positive and highly significant ($\beta_3 > 0$). This is in accordance with our argument that universities with past experience, in this case in spin-off activities, create a higher number of new spin-offs. This stands as a key result as it gives support to our argument about the presence of path dependency derived from the knowledge spillovers linked to the creation of spin-offs (O’Shea et al., 2005). However, the age of the university is proven to have no significant effect, and this supports the idea that it is not just seniority what helps creating spin-offs, but rather experiential involvement in knowledge transfer activities. Given the empirical findings, we partially support our hypothesis **H1** that states that human capital components are important factors that help explain the number of spin-off created.

It is worth noting that, even though entrepreneurial culture seems to be embedded into some Spanish universities, the results concerning the role of faculty and business incubators indicate that academic entrepreneurship has not been encouraged sufficiently by the creation of formal mechanisms designed for this purpose (university-affiliated incubator). Also overall size of the institution does not help in creating more spin-offs, as a negative and highly significant effect is observed. These results could indicate that academics perceive no incentives to engage in entrepreneurship, therefore, universities should create specific incentives and implement programmes on entrepreneurship in order to create an entrepreneurial culture within the university which is expected to increase the probability of academics to be involved in entrepreneurial activities. Consequently, this negative and not statistically significant influence prevents us to confirm our hypothesis stating that the presence of space facilities (an incubator affiliated to the university or being a large university) is positively correlated to the number of spin-offs created by universities. Consequently, in this case we cannot support our second

hypothesis (**H2**) that the presence of specific infrastructures positively impacts the creation of spin-offs.

Concerning the access to financial resources, our results indicate that those universities that generate higher levels of income from R&D activities create more spin-offs ($\beta_5 > 0$). This is consistent with our hypothesis about the presence of a positive relationship between the capacity of the university to generate income from R&D activities and the creation of academic spin-offs (**H3**). This finding could signal that universities that are more actively involved in R&D projects have significant incentives to promote research groups and develop knowledge transfer activities. This not only facilitates the access to higher levels of financial resources, but it also raises the probability of future spin-off activity (De Coster & Butler, 2005; Landry et al., 2007; O’Shea et al., 2005).

As for the degree of educational diversification our results in Table 3.8 show that, in the full model, specialisation in terms of academic degrees exerts a positive impact over the number of spin-offs ($\beta_6 < 0$). These results suggest that universities benefit from a more concentrated set of academic degrees, and this could be related to the presence of some disciplines that are more effective at creating spin-offs than others. For example, in the ranking of spin-offs created between 2007 and 2009 we find in the top-seven the Universitat Politècnica de Catalunya, the Universidad Politécnica de Madrid and the Universidad Politécnica de Cartagena, that is, polytechnic universities with a highly concentrated academic offer, especially in engineering studies (92.45%, 95.24%, and 90.48% respectively). Other universities in this group such as the Universidad de Almería or the Universidad del País Vasco also have an important portion of degrees in engineering (33.33% and 39.62%, respectively). These results confirm our hypothesis H4b that the number of spin-offs created within universities is positively related to the degree of academic specialisation.

We also tested whether specialised universities in some particular fields exhibit different results when it comes to explain differences in the number of spin-offs created. To do

this so, we included in the regression model two dummy variables taking the value of one if the university has a medical school or a polytechnic profile. Results confirm that neither universities with medical studies nor polytechnic universities have a distinctive performance that helps explaining differences in the number of spin-offs.

To further corroborate this, we tested if the spin-off performance in these universities (polytechnic universities and universities with medical studies) is significantly different compared to the rest of universities in the sample. Results for the *t-test* show that the number of spin-offs created in polytechnic universities (on average 5.75) is significantly higher (p -value=0.0298) than the average number of spin-offs created in more generalist universities (2.28). The comparison between universities with a medical school and universities with no medical studies indicate that the average number of spin-offs created in these two groups, 2.54 and 2.78 respectively, is not significantly different from zero (p -value=0.8412).

Chapter 6: An application of the DEA approach

Based on the results obtained in the previous chapter and considering the possible indicators to represent the inputs and outputs of the higher education system, in this chapter we carry out an efficiency analysis of the Spanish public higher education system. To this end, we calculate a relative efficiency index which comprises in a unique model the outputs resulting from teaching, research and knowledge transfer activities, assessing the overall performance of the universities. The methodology employed is the Data Envelopment Analysis (DEA), consisting on a set of non-parametric programming techniques that assist in identifying which set of decision making units may be considered as best practice.

6.1. The DEA approach

The selection of a methodological tool that allows at measuring how efficient organisations are has always been controversial, and this is mainly due to the lack of good estimation approaches (Rousseau & Rousseau, 1997), to problems in defining or clearly identifying the true production function, or to problems related to the sample under analysis.

In technical terms, production refers to the transformation process through which firms generate their output from any given input set (Frisch, 1965:3). Thus, the analysis of the input-output relationships that exist within any firm constitutes an important issue, as the efficient allocation of resources and any product generation process are consequence of firm’s production organisation.

Thus, the main objective of any productivity analysis heavily relies on to study of decision making processes that take place within the firm, in order to evaluate the available technology and the potential input-output relations that could lead to the selection of optimal input consumption levels consistent with the production maximisation objective.

Therefore, if a firm (z) uses an input set $(x_i \in \mathbb{R}_+^I)$ to produce an output set $(y_i \in \mathbb{R}_+^M)$, it

is possible to determine a production function $T_i = \{(x_i, y_i) : x_i \text{ can produce } y_i\}$, which is defined as the combination set located in the production possibilities set (production frontier) to produce the output from both inputs and technology.

The implication of this approach for performance assessments is two folded. On the one hand, it is necessary to introduce the concept of productivity, which comes from the ratio of total production relative to total resources. On the other hand, efficiency should be taken into account, and it emerges from the optimal input-output combination that directly locates any firm on the production frontier.

When dealing with multiple inputs yielding multiple outputs, efficiency literature usually employs frontier methods grounded in economic production theory. The analysis of firm's efficiency, considering production frontiers, was first introduced by Farrell (1957). His approach allows building an empirical efficiency frontier for the one input one output case. According to Farrell (1957), technical efficiency can be analysed in terms of realised deviations from an ideal frontier isoquant, characterising the relationship between observed production and some potential production level revealed from the observations. This definition of efficiency concerns the use of resources, that is, how efficiently inputs are transformed into outputs compared to the best performing unit. Thus, a production unit would be technically efficient if it is impossible to produce more of any output without producing less of some other output or consuming more inputs (Koopmans, 1951).

Farrell's efficiency measure was popularised by Charnes, Cooper & Rhodes (1978), who introduced a technique to assess the efficiency of a sample of firms (decision making units, DMU, as defined by Charnes et al., 1978). This technique is best known as Data Envelopment Analysis (DEA) (see Ray, 2004). DEA-based measures are non-parametric deterministic techniques that, through linear programming mathematical models, approximate the true but unknown technology, imposing no restrictions on the sample distribution, and do not require input or output prices. Efficient decision making units shape the best practice frontier, while for the rest of units DEA computes an inefficiency

score indicating their distance to the frontier (Kumbahakar & Lovell, 2000). Thus, at its core DEA is a complex benchmarking technique, where all analysed units are compared against each other. Note that the frontier is considered to be the best available technology (i.e. it is an approximation of the real technology), and therefore the model projects inefficient units on it without proposing any improvement of efficient units. DEA is a well-known instrument for measuring efficiency, however, this dissertation will only use DEA models as a tool and further technical explanations will not be presented here. Nevertheless, essential details are reported to facilitate its understanding and justify its suitability.

As it was indicated above, the fundamental underlying assumption of DEA models is that any production unit (i) can produce $\mathbf{y} = (y_1, \dots, y_M) \in R_+^M$ units of output with $\mathbf{x} = (x_1, \dots, x_J) \in R_+^J$ units of inputs. This way, through DEA results it is possible to yield a convex production possibilities set that defines an empirical envelope surface (Paretian frontier), and firms (DMU's) that lie on this surface are deemed efficient, whereas observations that do not are considered inefficient. Once a DMU (i) is identified as inefficient, it is possible to determine the input-output combination that allows to create a hypothetical firm (i^*) that is on the efficiency production frontier, and will be the efficient reference set for the DMU under analysis (i).

Yet another assumption, many times treated superficially, relates to the returns to scales. This translates in defining how the frontier production function is characterised, giving place to two possible formulations that depend on the assumption made about returns to scale (Cooper, Seiford & Tone, 2007). On the one hand, if the technology is characterised by constant returns to scale (CRS), the efficiency measure obtained is called overall technical efficiency and it shows how DMUs can linearly scale their resources (inputs) and results (outputs) leaving no change in average productivity. On the other hand, when the technology is characterised by variable returns to scale (VRS) efficiency scores emerge from a more flexible model that allows estimating distances to the production frontier controlling for the size of the benchmarks.

While assuming constant returns to scale has attractive properties, existing literature signalled that on most occasions the true technology experiences variable returns to scale (VRS). For instance, Chambers & Pope (1996) argue that restricting the returns to scale to constant should be avoided unless one analyses firms in long-run equilibrium. Moreover, and contrary to the analysis based on technical efficiency under constant returns to scale, pure technical efficiency (VRS) does not include scale efficiency, and is therefore more closely linked to reforming firm operations in the short term.

Third, when modelling DEA technology (T) is usually defined assuming convexity (VRS), and strong disposability of inputs and outputs. The strong disposability constraint imposes that a larger quantity of inputs can be used to produce the same quantities of outputs, or fewer outputs can be produced from a certain level of inputs. The technology described is modelled in equation [5] as follows:

$$\begin{aligned}
 T = \{(\mathbf{x}, \mathbf{y}) : & \sum_{i=1}^N \lambda^i y_m^i \geq y_m^i \geq 0, \quad m = 1, 2, \dots, M \\
 & \sum_{i=1}^N \lambda^i x_j^i \leq x_j^i, \quad j = 1, 2, \dots, J \\
 & \sum_{i=1}^N \lambda^i = 1 \\
 & \lambda^i \geq 0, \quad i = 1, 2, \dots, N\}
 \end{aligned} \tag{5}$$

Note that [5] develops the traditionally employed technology that defines outputs (\mathbf{y}) as a function of the vector of input (\mathbf{x}), and strong disposability of inputs and outputs. Also, the inclusion of $\sum_{i=1}^N \lambda^i = 1$ as an additional constraint to equation [5] allows assuming convexity to the model proposed, that is, the technology in [5] is characterised by variable returns to scale (VRS).

Finally, a last restriction concerning input or output orientation must be chosen. This decision brings about important implications as the results emerging are subject to changes depending on whether firms under analysis are considered as input ‘minimisers’ or output ‘maximisers’. In the input oriented approach, the possibility of reducing inputs

for the given value of outputs is considered, while the output orientation deals with the expansion of outputs from a given set of inputs. It is evident that the difference between the two specifications consists of the ability of each DMU to control input or output quantities.

For the purposes of this dissertation, and considering that the analysis focuses on public universities, we prefer to maintain output orientation in all the DEA models in our study because real world managers are never given a bundle of inputs and told to produce the maximum output from it. To the contrary, they are given output targets and told to produce it most efficiently, i.e., with minimum inputs (Sengupta, 1987: 2290). Nevertheless, the output orientation is also important for organisations. This is especially the case of public sector (or non-for-profit), where the workforce and the budget tend to be fixed and managers of these organisations are asked to produce the maximal possible output given the resources available. This is clearly the case of the public education system, and in the case of the universities under analysis, we defined their objective function according to maximisation criteria of academic and knowledge transfer activities.

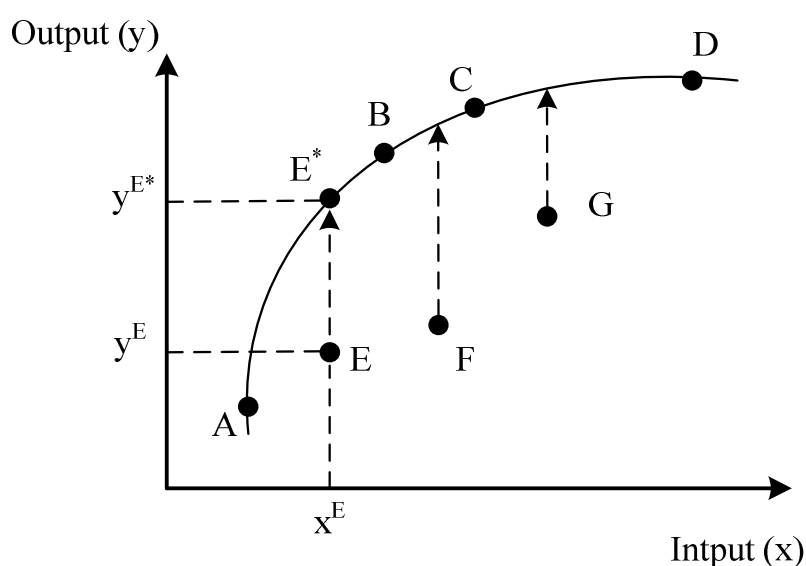
Taking into account all these considerations, to correctly model the technology described in [5] in terms of a linear program, and compute the efficiency score for each university, one must solve:

$$\begin{aligned}
 T(x^{i'}, y^{i'}) &= \max \delta^i \\
 \text{subject to } & \sum_{i=1}^N \lambda^i y_m^i \geq \delta^i y_m^{i'} \quad , m = 1, \dots, M \\
 & \sum_{i=1}^N \lambda^i x_j^i \leq x_j^{i'} \quad , j = 1, \dots, J \\
 & \sum_{i=1}^N \lambda^i = 1 \\
 & \lambda^i \geq 0 \quad , i = 1, \dots, N
 \end{aligned} \tag{6}$$

The maximisation of δ^i in equation [6] implies the production of the highest level of outputs (\mathbf{y}) possible given the resources available (\mathbf{x}). The term δ^i represents the efficiency score obtained for each unit (university) and for efficient universities, situated

on the best practice frontier $\delta^i = 1$, whereas values of $\delta^i > 1$ show the degree of inefficiency of the distance function. Figure 3.1 presents a simplified representation of the distance function by illustrating the two-dimensional relation between inputs and outputs. For illustrative purposes, let us suppose that a fictitious university (E) exhibits inefficiency in the sector. To operate efficiently and reach the frontier (E^*), this university should expand its outputs at the same intensity by $\delta^i - 1$, while keeping its inputs fixed.

Figure 3.1. Efficiency assessment based on Data Envelopment Analysis.



Source: Self-devised.

Efficiency analyses based on DEA models have become popular because of the many advantages this technique has. DEA models are very flexible and they do not require the specification of any particular functional form for the best practice frontier. This is probably its most enviable property, as it is not possible a priori to know the underlying production relationships (Seiford & Thrall, 1990). This way, solving the DEA’s linear program leads to construct a benchmark production frontier from the observed input-output bundles for the firms included in the sample.

Second, the DEA approach is particularly suitable for modelling organisations with multiple inputs and/or outputs, and in the absence of market prices, which is hardly

accomplished in stochastic frontier analysis (Ray, 2004). This is especially attractive for governments and organisations such as hospitals or education centres, which have multiple missions and where prices are usually unknown or exogenously determined by political administrations. This implies that all DMUs must perform uniformly, and they have to operate under the same market conditions. Furthermore, DEA models permit the inclusion of several input-output criteria simultaneously, bringing out the option to introduce into the analysis dissimilar variables.

DEA must be primarily considered as a diagnostic tool. It does not prescribe any strategy to transform inefficient units into efficient. It provides assistance and guidance for performance improvement by facilitating the localisation of best practice performing units amongst a group of like organisations. Hence, it can help institutions achieve their full potential once weaknesses have been identified.

Although DEA has many advantages, this methodology presents some constraints. Some of these are the sensibility of the results which are highly tied to the model specification (the variables selected or the orientation chosen), and the failure in identifying DMUs with significantly different productive behaviours. Also, and similar to any other analytical technique, DEA models cannot capture the potential effect that non-controllable factors can have over performance of the production units under analysis (Ray, 2004).

A second drawback commonly identified in the literature relates to the fact that DEA models do not assume any error term in the efficiency scores so, it is not possible to differentiate the inefficiency sources and determine if it comes from either a randomly distributed error or inefficiency (Green, Doyle & Cook, 1996).

A third limitation of DEA model deals with the restriction in the number of variables (inputs and outputs) that can be incorporated into the model, as the degrees of freedom are determined by the sample size. Thus, it becomes critical to choose those indicators that are proven to be highly representative of the production relation under analysis.

However, the lack of a systematic and uniform procedure for collecting comparable data makes it a difficult task.

Given all these considerations we believe that DEA is a reliable tool when it comes to assess HEIs (Thursby & Thursby, 2002). The first evidence of a DEA study applied to education institutions is found in the doctoral thesis by Rhodes (1978). Since this first application, the use of this technique has rapidly expanded to practically all research fields (Emrouznejad, Parker & Tavares, 2008). The large amount of existing works supports its uses (Lee & Park, 2005; Thursby & Thursby, 2002).

Table 3.9 summarises some studies from the literature addressing the evaluation of HEIs through the DEA approach. As it is shown, traditionally, DMUs represent individual universities from the same country/region, academic departments and research groups from the same university or departments and research groups from different HEIs that work in a similar area of knowledge.

Table 3.9. Examples in the literature of DEA-HEIs studies.

Unit of analysis	DMUs	Examples	Country
Universities	Public vs. private universities	Rhodes & Southwick (1986)	EUA
		Agasisti & Dal Bianco (2009)	Italy
	Universities grouped by academic spread	Athanassopoulos & Shale (1997)	UK
	Universities by countries	Warning (2004)	Germany
		Abbott & Doucouliagos (2003), Avkiran (2001)	Australia
		McMillan & Datta (1998)	Canada
		Breu & Raab (1994)	EUA
		Duch (2006), Gómez (2001)	Spain
		Forsund & Kalhagen (1999)	Norway
		Alfonso & Santos (2005)	Portugal
		Taylor & Harris (2004)	South Africa
		Celik & Ecer (2009)	Turkey
		Chang , Wu, Ching & Tang (2009)	Taiwan
Ng & Li (2000)	China		

Table 3.9. Continued.

Unit of analysis	DMUs	Examples	Country
Departments	Same area of knowledge (comparing different universities)	Harris (1990)	Australia
		Martínez (2000), Pina & Torres (1995)	Spain
		Korhonen, Tainio & Wallenius (2001)	Finland
		Johnes & Johnes (1993), Tomkins & Green (1988)	UK
	Departments from a single university	Arcelus & Coleman (1997), Van de Panne (1991)	Canada
		Martín (2003), Trillo (2001)	Spain
		Sarrico & Dyson (2000)	UK

6.2. Sample, variable definition and model specification

The data used in this study correspond to the academic periods 2006/07 and 2008/09. It should be noted that even though data collected refer to these periods, some reports¹³ adopt a different methodology to organise information. Therefore, data for some variables refer to the years 2006 and 2008 only.

Universities develop a wide array of activities and this implies the presence of multiple outputs that emerge from an input set. As it was pointed at the beginning of Part III, the information to carry out this analysis comes from RedOTRI annual surveys, CRUE reports, and Scopus datasets. From the RedOTRI reports we collected the information related to the number of spin-offs created by Spanish universities, whereas the information for the rest of variables comes from CRUE reports. Information about the number of publications was obtained from Scopus datasets. The original sample comprises data for all public universities in Spain (47). Yet, in the interest of following a rigorous methodology, we included in our final sample only those universities for which a complete dataset of the variables of interest could be clearly identified. The lack of information about the number of spin-offs created lead us to drop from the final sample the Universidad de Las Palmas de Gran Canaria, Universidad de León and the

¹³ Financial data from the CRUE report is collected annually, and the RedOTRI surveys only consider natural years instead of academic ones.

Universidad de Valladolid, so that the final sample consists of 44 Spanish public universities.

In order to study the overall efficiency of Spanish HEIs, we decided to select those inputs and outputs more frequently used in the literature. It is not surprising that the vast majority of studies addressing this topic from a multidimensional perspective points out that efficiency scores are distorted by the difficulties of effectively account for the quality of both inputs and outputs (De Groot, McMahon & Volkwein, 1991; Dundard & Lewis, 1995), compared to time and resource costs. Thus, we can find studies where missions are addressed individually (Daghbashyan, 2009; Warning, 2004), and considering different inputs regarding the specific goal to accomplish, in parallel with those studies where HEIs are evaluated in a combined model, mixing inputs and outputs from different missions (Agasisti & Pérez-Esparrells, 2010). In our opinion, we think that this second approach is better as universities have to simultaneously deal with different outputs and inputs have to be shared. Our final model includes three outputs (one for each mission) and four inputs, with the following characteristics (see Table 3.10 for the descriptive statistics).

To proxy the teaching mission, and unlike the previous chapter, we use the total number of graduated students for the academic year 2008/09. We do not express this variable as a proportion relative to the total number of students enrolled because the use of ratios in DEA models could potentially create contradictory results as one of the components of any ratio could be an input, leading to significant changes in the final results. Descriptive statistics in Table 3.10 show that on average, Spanish universities graduated 3,190.44 students during the academic year 2008/09. Taking into account the total number of students enrolled in all Spanish public universities (1,037,444 students), it can be seen that for every 100 students enrolled 14 completed their studies in that academic year.

Table 3.10. Descriptive statistics for the selected variables (DEA analysis).

Variable	Year	Obs.	Mean	Std. Dev.	Min	Max
Contemporary inputs (model 1)						
Academic staff	2008/09	47	2,055.04	1,284.15	459	6,249
Support staff	2008/09	47	1,061.66	760.37	252	4,136
Service expenditure*	2008	47	28,017.66	16,454.89	7,012.18	74,413.93
R&D income*	2008	47	31,607.22	26,482.78	2,399.75	118,627.94
Lagged inputs (model 2)						
Academic staff	2006/07	47	1,967.60	1,243.56	446	6,197
Support staff	2006/07	47	991.51	700.03	244	3,848
Service expenditure*	2006	47	23,832.38	14,661.22	6,838.23	73,250.85
R&D income*	2006	47	23,861.03	19,463.25	2,574.68	73,190.11
Outputs						
Graduates	2008/09	47	3,190.45	1,907.37	709	8,514
Papers	2009	47	921.19	694.83	139	3,236
Spin-offs	2009	44	2.59	3.08	0	14

* Monetary values are expressed in thousands of euro.

To the contrary, in the case of research and knowledge transfer outputs, we decided to maintain the same indicators as in the previous chapter. Thus, we considered the number of publications included in the Scopus database for 2009 (research output), and the number of spin-offs created in 2009 (knowledge transfer output).

As for the knowledge transfer output, it is worth noting that most studies focused on efficiency of universities do not include them in their input-output set. Some authors just mention them in the discussion (Agasisti, Dal Bianco, Landoni, Sala & Salerno, 2011; Parellada & Duch, 2006; Kim, 2011) but, due to the difficulties in obtaining relevant and reliable data, they just recognise its relevance as a growing stream of HEIs’ activities. Some studies using DEA approach and employing third stream magnitudes in their output set usually take into account the number of patents (Duch, 2006; Zhu, Zeng & Ren, 2010) or license income (Ken, Huang, Wu & Shiu, 2009). To the best of our knowledge, the number of spin-offs has not been used as an output, being the lack of information the main reason explaining the exclusion of this relevant factor from the analysis. For the purposes of this dissertation, it should be said that information about license income presented some inconsistencies and several missing values. In the case of

the number of patents, we do not include this into the output set on the basis that this variable only reflects the knowledge available. However, the number of spin-offs implies a deeper process where several agents within the university take part of, including those agents in charge of developing patents. Consequently, we followed the same criterion as in the case of the regression model ran in Section 5.4 (Chapter 5), that is, we selected the number of new academic ventures created by the university as the output linked to the third stream.

Inputs include faculty, both academic and administrative, current expenditures on goods and services, and income from R&D activities. The description of these variables follows.

As we previously highlighted in Section 3.3 (Chapter 3), universities can be deemed labour intensive organisations. Their labour force is a critical input, especially faculty members as they transmit knowledge to students as well as carry out most of research activities. In addition, the correct functioning of HEIs should also integrate human capital in all its forms including technical and administrative workers that on the one hand manage the day-to-day operations of the institution, and on the other hand, support teaching, research and knowledge transfer activities. Hence, the inputs related to labour comprise the number of faculty, and the number of technical and administrative staff. Looking at the descriptives for the contemporary model (Table 3.10), we observe that academic staff amongst Spanish public universities doubles administrative employees. The Universitat Autònoma de Barcelona (1.43) followed by the Universidad Politécnica de Cartagena and the Universidad Politécnica de Madrid (both 1.46) show the lowest ratio of academic staff per support staff, whereas the Universidad Carlos III de Madrid (3.00), the Universidad Rey Juan Carlos (2.95) and the Universidad del País Vasco (2.91) have the greatest proportion of faculty per administrative staff, meaning that faculty members in these later group of universities are more likely to carry out administrative tasks. We replicated the analysis for the case of the model specification based on the lagged inputs. Results do not vary significantly, and in terms of the proportion of faculty per administrative staff universities' ranking slightly changes. Figures reveal that large

universities exhibit low ratios of faculty per administrative staff. Given this, it is worth noting that we tested for the presence of any correlation between this ratio (faculty / administrative staff) and size (square meters). We found no significant correlation between these variables, which means that the distribution of the staff responds to different criteria.

Similar to Agasisti & Pérez-Esparells (2010) and Buzzigoli, Giusti & Viviani (2010), we account for the different support and maintenance tasks undertaken by universities. Thus, the third input considered relates to the administrative cost of goods and services (Chapter 2 of universities' budget). This includes the running expenses in relation to goods and services, financial expenditures, flow of funds, capital expenses, real investment, renting payments, maintenance, equipment and supplies, services' reimbursement, publication expenditures and other expenses (financial assets plus financial liabilities). As shown in Table 3.10, we express this amount in thousands of euro. A direct comparison between the values for 2006 and 2008 reveals that Spanish public universities have increased their expenditures by 17.56% in 2008 as compared to the figures observed in 2006. The increase in this variable holds for all the sampled universities, excepting for the Universidad Pública de Navarra and the Universidad de Alicante which experienced a decrease of 15.04% and 4.36%, respectively. Universidad of Salamanca shows the greatest increase in terms of expenditure between 2006 and 2008 (46.18%).

Finally a fourth input was included, accounting for the incomes derived from R&D activities. Although this input can also be considered as a research output (Katharaki & Katharakis, 2010; Martín, 2006; McMillan & Chan, 2006), R&D income is an indirect measurement of academic research as it measures the inflow of financial resources resulting from the development of new research activities. Consequently, we consider this variable as an input in our final model specification (Tzermes & Halkos, 2010). Similar to the case of expenditures we observe that, on average and for 2008, income from R&D activities significantly grew 32.46%, relative to the figure shown in 2006. A more in-depth

analysis shows that 37 out of the 47 public universities in the sample increased their revenues. In addition, 5 universities grew over 100% in terms of income from R&D activities between 2006 and 2008. Only 10 universities show a fall in the income in 2008 compared to the figure obtained in 2006.

At this point an important consideration is worth noting. In order to control for potential endogeneity between inputs and outputs in our final data, we created two datasets: one including inputs that correspond to the academic year 2008/09 (model 1, Table 3.11), and another one including inputs for the previous academic year (2006/07) (model 2, Table 3.11). In both cases outputs introduced correspond to the academic year 2008/09. This way, two efficiency scores were obtained and we tested whether the inclusion of lagged inputs in our DEA estimation significantly affect the efficiency result. To do this so, we make use of the Z-Wilcoxon signed rank test. Through this procedure we test if, for each university in the final sample, the two estimations are significantly different from zero. If the null hypothesis is not rejected, then it can be said that the median difference in the efficiency scores do not significantly vary, regardless the inputs used correspond to the same academic year than the output set or inputs are introduced as lagged terms (Gibbons, 1993).

Table 3.11. DEA models tested.

Indicator	Year	Type	Model 1	Model 2
Academic staff	2008/09	Input	×	
Support staff	2008/09	Input	×	
Administrative cost	2008	Input	×	
R&D income	2008	Input	×	
Academic staff	2006/07	Input		×
Support staff	2006/07	Input		×
Administrative cost	2006	Input		×
R&D income	2006	Input		×
R&D income	2006	Input		×
Graduated	2008/09	Output	×	×
Papers	2009	Output	×	×
Spin-offs	2009	Output	×	×

The DEA efficiency measures for the two models were estimated, and the result of the Z-Wilcoxon signed rank test (Z -value: 0.319, p -value=0.7496) leads us to not reject the null hypothesis, which means that the two sets of scores obtained from the different models follow the same distribution. As a result, the analysis is based on that model that considers inputs as lagged terms (model 2). This approach to efficiency not only allows us controlling for endogeneity problems, but it also helps examining the time-varying relationship between inputs and outputs in our sample (Foltz, Barham, Chavas & Kim, 2011). This implies that our model specification takes into account the fact that research and knowledge transfer outputs are conditioned by time. For instance, reviews and publication timing cannot be determined by the researcher but rather by the corresponding agent, so therefore, research efforts exerted by faculty would be observable in following periods, that is, a time span exists between researching and publication processes. Similarly, the process of creating a spin-off firm varies a lot amongst academic ventures. Once more, efforts aiming at launching any spin-off would lead to the creation of the academic venture in subsequent period(s) (Lockett & Wright, 2005).

Efficiency scores were calculated using the OnFront 2.0 software. While other statistical packages (i.e. Frontier Analysis, DEA Solver Pro, GAMS) seem oriented towards managerial applications, OnFront has been widely used by economists, practitioners and researchers (Barr, 2004).

6.3. Results and discussion

In a first step, a DEA analysis was run for the whole sample (44 universities) and for the two different models suggested (one with lagged inputs and the other with contemporary ones). A summary of the results obtained is presented in the aforementioned Table 3.12, (for full details by university, see Appendix B) being coherent with previous studies on the efficiency of Spanish universities using a DEA approach (Agasisti & Pérez-Esparrells, 2010; Duch-Brown & Vilalta 2010). Results refer to the case where the technology is characterised by variable returns to scale (VRS).

Table 3.12. Descriptive statistics for the efficiency scores.

	Lagged model (VRS scores)
Mean	1.1244
Bottom quartile	1.0000
Median	1.0517
Upper quartile	1.2197
Std. Dev.	0.1521
Highest inefficiency	1.5185
# Efficient units	19
Total Obs.	44

The results in Table 3.12 indicate that, according to our model specification, universities’ inefficiency is on average 12.44%. This means that on average universities can potentially increase their outputs by 12.44% employing the same levels of inputs. As it can be observed, 19 universities are efficient and act as peers.

Table 3.13 presents the efficiency score estimated for each university in our final sample, whereas Table 3.14 displays the regional inefficiency levels amongst Spanish universities.

Table 3.13. Efficiency level exhibited by Spanish universities.

University	Acronym	Location	Efficiency score
U. de Almería	UALM	Andalucía	1.0000
U. de Cádiz	UCA	Andalucía	1.2086
U. de Córdoba	UCO	Andalucía	1.1021
U. de Granada	UGR	Andalucía	1.0000
U. de Huelva	UHU	Andalucía	1.2806
U. de Jaén	UJA	Andalucía	1.0000
U. de Málaga	UMA	Andalucía	1.1575
U. Pablo de Olavide	UPO	Andalucía	1.4285
U. de Sevilla	USE	Andalucía	1.0661
U. de Zaragoza	UZA	Aragón	1.4101
U. de Oviedo	UOV	Asturias	1.0352
U. de las Islas Baleares	UIB	Islas Baleares	1.1355
U. de La Laguna	ULL	Islas Canarias	1.0240

Table 3.13. Continued.

University	Acronym	Location	Efficiency score
U. de Cantabria	UCN	Cantabria	1.3511
U. de Castilla-La Mancha	UCLM	Castilla-La Mancha	1.0671
U. de Burgos	UBU	Castilla y León	1.0000
U. de Salamanca	USAL	Castilla y León	1.0000
U. Autònoma de Barcelona	UAB	Catalunya	1.0000
U. de Barcelona	UB	Catalunya	1.0000
U. de Girona	UDG	Catalunya	1.3324
U. de Lleida	UDL	Catalunya	1.5185
U. Politècnica de Catalunya	UPC	Catalunya	1.0000
U. Pompeu Fabra	UPF	Catalunya	1.2151
U. Rovira i Virgili	URV	Catalunya	1.0000
U. de Alicante	UAL	Comunidad Valenciana	1.2038
U. Jaume I de Castellón	UJCS	Comunidad Valenciana	1.2335
U. Miguel Hernández de Elche	UMH	Comunidad Valenciana	1.0000
U. Politècnica de València	UPV	Comunidad Valenciana	1.1975
U. de València (Estudi General)	UVEG	Comunidad Valenciana	1.0000
U. de Extremadura	UEX	Extremadura	1.0000
U. de La Coruña	ULC	Galicia	1.2455
U. de Santiago de Compostela	USC	Galicia	1.0783
U. de Vigo	UVI	Galicia	1.0000
U. de Alcalá de Henares	UAH	Madrid	1.2835
U. Autónoma de Madrid	UAM	Madrid	1.0000
U. Carlos III de Madrid	UC3M	Madrid	1.0373
U. Complutense de Madrid	UCM	Madrid	1.0000
U. Politècnica de Madrid	UPM	Madrid	1.4507
U. Rey Juan Carlos	URJC	Madrid	1.1119
U. de Murcia	UMU	Murcia	1.0000
U. Politècnica de Cartagena	UPCT	Murcia	1.0000
U. Pública de Navarra	UPN	Navarra	1.2985
U. del País Vasco	EHU	País Vasco	1.0000
U. de La Rioja	URI	La Rioja	1.0000
Average			1.1244

Figures in Table 3.14 not only show that all Spanish regions are represented, but also that the greatest number of universities is found in the regions of Andalucía (9 universities), Catalunya (7), Madrid (6) and Comunidad Valenciana (5). In terms of regional inefficiency, the territories with multiple universities that exhibit higher efficiency levels are Castilla y León (Table 3.13: 2 efficient universities) and Murcia (Table 3.13: 2 efficient universities).

Table 3.14. Efficiency in Spanish universities (by region).

Region	Average inefficiency	Number of universities
Andalucía	1.1382	9
Aragón	1.4101	1
Asturias	1.0352	1
Illes Balears	1.1355	1
Islas Canarias	1.0240	1
Cantabria	1.3511	1
Castilla-La Mancha	1.0671	1
Castilla y León	1.0000	2
Catalunya	1.1523	7
Comunidad Valenciana	1.1270	5
Extremadura	1.0000	1
Galicia	1.1079	3
Madrid	1.1472	6
Murcia	1.0000	2
Navarra	1.2985	1
País Vasco	1.0000	1
La Rioja	1.0000	1
Average	1.1244	44

To the contrary, universities in the territories of Catalunya (average inefficiency: 15.23%), Madrid (14.72%), and Andalucía (13.82%) show the poorest efficiency results. However, it is worth noting that in the case of Catalunya, the average inefficiency is heavily biased by Universitat de Lleida (Table 3.13: 51.85% inefficiency), and the average inefficiency level excluding this centre falls to 9.12%. A similar picture is observed in the case of Madrid, where Universidad Politécnica de Madrid (Table 3.13: 45.07% inefficiency)

negatively biases the results. For this region, the average inefficiency without considering this university is 8.65%. In Andalucía, regional inefficiency is influenced by Universidad Pablo de Olavide (Table 3.13: 42.85% inefficiency), and the average inefficiency in this territory decreases to 10.19% when this university is not considered.

On the basis that Spain is a country where it is possible to find severe regional differences in terms of economic development and territorial investments (public and private) (Buesa et al., 2002), we also compare universities' efficiency amongst Spanish regions. It is widely recognised that, given their industry configuration, there are four regions in Spain that represent the economic engines of the country. These regions, Catalunya, Madrid, País Vasco and Navarra not only have the greatest economic and technological development, but also have a highly developed industry fabric (Buesa et al., 2002; Navarro Arancegui & Gibaja Martíns, 2009). In particular, according to Gómez Uranga, Zabala Iturriagoitia & Fernández de Lucio (2009), Catalunya and Madrid are the regions that have the greatest critical mass of businesses as a consequence of their economic entity, while País Vasco and Navarra have a mature and highly industrialised territory, also committed to the development of new industry clusters.

Hence, we argue that universities in these territories are likely to exhibit better efficiency levels given their regional-specific distinctiveness. Therefore, we ran a test to compare inefficiency in these regions relative to that shown by universities in the rest of Spanish territories. Even though inefficiency of universities in the aforementioned regions (14.99%) is higher in absolute terms than the inefficiency level of universities located in the remaining Spanish regions (11.11%), the result of the *t-test* (*t*-value: -0.7957) indicates that efficiency is not conditioned by the territory where the university is located. This finding points towards a homogenous higher education system, where Spanish universities are achieving their different outputs (academic and related to third stream objectives) regardless the economic context of the region they are located.

To further corroborate the consistency of the efficiency scores, we compare our results with the ranking of universities proposed by two of the most recognised international

agencies worldwide: the Academic Ranking of World Universities (ARWU)¹⁴ developed by the Shanghai Tiao Tong University and the QS World University Ranking (QS).¹⁵ In particular, in the 2009 edition, the ARWU ranked 11 Spanish public universities in the top 500 worldwide, whereas the QS placed 12 universities in the top 600. Even though the methodology used in these two rankings substantially differs from that used in this study (DEA), results partially converge. This is the case of the UB, UAM, UCM, UAB, UVEG, and UGR. These universities are efficient and are also included in these selected rankings.

Nevertheless a more in-depth interpretation is needed. As shown in Table 3.15, it is surprising that inefficient universities such as USE, USC, UPV, UPF, and UZA are better ranked in these two rankings than some efficient universities. This is the case of the UZA, a university that exhibits one of the highest inefficiency levels (41.01%).

Table 3.15. Comparison between efficiency scores and international rankings.

University	Efficiency score	ARWU	QS
U. de Barcelona	1.0000	151-200	171 (57.16)
U. Autònoma de Madrid	1.0000	201-302 (1)	215 (51.94)
U. Complutense de Madrid	1.0000	201-302 (2)	252 (47.75)
U. Autònoma de Barcelona	1.0000	303-401 (1)	211 (52.15)
U. de València (Estudi General)	1.0000	201-302 (3)	401-500 (2)
U. de Granada	1.0000	402-501 (1)	401-500 (1)
U. de Navarra (Private university)	1.0000		381 (37.01)
U. de Sevilla	1.0661	402-501 (4)	501-600 (1)
U. de Santiago de Compostela	1.0783	402-501 (3)	501-600 (3)
U. Politècnica de València	1.1975	303-401 (2)	501-600 (2)
U. Pompeu Fabra	1.2150	402-501 (2)	324 (41.51)
U. de Zaragoza	1.4101	402-501 (5)	

It is also remarkable the way universities are ranked, as there are clear methodological differences between these two rankings. For instance, UB is according to these two

¹⁴ <http://www.arwu.org/>

¹⁵ <http://www.topuniversities.com/university-rankings/world-university-rankings/home>

agencies the best ranked Spanish university, whereas for the rest of Spanish public universities their positions in these rankings vary significantly. This can be explained by the discrepancies in the selection of the indicators used to create these assessment tools. As shown in Chapter 3, rating systems have been subject to criticism as they present certain inconsistencies in the selection and weighting of their specific indicators. As it can be seen in Table 3.16, differences between the two aforementioned rankings are notorious. The ARWU ranking gives greater importance to research outputs (40%), whereas the QS gives no weight to this criterion and assigns 60% to the prestige of the university (40% from surveys, and 20% related to research impact). Another important difference relates to the quality of education. The ARWU proxies quality education through Nobel prizes and Fields Medals obtained by alumni. The QS uses the ratio of students per faculty to measure this concept. It is worth noting that these rankings do not consider all potential dimensions related to university’s objectives, including third stream activities. Therefore, these rankings present an incomplete picture of university’s performance and quality, and consequently their partial results should be taken with a grain of salt.

Table 3.16. Approach used by ARWU and QS to rank universities.

Criteria	ARWU		QS	
	Quality of education	Alumni with Nobel Prizes and Fields Medals	10%	Faculty student ratio
Internationalisation			International student ratio	5%
			International faculty ratio	5%
Size	Per capita academic performance of an institution	10%		
Research output	Papers published in Nature and Science	20%		
	Papers indexed in SCI & SSCI	20%		
Impact	Highly cited researchers	20%	Citations (Scopus) per faculty	20%
Prestige	Staff with Nobel Prizes and Fields Medals	20%	Academic peer review	40%
			Global employer review	10%

Source: Adapted from Aguillo, Bar-Ilan, Levene & Ortega (2010), based the information from <http://www.arwu.org/ARWUMethodology2009.jsp> and <http://www.topuniversities.com/world-university-rankings/understanding-qs-world-university-rankings%C2%AE-methodology>

In order to explain differences in universities' performance arising from exogenous variables, that is, uncontrollable environmental factors, in a second-stage analysis we ran a truncated regression model using the DEA scores as the dependent variable. Following Simar & Wilson (2007), the highly skewed and truncated distribution of the DEA scores lead to conclude that an analysis based on a truncated regression is the most appropriated. Although truncated regression fits relatively well to the data, results showing the significance of parameter estimates linked to the explanatory variables are not presented because they are weak. Due to this lack of significance, results are not reported but are included in Appendix C.

Chapter 7: Patterns followed by Spanish universities

According to the results obtained in the previous chapter (Chapter 6), we observe that structural variables do not help explaining performance differences amongst Spanish universities. However we are aware that there may exist potential complementarities between the different explanatory variables considered when it comes to explain universities' performance, as suggested in previous studies (García-Aracil & Palomares-Montero, 2008; Huggins & Johnston, 2009; Kelly, Marsh & McNicoll, 2010; 2007; Nilsson, 2005; Siegfried, Sanderson & McHenry, 2007). Thus, the purpose of this last empirical chapter, as a compilation of the results obtained so far, is to test whether Spanish universities are affected by the exogenous variables simultaneously. We also aim at looking for similarities and differences amongst HEIs that can give us a better grasp on how these institutions behave according to their environment and internal strategies. This way, we expect to understand the underlying rationale to their strategic approach adopted in terms of their missions.

7.1. Cluster analysis and model specification

Cluster analysis is a technique that allows identifying groups of observations with different behavioural paths, given the presence of specific variables that are expected to influence the sampled units (Everitt, 1980). For the purposes of this analysis, we introduce exogenous factors, alien to universities control, in order to inquire for the existence of similar performance patterns amongst universities. This way, the proposed grouping of universities permits us to assess whether university strategic choices and outputs are affected by economic conditions and certain policies adopted by public administrations.

Five exogenous variables were chosen to cluster Spanish universities, and descriptive statistics are presented in Table 3.17. To account for the inflow of students that universities face, the first variable considered is the ratio of total number of students enrolled at the university divided by total faculty. Despite this variable can be seen as a

strategic one, the number of students is exogenous with respect to the university, as final enrolment decisions are made by students. Although the size of the university conditions its capacity to absorb students, it has been recognised that factors related to course content, economic conditions (which can affect tuition), reputational effects as well as the location of the university and the social consideration also exert an impact on the number of enrolments (Hoare, 1991; Marginson, 2006; Moogan, Baron & Harris, 1999).

Table 3.17. Cluster analysis: Descriptive statistics for the selected variables.

Variable	Obs.	Mean	Std. Dev.	Min	Max
Students / Faculty	47	10.8363	1.8469	7.7148	14.3636
Educational diversity	47	3.1671	0.8005	1.1011	4.2368
Self-financing (%)	47	0.1775	0.0388	0.1163	0.3052
Expenditure per student	47	8.8280	0.1791	8.5039	9.1770
Expenditure on R&D / GDP	47	0.0124	0.0045	0.0036	0.0201

Universities choose the academic degrees offered and the minimum number of students that can enrol each faculty. Yet, the degree of specialisation achieved comes from several factors where economic sustainability and market demand play a key role. As a result, the number of degrees and more specifically the educational diversity has to be reflected in the analysis. To do this so we introduced the Herfindahl index previously used in Chapter 5, to account for the degree diversification amongst the sampled universities.

To take into consideration financial resources, we included two variables. First, we considered the university’s self-financing capability, measured as the proportion of own resources relative to total financial resources. It should be noted that, rather than measuring the economic power of universities, through this variable we aim at capturing the capacity that each university has to fund their activities with internal resources (teaching) and external financial resources coming from different activities (research and knowledge transfer). Second, we included the ratio of current public expenditure divided by the total number of students. This measure could proxy the investments that universities make on their students avoiding size effects (Fundación CYD, 2010). This variable is heavily conditioned by public expenditure on higher education. Therefore, the

result of this variable is not influenced by universities, but rather is exogenously determined by governmental authorities.

Finally, we are also interested in including in the analysis an exogenous variable that reflects the geographic location of universities. Following the NUTS-2 criterion, Spain is divided in 17 regions (autonomous communities). Based on this approach, and given that in the literature there is no clear agreement on what public policies and regional factors may impact HEIs' performance (García-Aracil & Palomares-Montero, 2008), we introduced four factors that may be relevant to explain the achievement of university's objectives. The description of these factors follows: (1) the wealth of the region, proxied by the regional Gross Domestic Product per capita (GDP divided by total population); 2) the regional public investment on tertiary education, measured as the ratio of public expenditure on tertiary education divided by the regional GDP; (3) the R&D intensity which is calculated as the ratio of regional R&D expenditure divided by the regional GDP; and (4) the employment in R&D sectors relative to total employment in the region. Information for these variables was gathered from the Spanish National Institute of Statistics (INE), for the year 2008, and descriptive statistics for the 17 regions are depicted in Table 3.18.

Before to run the cluster analysis, we consider important to scrutinise the data and assess which regional factors from the aforementioned help explain differences in university' outputs (graduates, publications and spin-offs) as well as in their efficiency (using the score obtained in Chapter 6). In this first exploratory analysis we use the Mann-Whitney *U-test* as our principal method. Through this procedure it is possible to test whether the observed median differences between two groups of universities do not share the same central tendency. This statistical test is appropriate for this type of analysis as we can assess whether the medians of the two groups are significantly different. The analysis also considers a *t-test* of mean differences to further corroborate the findings obtained. Results are presented in Table 3.19.

Table 3.18. Mean values for the selected variables by regions (year 2008).

Variable	Num. of HEIs	GDP per head (euros)	Public expenditure on tertiary education (%)	R&D intensity	Employment in R&D sectors (%)
Andalucía	9	18,384	96.9895	1.03	0.031
Aragón	1	26,093	11.3765	0.97	0.095
Asturias	1	22,427	9.6477	0.36	0.047
Islas Baleares	1	25,706	3.6532	0.36	0.028
Islas Canarias	2	20,827	15.0784	0.63	0.020
Cantabria	1	24,222	4.9476	1.01	0.063
Castilla-La Mancha	1	18,425	24.5573	0.72	0.037
Castilla y León	4	23,206	13.0661	1.27	0.061
Catalunya	7	27,897	54.2676	1.62	0.102
Comunidad Valenciana	5	21,392	57.9852	1.05	0.048
Extremadura	1	16,845	9.5259	0.86	0.024
Galicia	3	20,546	29.6164	1.04	0.051
Madrid	6	30,928	57.5259	2.01	0.104
Murcia	2	19,694	14.2567	0.86	0.027
Navarra	1	30,296	3.0960	1.94	0.098
País Vasco	1	31,791	14.7944	1.98	0.116
La Rioja	1	25,631	1.7900	1.01	0.042
Average	47	404,310	422.17416	18.72	0.994

Source: Spanish National Institute of Statistics (INE).

Our results in Table 3.19 indicate that, in our sample, the only regional economic factor that consistently affects universities’ performance (teaching performance in this case) is the R&D intensity (regional R&D expenditure divided by regional GDP). In particular, universities located in regions that show an above-the-median R&D intensity exhibit a significantly higher level of graduates than those below the median. A similar pattern is observed when exploring basic research outputs. Universities located in regions with high levels of R&D intensity (above the median) show a higher number of publications, however, the significance of this result is partially supported (*t-test*). Despite the lack of significance, it is worth mentioning that, from a descriptive perspective, efficient universities and those creating more spin-offs are concentrated in territories with lower levels of both GDP per capita and R&D intensity (Table 3.19). These may suggest that other than structural factors, universities heavily rely on their own resources and capabilities to achieve their objectives (Altbach, 2009). Based on this, we decide to use the regional R&D intensity as the structural factor to be included in the cluster analysis.

Table 3.19. Mann-Whitney *U*-tests and *t*-tests.

	GDP per head		Public expenditure on tertiary education (%)		R&D intensity		Employment in R&D sectors (%)	
	< Median	> Median	< Median	> Median	< Median	> Median	< Median	> Median
Graduate students	3,186.22 (1,832.03)	3,194.50 (2,016.35)	2,893.33 (1,652.11)	3,591.55 (2,185.88)	2,948.35 (1,721.89)	3,422.46 (2,079.74)	3,051.96 (1,903.33)	3,323.17 (1,942.53)
Mann – Whitney test	-1.128		-0.452		-2.043 **		-1.426	
<i>t</i> -test	-1.2041		-0.3874		-2.2595 **		-1.6503	
Observations	23	24	23	24	23	24	23	24
Publications	791.61 (501.94)	1,045.38 (831.69)	876.22 (716.28)	981.90 (678.26)	712.13 (421.74)	1,121.74 (842.53)	742.83 (509.36)	1,092.13 (809.39)
Mann – Whitney test	-0.809		-0.549		-1.532		-1.532	
<i>t</i> -test	-0.6687		-0.7355		-1.6766 *		-1.5984	
Observations	23	24	23	24	23	24	23	24
Spin-offs	3.00 (3.83)	2.18 (2.11)	2.58 (3.24)	2.60 (2.96)	3.32 (3.80)	1.86 (1.98)	2.77 (3.85)	2.41 (2.13)
Mann – Whitney test	0.012		-0.096		1.004		-0.741	
<i>t</i> -test	0.8779		-0.0178		1.5926		0.3873	
Observations	22	22	22	22	22	22	22	22
Efficiency	1.1042 (0.1221)	1.1445 (0.1778)	1.1130 (0.1603)	1.1381 (0.1445)	1.1177 (0.1419)	1.1310 (0.1647)	1.0973 (0.1189)	1.1515 (0.178)
Mann – Whitney test	-0.441		-0.787		0.171		-0.710	
<i>t</i> -test	-0.8706		-0.5460		-0.2867		-1.1881	
Observations	22	22	22	22	22	22	22	22

Standard deviation is presented in brackets. *, **, *** indicate significance at the 10%, 5%, and 1%, respectively.

Given the aforementioned considerations, we choose as explanatory factors the five variables presented in Table 3.17: 1) the ratio of total number of students enrolled at the university divided by total faculty, 2) the educational diversity, 3) the university’s self-financing capability, 4) the ratio of current public expenditure divided by the total number of students, and 5) the R&D intensity.

The final sample used for the cluster analysis comprises 44 Spanish public universities. This is so because information about the number of spin-offs in 2009 is incomplete for Universidad de Las Palmas de Gran Canaria, Universidad de León, and Universidad de

Valladolid. Consequently, their efficiency scores cannot be estimated. In order to ensure the robustness of the results of the cluster analysis, we included in the final sample those universities with complete information, that is, excluding the three aforementioned institutions from the sample.

Concerning the econometric technique used for this analysis, we chose to run a non-hierarchical cluster analysis (K-means) using the exogenous variables previously described. Through this procedure, initial cluster centroids (the ‘centre points’ of clusters along input variables) are selected, and each observation is assigned to the group with the nearest centroid (Everitt, 1980). As each new observation is allocated, the cluster centroids are recomputed. Multiple passes are made through the data to allow observations to change cluster membership based on their distance from the recomputed centroids, which is the main advantage of non-hierarchical methods over hierarchical ones. The final solution is reached once no observations change clusters (Anderberg, 1973).

However, the efficient optimisation of the within-cluster homogeneity and between-cluster heterogeneity implies that the number of clusters be specified prior the estimation. This represents the main pitfall of non-hierarchical cluster analysis, because in many research fields (including social sciences) cluster analyses are often exploratory. Consequently, we adopted two approaches to corroborate the number of clusters and the validity of our analysis. First, we computed the Calinski & Harabasz (1974) statistic. This

index is obtained as $CH(k) = \frac{B(k)/k-1}{W(k)/n-k}$, where $B(k)$ and $W(k)$ are the between and

within-cluster sums of squares, with k clusters and a sample size of n observations. Since the between-cluster difference should be high, and the within-cluster difference should be low, a largest $CH(k)$ value indicates the best clustering. Despite this index can be computed after a hierarchical clustering, we decided to compute it after a non-hierarchical cluster analysis, in order to compare the resulting $CH(k)$ values to alternative number of clusters. From our data, the number of clusters that maximises the $CH(k)$ index is 5 (*pseudo-F* value=70.41). Therefore, the final non-hierarchical cluster asks for a five-ways

division. Second, we ran a discriminant analysis to further validate our cluster analysis. Results from the discriminant analysis are presented in Table 3.20, indicating that our approach to cluster is appropriate.

Table 3.20. Results of the discriminant analysis.

True Groups	Classification					Observations
	1	2	3	4	5	
Group 1	8 (100.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	8
Group 2	0 (0.00%)	12 (100.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	12
Group 3	0 (0.00%)	0 (0.00%)	8 (100.00%)	0 (0.00%)	0 (0.00%)	8
Group 4	0 (0.00%)	0 (0.00%)	0 (0.00%)	7 (100.00%)	0 (0.00%)	7
Group 5	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	9 (100.00%)	9
Total	8 (18.18%)	12 (27.27%)	8 (18.18%)	7 (15.91%)	9 (20.45%)	44

7.2. Cluster analysis: Results

Having corroborated that clusters emerging from our model specification are valid, we present in Table 3.21 detailed information about the universities included in each group.

From Table 3.21 it can be seen that the five groups emerging from our analysis exhibit some relevant within similarities (at the column level) and between differences (at the row level). As a result, universities can be grouped as follows: efficient universities (cluster 1), small universities with a lack of resources and institutional support (cluster 2), universities fostering the creation of spin-offs (cluster 3), specialised universities (cluster 4), and universities more concerned in graduating students (cluster 5).

Table 3.21. Classification of universities based on the cluster analysis.

Cluster	Obs.	Main trait	Universities
Cluster 1	8	Efficient universities	Autónoma de Madrid (UAM), Barcelona (UB), Cádiz (UCA), Complutense (UCM), Illes Balears (UIB), Miguel Hernández (UMH), Oviedo (UOV), Salamanca (USAL)
Cluster 2	12	Small HEIs with lack of resources and institutional support	Alicante (UAL), Castilla-La Mancha (UCLM), Córdoba (UCO), Extremadura (UEX), Huelva (UHU), Laguna (ULL), Murcia (UMU), Pablo Olavide (UPO), Santiago de Compostela (USC), La Rioja (URI), Rovira i Virgili (URV), Vigo (UVI)
Cluster 3	8	Spin-off focus (mainly from Andalucía)	Almería (UALM), Granada (UGR), Jaén (UJA), La Coruña (ULC), Málaga (UMA), Rey Juan Carlos (URJC), Sevilla (USE), València (UVEG)
Cluster 4	7	Polytechnic and specialised HEIs	Burgos (UBU), Carlos III (UC3M), Jaume I (UJCS), Politècnica de Catalunya (UPC), Politècnica de Cartagena (UPCT), Politècnica de Madrid (UPM), Politècnica de València (UPV),
Cluster 5	9	Graduate-focus	Autònoma de Barcelona (UAB), Alcalá de Henares (UAH), Cantabria (UCN), Girona (UdG), Lleida (UDL), Pompeu Fabra (UPF), Pública de Navarra (UPN), País Vasco (EHU), Zaragoza (UZA)

Aiming at understanding the underlying rationale for the cluster’s outputs, we present in Table 3.22 the descriptive statistics for all the variables considered throughout this empirical study, grouped in three main panels: performance variables (indicating universities’ main goals), organisational variables (those included in the regressions in Chapter 5) and structural variables (referring to the potential effect spillovers might have).

Universities in **cluster 1** are, on average, the most efficient ones (average inefficiency: 4.74%). This group includes three universities with more than 450 years of experience (UB: 559 years old, UCM: 510 years old, and USAL: 791 years old), whereas the rest of universities in this group are relatively new, with less than 41 years of experience. Universities in this group are also the largest, in terms of education installations (average size: 355,312 square meters). Despite the size differences, it should be noted that universities in this group have the lowest proportion of teaching space relative to their size. They also show the greatest proportion of faculty members with a PhD (67.11%), and the greatest set of degrees offered (degrees in nearly four academic categories). Regarding financial issues, it is worth highlighting that both the self-financing capacity (measured as the proportion of own resources relative to total financial resources) and the expenditure per student (measured as the current public expenditure divided by the total

number of students) are low amongst these universities (fourth and third ranked, respectively). As for the performance variables analysed, universities in this group do not seem to excel in any, however, it is important to remark that they are very good at publishing, having a high rate of papers per faculty (second ranked), and the highest number of thesis dissertations. Nevertheless, they fail in the creation of spin-offs (two on average, and with two universities reporting zero spin-offs in 2009). As for the teaching mission, universities in this group are the third ranked in terms of graduates per students enrolled.

The results for universities in **cluster 2** show that they are more oriented towards teaching objectives rather than research or knowledge transfer missions. The figures in Table 3.22 reveal that universities in this cluster are the smallest (average size: 251,285 square meters). The teaching orientation of these universities becomes evident in the results presented in Table 3.23. Here it can be seen that five universities in this group (42% of the total number of universities in this cluster) have an above the median level of graduates per students enrolled, compared to full sample of universities. This only holds for undergraduate studies, as the stock of knowledge is by far the lowest in terms of patents and thesis dissertations (Table 3.22). Results for the self-financing ratio show that these universities have a very constrained financial capacity, more specifically, they have the poorest self-financing ratio (16.19%). Based on these findings, our results suggest that universities in this group lack internal resources and capabilities, have a restricted financial capacity, and the availability of appropriate infrastructures for the development of their day-to-day activities is limited. This resource shortage is also observed in terms of human capital, as they have a reduced and a relatively inexperienced staff (low percentage of both PhD faculty members and faculty involved in knowledge transfer activities). Furthermore, these institutions are located in Spanish territories where R&D investments are the lowest, suggesting a poor institutional support.

Table 3.22. Descriptive statistics for the cluster analysis.

	Cluster 1		Cluster 2		Cluster 3		Cluster 4		Cluster 5	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Performance variables										
DEA score	1.0474	0.0803	1.0987	0.1377	1.0726	0.0924	1.1313	0.1719	1.2677	0.1738
Graduates	4,095.88	2,509.25	2,706.33	1,140.43	4,217.50	2,420.04	2,656.71	1,417.07	2,767.56	1,939.15
Flow: Graduates / Students	0.1488	0.0159	0.1509	0.0246	0.1365	0.0198	0.1434	0.0260	0.1651	0.0149
Academic performance (06/07)	62.9794	3.1322	60.3580	5.1800	58.440	2.3123	59.1974	7.0829	67.9475	6.2507
Failure rate	0.2051	0.0396	0.1840	0.0677	0.1614	0.0299	0.1942	0.0551	0.2041	0.0470
Papers	1,367.88	1,078.68	662.67	333.75	990.63	627.55	991.57	738.93	909.89	666.22
Papers / Faculty	0.4761	0.1944	0.4236	0.1307	0.4192	0.0685	0.4925	0.1914	0.4463	0.1114
Spin-offs	2.0000	1.5119	1.5000	1.7321	4.1250	3.9438	3.4286	5.4729	2.5556	1.9437
Organizational variables										
Human Capital										
Students / Faculty	10.0931	0.4583	11.7753	0.2919	13.3944	0.6589	10.0823	0.7409	8.2607	0.3651
PhD Faculty (%)	0.6711	0.1148	0.6321	0.1034	0.6669	0.0780	0.5447	0.0829	0.5937	0.0506
Faculty in KT (%)	0.2078	0.1949	0.2187	0.0754	0.2068	0.0677	0.3498	0.1482	0.2388	0.1512
Infrastructure										
Size (square meters)	355,312.80	237,874.00	251,284.50	141,975.50	300,948.70	151,088.80	259,985.60	174,847.00	274,534.80	203,374.10
Teaching area	0.2817	0.1071	0.3002	0.0877	0.2983	0.0614	0.3099	0.1170	0.3235	0.0922
Research area	0.1522	0.0824	0.1516	0.0569	0.1488	0.0416	0.1785	0.0632	0.1664	0.0540
Incubator	0.8750	0.3536	0.4167	0.5149	0.7500	0.4629	0.5714	0.5345	0.7778	0.4410
Science Park	0.6250	0.5175	0.5833	0.5149	0.5000	0.5345	0.8571	0.3780	0.6667	0.5000
Age KTO	18.8750	4.4541	16.9167	3.6546	16.8750	4.5493	16.8571	4.8452	19.3333	2.8284
Knowledge accumulation										
Thesis	278.1250	234.0833	104.0000	54.2033	169.7500	133.1881	119.0000	96.5091	155.2222	142.3620
Patents	10.6250	5.9025	8.1667	7.0689	14.5000	9.3656	17.4286	14.2227	8.4444	6.6353
Experience										
Age HEI	248.5000	318.0575	84.0833	144.7791	199.2500	247.1106	26.8571	14.2177	75.8889	146.9119

Table 3.22. Continued.

	Cluster 1		Cluster 2		Cluster 3		Cluster 4		Cluster 5	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Papers 3-years/Faculty	1.3019	0.5300	1.1177	0.3336	1.1462	0.1916	1.0220	0.1218	1.4005	0.4615
Spin-offs 2-years	5.2500	10.4437	3.0833	2.9375	7.2500	7.5166	7.1429	8.8021	4.4444	3.3208
Finance										
R&D Income (thousand euros)	37,434.57	28,945.34	23,926.33	15,041.14	28,531.67	21,565.87	49,422.42	44,501.36	31,902.06	23,183.49
Self-financing	0.1776	0.0325	0.1619	0.0272	0.1824	0.0519	0.1801	0.0485	0.1939	0.0379
Current expenditures / Student	7,001.17	603.34	6,359.44	891.05	5,618.16	459.44	7,398.91	1,142.10	8,678.40	689.69
Academic spread										
Educational diversity	3.6638	0.3223	3.4492	0.5685	3.3646	0.3876	1.6851	0.6260	3.2967	0.5915
Medical School	1.0000	0.0000	0.8333	0.3892	1.0000	0.0000	0.1429	0.3780	0.8889	0.3333
Polytechnic University	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5714	0.5345	0.0000	0.0000
Structural variables										
Employment high-tech / GDP	0.0656	0.0329	0.0413	0.0218	0.0448	0.0254	0.0706	0.0322	0.0982	0.0144
GDP per capita	25,108.50	4,562.38	20,579.58	3,213.89	20,598.25	4,340.03	25,062.43	4,761.92	28,324.22	2,377.57
Public exp. on HE / GDP	0.0438	0.0322	0.0440	0.0359	0.0788	0.0266	0.0447	0.0212	0.0343	0.0247
R&D expenditure / GDP	0.0121	0.0065	0.0099	0.0024	0.0116	0.0035	0.0141	0.0047	0.0160	0.0038

Table 3.23. Frequency table for the performance in first and second missions (by cluster).

	Cluster 1		Cluster 2		Cluster 3		Cluster 4		Cluster 5		Overall	
	N	%	N	%	N	%	N	%	N	%	N	%
Panel A: Graduates per student (2008/09)												
Bottom quartile (<0.1336)	2	0.250	2	0.166	4	0.500	3	0.428	0	0.000	11	0.250
Inter-quantilic interval (0.1336 – 0.1628)	5	0.625	5	0.417	4	0.500	2	0.286	6	0.667	22	0.500
Upper quartile (>0.1628)	1	0.125	5	0.417	0	0.000	2	0.286	3	0.333	11	0.250
Panel B: Papers per faculty (2009)												
Bottom quartile (<0.3650)	2	0.250	6	0.500	1	0.125	1	0.143	1	0.111	11	0.250
Inter-quantilic interval (0.3651 – 0.5072)	4	0.500	3	0.250	6	0.750	3	0.429	6	0.667	22	0.500
Upper quartile (>0.5072)	2	0.250	3	0.250	1	0.125	3	0.429	2	0.222	11	0.250
Total	8	1.000	12	1.000	8	1.000	7	1.000	9	1.000	44	1.000

Universities in **cluster 3** exhibit both the lowest average number of papers per faculty (0.4192) and the poorest rate of graduates per student (0.1365). In this group, universities show the highest ratio of students per faculty (13.39), and the lowest academic performance (measured as the total number of credits¹⁶ approved per total number of students enrolled divided by the total number of credits registered for a given academic year: 58.44%). The bad results obtained in the latter variables linked to the teaching objective can be related to the small proportion of the university's area devoted to teaching facilities and their poor level of investments per student (despite the high levels of public expenditure on higher education of their regions). These results could give support to our hypothesis that a more personalised academic formation can potentially lead to better academic results. Universities in this group show the lowest proportion of the total size devoted to research activities (14.88%), and they do not have a critical mass of faculty carrying knowledge transfer activities (20.68%). Despite these, their success may rely on a reduced but highly skilled faculty that enables these universities to take full advantage of their knowledge stock (in terms of patents) and learn from their recent entrepreneurial experience through an efficient use of resources. These universities have a clear knowledge transfer orientation, and this is observed in their capacity to create patents (on average 14.50) and their spin-off performance, which is the highest amongst Spanish universities (on average 4.1250).

It is also remarkable that five of the eight universities in this group belong to the same region, Andalucía. Concerning the rest of universities, two institutions (ULC and UVEG) show similar values to those obtained for the Andalusian universities, whereas the URJC can be considered an outlier in this group, as its values for all structural factors are in both tails of the distribution of these variables.

¹⁶ Those academic credits corresponding to validated, adapted or recognized teachings are excluded from this computation.

The main common feature shown by universities in **cluster 4** relates to the degree of academic specialisation. In this group we find the four polytechnic universities (UPC, UPCT, UPM and UPV), clearly focused on engineering degrees. The other universities in this cluster (UBU, UC3M and UJCS) also have high levels of specialisation, and they concentrate their degrees in social sciences and engineering fields. In particular, social sciences is the knowledge field with the largest number of degrees offered, accounting for more than half of the total number of degrees offered (UJCS: 61.90%, UC3M: 53.57%, and UBU: 50%). Engineering and technical degrees are the second ranked category, and they nearly represent a quarter of the total degrees offered (UC3M: 32.14%, and 23.81% for UBU and UJCS). Another attribute shared by these universities is linked to their experience in the market (age). Universities in this group are, by far, the youngest, being the UPV the oldest (48 years old), and the UPCT the youngest (11 years of existence). These universities have focused their efforts on a unique direction, pledging their resources and commitment to the creation of knowledge with potential commercial applications (patents), and its subsequent valorisation in the marketplace (spin-offs).

Finally, **cluster 5** comprises the most inefficient universities (average inefficiency: 26.77%). In terms of strategic paths, they are clearly oriented towards academic goals. Results in Table 3.22 show that these universities have the smallest number of students per faculty (8.26), the highest expenditure per student, and the greatest proportion of their area devoted to teaching activities (32.35%).

Contrary to the case of universities in cluster 4, in this case we observe how universities in this group have chosen a strategy where students are the key agent benefiting from their activities. Even though their high levels of skilled faculty and the presence of research areas (16.64% of total size devoted to research), their extremely biased (academic) orientation may help explain their poor efficiency results. These results may indicate that these universities have a strong preference for teaching, and this could lead to an inefficient allocation of research resources and knowledge transfer outcomes. It should be noted that, in this group, the UPF can be considered an outlier. This Catalan university is

considered one of the best universities in terms of scientific publications in top journals around the world. Their publication intensity (ratio of publications per faculty) is not negatively correlated to the quality of those publications. In fact UPF's publication ratio (0.5932) is relatively high compared to the average value of all Spanish universities (0.4359 papers per faculty). Thus, in this case it is clear that although graduating is an important objective, quality research plays a critical role for this institution.

Based on these findings and those from Chapters 5 and 6 we can conclude that, although universities exhibit some relevant differences, it is possible to identify specific traits shared by Spanish universities that facilitate the identification of their behavioural paths.

In terms of the academic mission, our findings corroborate that universities in cluster 5 are more oriented towards the achievement of this objective. They have the lowest rate of students per faculty, and show the highest proportion of their total size devoted to teaching facilities. Also, they have a diversified academic offer. It should be noted that, despite for this group the observed average educational diversity is the second lowest (3.2967), this value is clearly pointing towards a wide academic spread, and it is far above than that shown by universities in cluster 4 (1.6851).

Results for the regression analysis (Chapter 5) also indicate that small universities have a significant increase in the flow of graduates per students. A more in-depth analysis within cluster 5 reveals that this is the case of UdL and UDG. Although size has been identified as an influential variable, the cluster analysis reveals that graduating is affected by other factors such as the capacity to access financial resources, and high levels of expenditure per student.

Findings in Panel A of Table 3.23 further corroborate the teaching orientation of these universities, as 33% of these institutions have a ratio of graduates per students enrolled positioned at the upper quartile of the distribution of this variable. A similar pattern is found for universities in cluster 2: 42% of universities are in the upper quartile of the distribution of the ratio of graduates per students. To the contrary, universities in cluster

3 not only show the lowest rate of graduates per student (0.1365), but also the proportion of universities at the bottom quartile of the distribution of this variable is the highest (50%).

Excepting the case of the UPF, it seems that the adoption of this strategy potentially leads to put research and knowledge transfer activities aside. We argue that, on the one hand, the relatively poor performance in the second and third missions may be consequence of an objective function where faculty is not taking advantage of their knowledge to create research outcomes, but rather focusing on students' demands. On the other hand, and despite these universities are clearly involved in a learning process oriented towards academic entrepreneurship (all have a KTO, almost all a business incubator, and have started to value knowledge), the lack of a consolidated entrepreneurial culture could be negatively affecting their capacity to improve their research and knowledge transfer results.

Regarding the second mission, empirical findings in Panel B of Table 3.23 show that cluster 4 achieve superior basic research results (publication counts per faculty). Here, 43% of these universities in this group are positioned in the upper quartile of the distribution of this variable in 2009, and this represents a third of the total number of universities in the top quartile of publications per faculty. An in-depth analysis of cluster 4 allows us to see that, compared to the figures for 2005 universities in this group experienced an average annual improvement in their rate of publications per faculty of 18.58%, whereas the average annual change in the rate of publications amongst Spanish universities during the same period stood at 10.80%. Also for this group (cluster 4), it should be noted that the only exception is the UBU. Despite its number of publications in absolute numbers increased in the last years, it shows the poorest number of publications per faculty in 2009 (0.2176).

Consequently, results in Table 3.22 show that clusters 1 and 4 comprise universities which strategies are more oriented towards the research mission. Consistent with the results obtained in Section 5.3 of Chapter 5, it becomes clear that research excellence objectives

are linked to appropriate infrastructures, in the sense of space to perform research activities and generate knowledge (represented by libraries and laboratories), and high levels of R&D income. On this basis, we believe that the efficient achievement of research goals can come from two possible approaches.

On the one hand, a more “traditional” path to basic research followed by universities in cluster 1. This consists of having a highly qualified faculty (proxied by a high proportion of PhD faculty) and prior experience publishing. Also, knowledge accumulation from thesis dissertations plays an important role, as theses reveal the presence of a critical mass of PhD students that would become doctors in the future. As it was shown in Section 5.3.3, in Spain incentives to publish are greater for young researchers, as publications represent a signal used by universities to minimise adverse selection problems.

On the other hand, we have the applied research approach. This is the case of specialised universities in cluster 4 (mainly polytechnic). These universities focus their efforts on generating knowledge with practical uses (patents), which can later be materialised into new products and/or services. Likewise, the university may be willing to undertake this industrial process, and thus, will create a new venture in order to exploit the benefits arising from the commercial development. All this knowledge generated, with a high-tech content is particularly valued by the scientific community. Thus, the dissemination of this knowledge through publications in scientific journals is a valid mechanism that should be explored by universities (Gulbrandsen & Smeby, 2005; Van Looy, Callaert & Debackere, 2006; Van Looy, Ranga, Callaert, Debackere & Zimmermann, 2004).

Observing the frequency table linked to the third stream performance (Table 3.24), it can be seen that clusters 3 and 4 comprise universities with a more active involvement in the creation of new academic ventures. In particular, the number of new spin-offs reported by universities in these two clusters represents 50% of the total number of Spanish academic spin-offs created in 2009. It should be remarked that the most representative examples of universities that create academic spin-offs in cluster 3 are UGR (10 spin-

offs), UALM (9) and USE (7), whereas in cluster 4 the highest spin-off performance is shown by UPCT (14) and UPC (8).

Table 3.24. Frequency table for spin-off performance (by cluster).

Spin-offs in 2009	Cluster 1		Cluster 2		Cluster 3		Cluster 4		Cluster 5		Overall	
	N	%	N	%	N	%	N	%	N	%	N	%
0	2	0.250	5	0.417	1	0.125	3	0.429	4	0.444	15	0.341
1	1	0.125	2	0.167	2	0.250	2	0.286	2	0.222	9	0.204
2	1	0.125	2	0.167	1	0.125	0	0.000	0	0.000	4	0.090
3	3	0.375	1	0.083	1	0.125	0	0.000	0	0.000	5	0.114
4	1	0.125	1	0.083	0	0.000	0	0.000	1	0.111	3	0.068
5			1	0.083	0	0.000	0	0.000	1	0.111	2	0.045
6					0	0.000	0	0.000	1	0.111	1	0.023
7					1	0.125	0	0.000			1	0.023
8					0	0.000	1	0.143			1	0.023
9					1	0.125	0	0.000			1	0.023
10					1	0.125	0	0.000			1	0.023
11							0	0.000			0	0.000
12							0	0.000			0	0.000
13							0	0.000			0	0.000
14							1	0.143			1	0.023
Total	16	1.000	18	1.000	33	1.000	24	1.000	17	1.000	114	1.000
HEIs	8	0.182	12	0.273	8	0.182	7	0.159	9	0.204	44	1.000

Descriptives in Table 3.22 show that universities in clusters 3 and 4 are actively involved in knowledge transfer activities. We observe a strong influence of those variables related with prior experience in the creation of new academic ventures, as well as in the number of patents granted in the previous year (Table 3.22). This further confirms the results obtained in Section 5.4 (Chapter 5), which aims at explaining spin-off performance. This finding translates in saying that knowledge accumulation and previous experience reflect the entrepreneurial commitment adopted by universities in their strategies, and how it drives universities to innovate and put their knowledge and discoveries into the marketplace (Lockett & Wright, 2005; Mowery et al., 2002; Zahra & Bogner, 1999). Yet, universities that excel at knowledge transfer outcomes not only have developed and consolidated their research processes which facilitate the patenting activity, but they also have been successful in bridging the gap between inventions and academic entrepreneurship. Therefore, and consistent with our hypotheses, we can assert that

universities with an entrepreneurial culture are more prone to create new academic ventures indicating the existence of a path dependency, that is, current decisions linked to the creation of a spin-off are heavily influenced (and constrained) by previous spin-off experience.

Concerning the educational spread (in terms of degrees offered by universities), and consistent with our hypothesis on the academic orientation (H4b), it is suggested that universities may obtain important gains from a concentrated structure of academic degrees, as some disciplines can be more aligned with the creation of academic spin-offs (Fontes, 2003; Landry et al., 2007; O’Shea et al., 2008). It is worth noting that cluster 4 comprises all the public polytechnic universities and three universities with a highly specialised profile, and that 68.70% of the total degrees offered by the seven universities in this group are in engineering disciplines. Universities in cluster 3 also show a high concentration of academic degrees, however, in this case in social science fields. Despite UJA and ULA have a major proportion in engineering degrees; the average proportion of degrees in social sciences for universities in this cluster is 41.19%, a result that is higher than that observed for engineering studies (24% of the total number of degrees).

Regarding the financial variables, and as it was hypothesised at the end of Chapter 3, those universities reporting higher levels of R&D income and issuing a higher number of patents create more spin-offs. This does not hold for universities in cluster 3, as they have a high self-financing structure. As a result, universities not only create knowledge, but they also exploit their knowledge-based outcomes, which can explain the higher number of spin-offs created.

Another relevant factor that may contribute to explain the spin-off performance of these universities is linked to their facilities. For instance, from Table 3.22 we observe that size widely varies between universities in these two groups. The negative sign found in the regression analysis in Chapter 5 can be explained by the relatively small size of universities in cluster 3. These universities are rather small, but they have the greatest number of spin-offs, confirming the influential effect that the presence of appropriate facilities has over

spin-off performance (Elgen, Gottschalk & Rammer, 2004; Gübeli & Doloreux, 2005). A similar result was found for the proportion of faculty involved in knowledge transfer activities. Universities in cluster 4, due to their orientation highly tied to high-tech developments, have the highest proportion of faculty involved in knowledge transfer activities. To the contrary, universities in cluster 3 show the lowest ratio of faculty involved in knowledge transfer activities, revealing that they lack the human capital, the infrastructures and institutional support necessary to consolidate their third stream strategies. Yet, their efficient use of resources and their entrepreneurial culture could have helped them bridge the knowledge transfer gap, leading to position these universities on the top in terms of knowledge transfer outcomes.

Finally, it is important to highlight the weak role played by science parks and business incubators, at least at the Spanish level. Consistent with previous results obtained in this study, we observe that these infrastructures, which are supposed to contribute to increase the results arising from R&D activities, do not exert a significant effect over knowledge transfer outputs. These incubators and science parks emerged in the 90's and spread throughout Spanish universities as a result of different policies designed to foster knowledge transfer activities. The incubator and science park waves focused on their settlement rather than on their functioning, so therefore, there was not clear understanding on what these support infrastructures really do. Thus, universities started to build up these spaces very rapidly; however, strategies to efficiently make the most of these infrastructures were not designed. An analysis on the mechanisms that drove the creation of these spaces, science parks in particular, is presented in Berbegal, Martín & Solé (2010), and the authors distinguish between the characters of necessity from desire to explain the sprouting of these infrastructures in Spain.

Chapter 8: Conclusions

In this chapter we summarise and discuss the main findings obtained in Part III.

8.1. Discussion

The assessment of universities has received great attention by academics and policy makers, stressing the impact that certain factors, institutional support and other non-controllable processes, have over their performance as a consequence of the knowledge flow resulting from the development of their objective function. It is also a fact that the relatively recent shift from teaching and research activities towards entrepreneurial ones has led universities to experience substantial transformations given their knowledge-brokerage orientation. Nevertheless, universities have faced these changes (at structural, normative and cultural levels) at different speeds and levels of commitment.

In this study, we aimed at shedding some light on the factors that help explain the differences in the performance of Spanish public universities. To do this so we have conducted a three stages empirical analysis using an initial dataset of 47 public Spanish universities that was reduced to 44 due to missing information.

First, we assess through different regression models (Chapter 5) the explanatory power that organisational and knowledge-based factors have over universities' core missions: teaching, research and knowledge transfer. The interpretation of the empirical findings for each mission is discussed, and Table 3.25 summarises the main results in relation to the different models tested and the hypotheses proposed.

Concerning the first mission (teaching), our results reveal that the human capital proxy is an important factor that helps explain the flow of students (**H1**). We find that students'

flow is high when the ratio of students per faculty decreases, emphasising the importance of small groups to create a more personalised learning process.

About the impact that the presence of specific infrastructures has over the development of teaching activities, our second hypothesis (**H2**) is confirmed. Spaces such as lecture rooms and libraries are found to be positively correlated with higher rates of graduates. The full size of the university has no distinctive influence on teaching activities; however, small universities seemed to achieve better teaching results. Finally, concerning the university’s profile, our results verify **H4a** that states that universities with a more diversified academic offer have higher levels of graduates.

Table 3.25. Validation of hypotheses.

Hypotheses	Factor	University objectives		
		Teaching	Research	Third stream
		Graduates / Students	Papers	Spin-offs
H1	Faculty	Accepted (b>0)	Rejected (b<0)	Partially accepted (b<0)
	Knowledge accumulation	-	Accepted (b>0)	Accepted (b>0)
	Experience	-	Partially accepted (b>0)	Accepted (b>0)
H2	Specific infrastructures	Accepted (b>0)	Rejected (b>0)	Rejected (b<0)
H3	Financial resources	-	-	Accepted (b>0)
H4a	University’s profile	Accepted (b>0)	-	-
H4b		-	Accepted (b<0)	Partially accepted (b>0)

As for the research mission, proxied by the number of papers published, our results do not give support to the argument that enhanced human capital positively impacts publication intensity. Given the inherent complexity of generating new knowledge that can potentially be disseminated through academic journals, universities have to capture both the tacit and explicit knowledge derived from research activities. This knowledge stock represents the source of further research developments. Our results corroborate this intuition and knowledge accumulation in the form of theses is a relevant factor

exerting a positive impact over the achievement of HEIs’ competitive advantage in terms of research productivity. However, the effect of past publishing experience is not as clear as in the case of the number of theses. We observe different behaviours depending on the model specification chosen, and based on these findings we can conclude that **H1** is partially confirmed for the research mission.

Regarding the availability of specific research infrastructures such as laboratories and libraries, our results suggest that despite its lack of statistical significance this component has a positive impact on publication counts. In addition, large universities obtain advantages in research activities. Thus, **H2** is not supported. Research outputs are negatively influenced by the portfolio of degrees offered. Therefore, **H4b** is supported, indicating that universities with a more concentrated academic offer achieve better research results.

In the case of the third mission (spin-offs), we observe that faculty involved in knowledge transfer activities do not explain the creation of more academic ventures. Similar to the case of research activities, the availability of knowledge-based resources (in this case, patents) as well as previous spin-off experience also help in creating a more fertile setting for academic entrepreneurship at the university level. In particular we find that previous experience is critical and this is more evident in those universities where entrepreneurial culture is enhanced. Thus, those universities that underwent a significant shift towards a culture of entrepreneurship and innovation are more likely to successfully address the creation of new academic ventures. Hence, and considering all these arguments we conclude that **H1** is partially supported.

Our results are not in accordance with our hypothesis **H2** stating that the creation of spin-offs is maximised in the presence of infrastructures, in our case business incubators, designed to support knowledge-based activities. As it was indicated in Section 5.4.3, this variable is not statistically significant in the spin-off regression and this may reflect an inefficient use of these instruments, and to the lack of mechanisms that motivate faculty to engage in entrepreneurial projects. This argument is supported by the no

correspondence between the high presence of business incubators in the Spanish public university system (63.83%), and the rate of spin-offs per university. We also find that only a small group of universities have an appropriate entrepreneurial culture that enabled them to create spin-offs.

The access to financial resources has been found to be crucial, and therefore, results confirm our third hypothesis (**H3**). This suggests that in the case of third stream activities, in our case spin-off creation, the income generated from R&D activities in the previous year contribute to the creation of a greater number of spin-offs in the following year. The underlying rationale for this relates, on the one hand, to the existence of an economic cushion that helps developing new entrepreneurial activities (spin-offs tend to require a large initial investment). On the other hand, income from R&D activities can drive knowledge transfer activities as the incentives linked to potential extraordinary revenues could represent an important motivation for both the institutions and its faculty. Finally concerning the influence of the university’s academic spread over spin-off performance, our results partially support our hypothesis **H4b** that states that universities with a more concentrated academic offer create more spin-off firms.

Having assessed HEIs’ missions individually, in a second analysis (Chapter 6) we estimated the technical efficiency of Spanish public universities through the Data Envelopment Analysis (DEA) methodology. Our model specification includes as outputs variables related to critical objectives pursued by universities: teaching, research and knowledge transfer activities. The final model takes into account the fact that research and knowledge transfer outputs are time constrained, therefore we used contemporary outputs and lagged inputs. Our results suggest that universities’ inefficiency is on average 12.44% under the assumption of variable returns to scale (VRS). This means that, holding the set of inputs constant at their values, universities can potentially expand their outputs by 12.44%. Detailed information about the efficient units (19) and the inefficient ones is provided.

We also analysed the potential efficiency differences that exist amongst universities according to their geographic location. Results give support to the argument that universities' performance is not conditioned by the economic context of the region. This reinforces that universities, mainly funded by local administrations and governmental dependencies, achieve their missions and that this process is not affected by regional economic conditions in a significant way.

Aware of the influence exogenous variables might have on the performance of universities, and due to the multiplicity of functions universities have to face, in our last empirical study (Chapter 7) we carried a cluster analysis in order to evaluate whether there exist similarities in the patterns followed by Spanish universities when it comes to explain the way they shape and align their strategies with their objective function. From this cluster analysis we obtained a consistent categorisation of universities, consisting in 5 groups with clearly different behaviours: efficient universities that are very good in publishing (cluster 1), universities with a clear lack of resources and institutional support (cluster 2), universities with a clear knowledge transfer orientation (cluster 3), specialised universities (cluster 4), and universities with a more academic orientation (cluster 5).

In order to target potential strategies and factors that lead to an improved use of resources and capabilities of universities when addressing their objective function, bringing together all the results obtained in this empirical part, we have obtained three possible paths, one for each sub-objective function. In broad terms, the underlying backbone for universities pursuing academic excellence in terms of graduates (those in cluster 5) relies on a high expenditure per student, which allows a more personalized education (lower percentage of students per faculty), an increased investment in teaching facilities and spaces (classrooms, laboratories and libraries) and the possibility to offer a wider range of degrees.

In the case of universities basing their efforts on the diffusion of knowledge through publications, we find two different ways to address this goal. On the one hand, we have those universities (cluster 1) that base their strategy in disseminating the knowledge stock

through scientific publications and they are really good doing so, but they leave aside the possibility to translate the research results in something valued by the market. This path suggests that although they have the means to transform this knowledge into marketable results (in the form of patents or spin-offs), they are probably lacking an entrepreneurial culture which is constraining the development of knowledge transfer activities. Therefore we believe that, in terms of policy making, these universities could implement specific policies and programmes in order to create an entrepreneurial culture (Del-Palacio, Solé & Montiel, 2006), that help academics to develop their research activities in an entrepreneurially active setting, while exploiting all the knowledge stock they already have. On the other hand, universities in cluster 4 are precisely taking advantage of the natural spillovers that arise from the adoption of an entrepreneurial culture. Consequently, they base their strategy on their capacity to transform their different resources (income from R&D activities, patents issued, faculty involved in KT activities), accumulated knowledge and make use of their previous experience to create academic spin-offs, reporting the research results arising from these experiential way of doing research through publications.

A third group, including universities in clusters 3 and 4, are those universities orienting their objective function to third stream activities. In fact, universities in cluster 3, despite not having the best environmental conditions and resources, are doing an efficient use of resources, betting on the creation of new academic ventures, as academic entrepreneurship is a crucial component necessary to consolidate knowledge transfer processes and contribute to renew the local industry fabric.

Finally, we identified a group of universities that lack both research outcomes and an entrepreneurial culture. These universities, perhaps more oriented towards the education, not only show the lowest concentration of knowledge (patents and theses) but also a weak experience in knowledge transfer activities. It is also remarkable that universities of this group are also lacking an enabling environment, as they show the poorest institutional support, in terms of regions' average wealth. However, they have significantly improved

their spin-off performance since 2004. Rather than introducing abrupt policies aimed to rising simultaneously all the outputs they produce, we think that these universities first need to define where they want to excel, and afterwards guide all their actions and efforts to this particular direction.

PART IV: CONCLUSIONS

This last part discusses the main conclusions arising from this empirical dissertation. A brief summary of the different parts of the thesis is provided, emphasising how each part has contributed to the existent literature, and how the objectives defined in Part I have been achieved. While there remains space for future research in the field of universities' management, this study represents a solid step in the assessment of universities' performance, from both a theoretical and an empirical perspective.

Chapter 9: Overall conclusions and discussion of this research

This chapter is organised in two main sections. We first do a comprehensive review of the results obtained, highlighting the most relevant findings. Secondly, and taking into consideration the limitations of this study we suggest some future research avenues.

9.1. Findings and conclusions

In a knowledge-driven setting where different stakeholders demand more transparency in the autonomous governance of public institutions, universities are trying to find an appropriate balance between their three core missions, assuming new roles and responsibilities that could potentially lead to the modernisation of their governance structures and operations. In this context, the study of the ways through which universities align their resources in relation to the achievement of their multiple objectives has become a critical research issue. Thus, it is important to question whether both environmental factors and internal resources and capabilities can explain performance differences in higher education institutions.

Throughout this dissertation we have attempted to bring further insights on these specific topics linked to the management of universities. Despite many theoretical developments can be found pointing out the factors and mechanisms that help explain universities' performance, little empirical evidence is provided in the literature. In order to bridge this theory and research gap, we first embarked on the analysis of the different roles played by universities and their underlying objectives. Second, we empirically evaluate how universities allocate their resources when simultaneously dealing with teaching, research and knowledge transfer missions. This results in the identification of different performance pathways.

To do this so, we focus our research on the Spanish public university sector. These universities are characterised by a high degree of heterogeneity which can be explained by economic and geographic differences, by changes in the environment that condition their behaviour, and by their dissimilar speed of adaptation to these environmental changes. The sample used in this study comprises information for all the population of Spanish public universities (47 institutions). These universities are located across the 17 Spanish regions (autonomous communities).

The findings presented throughout this dissertation contribute to get a better understanding of the different behaviours shown by universities. In particular, the thesis sheds light on the mechanisms used by Spanish public universities to engage with their regions through the development of different activities. Hence, we adopt an empirical strategy that leads us to address both external and internal dimensions of universities. This way, we aim to fill the existing gap in the literature on the strategic management of universities, and we propose a new framework that helps explain universities' performance. In addition, an internal analysis of how universities manage their resources and achieve their different missions is developed, modelling their goals through a unique objective function, which allows us to identify different behavioural paths.

In order to understand the rationale behind the changes universities underwent Chapter 2 of Part II presents the literature review of the main theoretical frameworks that have

described the matching between university’s goals and society’ demands. Thus, theories explaining the roles universities are playing are summarised (Sections 2.2 and 2.3), mainly focusing on the literature on regional innovation systems (Freeman, 1992; Lundvall 1992), the “mode 2” (Gibbons et al., 1994), the Triple Helix model (Etzkowitz & Leydesdorff, 1997; Etzkowitz et al., 2000) and the approach of the engaged university (Chatterton & Goddard, 2000; Holland, 2001). Next, we evaluate the economic impact that universities are having on knowledge-based societies (Section 2.4), suggesting an illustrative scheme where universities are simultaneously presented as employers, creating a wide range of job opportunities; as suppliers of a highly skilled workforce, knowledge and technological developments; and as consumers of goods.

The relevance of the objective placed in Part II becomes clear in Chapter 3. Based on the studies reviewed, in this chapter we propose a conceptual framework for the study of universities’ engagement with their regions (Section 3.1). Our theoretical approach considers universities as core elements within regional innovation systems, contributing to the economic, social and cultural development of the region by undertaking their main goals, that is, teaching, research and knowledge transfer activities. This scheme contributes to reflect the different interactions between universities’ missions as well as to connect universities with other relevant agents of innovation systems (industry and government).

To further explore the effectiveness of the actions taken by universities to accomplish their different missions, we first identify the factors that can foster or hinder the development of these tasks. This facilitates the modelling of universities’ objective function, and we adopt a production approach to efficiency where multiple inputs yield multiple outputs (Astin, 1993; Cave et al., 1991; Borden & Bottrill, 1994). Therefore, Section 3.3 presents the analysis of the factors and variables that can represent appropriate proxy indicators of both inputs and outputs at the university level. Our interpretation considers as university’s inputs their internal resources, that is, human capital, specific infrastructures, financial resources and university’s specific features. These

inputs are assumed to produce a set of outputs related to teaching, research and knowledge transfer activities, proxied by the number of graduates per students enrolled, the number of publications in peer-review journals, and the number of spin-offs created, respectively.

Following this variable definition, Part II ends with the modelling of universities' objective function using a specific technology that simultaneously deals with the three missions universities try to accomplish. To the best of our knowledge, previous research efforts attempting to target the management of universities from a resource-based perspective are scarce. This study represents an innovative approach that goes beyond ranking systems and efficiency studies that have been criticised, as they do not cover all the objectives of higher education institutions (Liu & Cheng, 2005; van Raan, 2005).

In order to provide empirical evidence of the factors that help explain performance differences amongst universities, in Part III we carried out a three-stage analysis that led to obtaining an exhaustive and complete examination of the Spanish public higher education system.

The first stage, reported in Chapter 5, assesses through different regression models the explanatory power that the factors identified in Part II have over each university's mission. As for the empirical findings, results for the teaching mission are in accordance with our hypotheses. In particular, human capital factors, the availability of areas devoted to teaching activities as well as the diversification of university's studies positively contribute to improve the teaching process. Regarding research activities, our results signal that both knowledge accumulation and previous research experience positively influence research outcomes. Also, academic specialisation is found to be critical. Yet, we cannot corroborate that the presence of a highly qualified faculty (which translates in faculty holding a PhD) contributes to research through the publishing of a greater number of articles. Similarly, we cannot confirm that the existence of specific areas oriented towards research help explain differences in the number of academic publications. Finally, our results concerning third stream activities indicate that human

capital is a key determinant that helps explain the creation of spin-offs. This holds for all human capital variables considered in the analysis with the exception of faculty involved in knowledge transfer activities. Our hypothesis stating that specific infrastructures (proxied by the presence of a business incubator) exert a positive influence over regional engagement is not supported. In addition, we find that polytechnic universities are more involved in knowledge transfer activities relative to universities offering a large portfolio of academic degrees.

The second stage of the analysis employs a non-parametric linear programming technique, Data Envelopment Analysis, to assess the overall efficiency of Spanish universities. Imposing no constraints to the technology, our model specification assumes that universities use human capital and financial resources to produce outputs related to teaching, research and knowledge transfer activities (Chapter 6). Based on our framework, and according to the universities’ production system proposed, it should be noted that our model specification considers that inputs available in one period helps produce outputs in the following period. The results for the efficiency scores are in line with previous studies (Agasisti & Pérez-Esparrells, 2010; Duch-Brown & Vilalta, 2010). Empirical findings show that, in our sample and considering a technology that exhibits variable returns to scale, 19 out of 44 universities are efficient and the average inefficiency is 12.44%.

The first and second stages did not consider into the analysis the potential consequences derived from the exposure to regional specific factors. Structural factors related to macroeconomic variables may shape universities’ strategic actions and therefore, affect their performance. This way, Chapter 7 addresses this issue by scrutinising whether the behaviour of Spanish public universities is conditioned by exogenous factors related to the region where they are located. To do this so we run a non-hierarchical cluster analysis. Results allow classifying universities in five categories: efficient universities that are very good at publishing (Cluster 1), universities with a clear lack of resources and institutional support (Cluster 2), universities with a knowledge-transfer orientation (Cluster 3),

specialised universities (Cluster 4), and universities with a more academic orientation (Cluster 5). Therefore, our findings verify our intuition that universities tend to concentrate on certain specific competences, suggesting that universities have different ways to implement their strategy according to the characteristics of the region they operate.

Universities with a clear teaching orientation (Cluster 5) show a higher expenditure per student, a more personalised education, and an increased investment in teaching facilities to offer a greater number of degrees. Hence, they concentrate in academic excellence in terms of graduates. Universities in Cluster 2 could be also included in this group. However, our empirical results reveal that they do not have the resources and facilities that universities in Cluster 5 possess.

Research oriented universities are those that concentrate their efforts in obtaining outstanding research results. Here, on the one hand it is possible to observe that universities in Cluster 1 have a strong interest in research outputs. Although universities in this group have the means to transform this knowledge into marketable results, they are probably lacking an entrepreneurial culture that could help develop their third stream activities. On the other hand, we find specialised universities (Cluster 4). These universities take advantage of the natural spillovers that arise from the adoption of an entrepreneurial culture. They stress the importance of external collaborations and the participation in competitive environments that enable them to transforming their different resources and human capital into knowledge transfer activities that later will give rise to research results.

Knowledge transfer led universities are those meeting private and public needs, that is, universities strongly committed to regional engagement, aiming at narrowing the gap between academic research and the industry. Universities in Clusters 3 and 4 follow this behavioural path. Despite universities in Cluster 4 are catalogued as research oriented, we can also consider them as knowledge transfer oriented universities because their inputs available include an entrepreneurial culture that allows them to be good at research tasks.

Universities in Cluster 3 do not enjoy a favourable environmental setting. Yet, they make an efficient use of their resources, pledging their commitment to academic entrepreneurship objectives to consolidating third stream activities.

Following the theoretical works of Curran (2000), Hazelkorn (2005) and Temple (2009), our results give empirical evidence about the existence of specialised institutions concentrated on specific competences, and that this characteristic helps explaining their teaching, research and knowledge transfer performance. Thus, the observed differences in the paths followed by universities to address their objective function suggest that universities use various strategies to engage regional needs.

It is worth noting that universities are organisations with a clear long-term strategic planning, and that their long-term contributions to regional development become observable after their implementation. This does not imply that universities are neither adaptable nor flexible. To the contrary, universities’ missions and structures have been redefined in an attempt to fulfil both social and labour market demands. Universities are therefore reshaping their internal structures in order to perform more efficiently and achieve these new demands.

Similar to Clark’s (1998), our findings also reveal that the adoption of entrepreneurial mindsets is seen as a good practice that helps enhance the interconnectivity of the different university’s internal structures (departments and units), and this expands the services offered as well as create and reinforce ties with the innovation system. Entrepreneurial culture is therefore a critical factor necessary for universities to consolidate their regional engagement duty (O’Shea et al., 2005). Firms are more likely to create collaborative initiatives, as they perceive the potential benefits derived from a closer partnership with the academia. From an academic perspective, these collaborations may not only turn into research results (publications, patents, sponsorships, etc.), but also into additional financial resources. From a market-oriented view, universities assume that the market is the driving force that encourages external collaborations with the industry.

This contributes to attracting additional non-public funding while strengthening the academic performance.

Governmental agencies design incentives that promote the adoption of an entrepreneurial culture that, subordinated to cultural patterns and natural territory barriers, influences the way through which universities create and disseminate knowledge transfer activities. While metropolitan areas face the challenge of having a highly fragmented economic activity, in old industrial regions reminiscences of earlier activities hinder the development of new occupations. In peripheral areas, the institutional thinness (small amount of key actors) hampers innovation activities (Tödting & Trippel, 2005).

This implies that a balance between the coordination of national policies and regional diversity must be created. Regions respond to a specific reality and it is not possible to have excellence centres in each region. The specialisation of any territory must be accompanied by a proper analysis of each region's potential.

We are aware that universities have different structures and missions, and that they are somehow embedded in their regional contexts. This complicates any effort to converge on a homogenous policy design that aims at consolidating universities as knowledge centres. This heterogeneity amongst universities also makes the assessment of universities' performance more difficult.

We think that far from falling into the inherent controversy of rankings and efficiency studies, this dissertation has shed further insights on the performance of universities from a broad perspective, making both a conceptual and an empirical contribution to the existing literature on the management of universities.

9.2. Limitations and further studies

Although we believe that this dissertation provides important and useful insights to the analysis of universities, it is important to note that we identified some limitations that clearly represent future research lines.

Probably the main limitation of this study relates to the specific analysis of the Spanish public higher education system, from where two potential research avenues emerge. First, it would be interesting to compare the performance of public and private universities, and determine whether the presence of shareholder-driven objectives and the presence of a different financial structure condition universities' performance. However, the lack of a homogenous disclosure policy for public and private universities prevents us to undertake a direct comparison between these two types of institutions. Second, further research is necessary to confirm if our results regarding the influence that certain internal and external factors are having over universities' performance are particular to the case of Spain, or if they are valid in other geographic settings.

Even though it is not the purpose of this dissertation, a recommendation for further studies relates to cross-country comparisons. Notwithstanding we are aware of the difficulties in obtaining homogeneous data, as information tends to be country-specific, responding to national criteria.

It is also important to remark that data available are rich and it was possible to create reliable variables to assess universities' performance. Yet, we also consider relevant to question whether the selected variables represent the core influential factors that are hypothesised to impact the performance of universities. While in theoretical models variables seem to be relatively easy to be measured, their transformation and practical implementation is constrained by the availability of appropriate information. Consequently, data limitations constrained the analysis to certain specific factors that, despite their relevance, could represent only a portion of the total number of variables that affect universities' performance.

Another limitation that we consider worth mentioning relates to the absence of a longitudinal analysis that could have given a greater evolutionary perspective to the study. Even though we have controlled for endogeneity problems, the lack of a systematic process to collect comprehensive data for all the universities in the sample and for a longer time span conditioned our study, limiting the temporal scope of this dissertation.

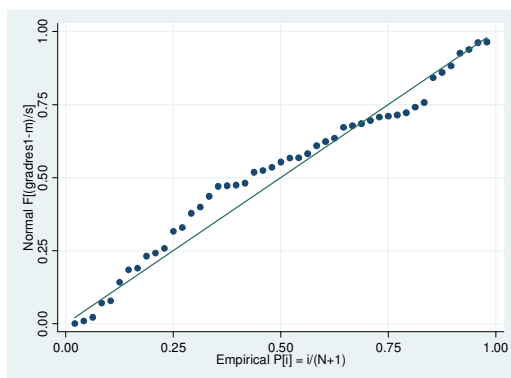
Finally, and given the importance of universities in regional innovation systems, further research efforts are necessary to determine the extent to which universities contribute to the social and economic development of their geographic areas of influence.

Even though these limitations, we believe that this doctoral thesis has demonstrated that it is possible to scrutinise the management of universities. Regardless the potential deficiencies identified in our empirical applications, our results confirm that university performance is a multidimensional construct, and efforts aiming to assess this should be undertaken on the basis of a framework that, as in our case, considers the different outputs that interact in university’s objective function.

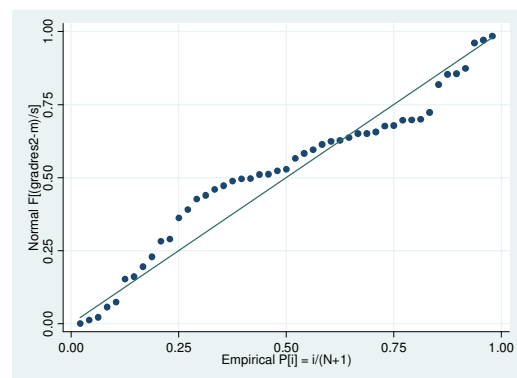
APPENDIX

Appendix A: Probability plots

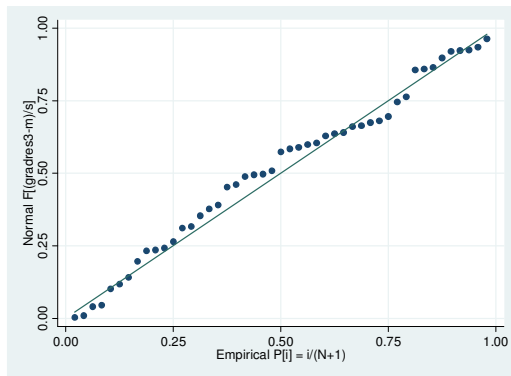
Figure A.1. Graduates: Normal probability plots for regressions 1 to 5.



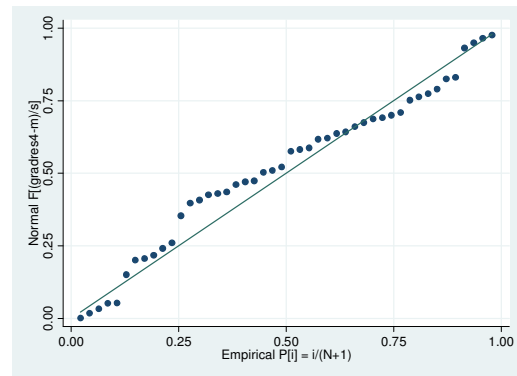
Model 1



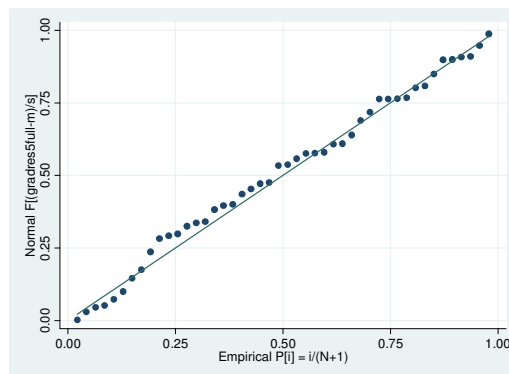
Model 2



Model 3

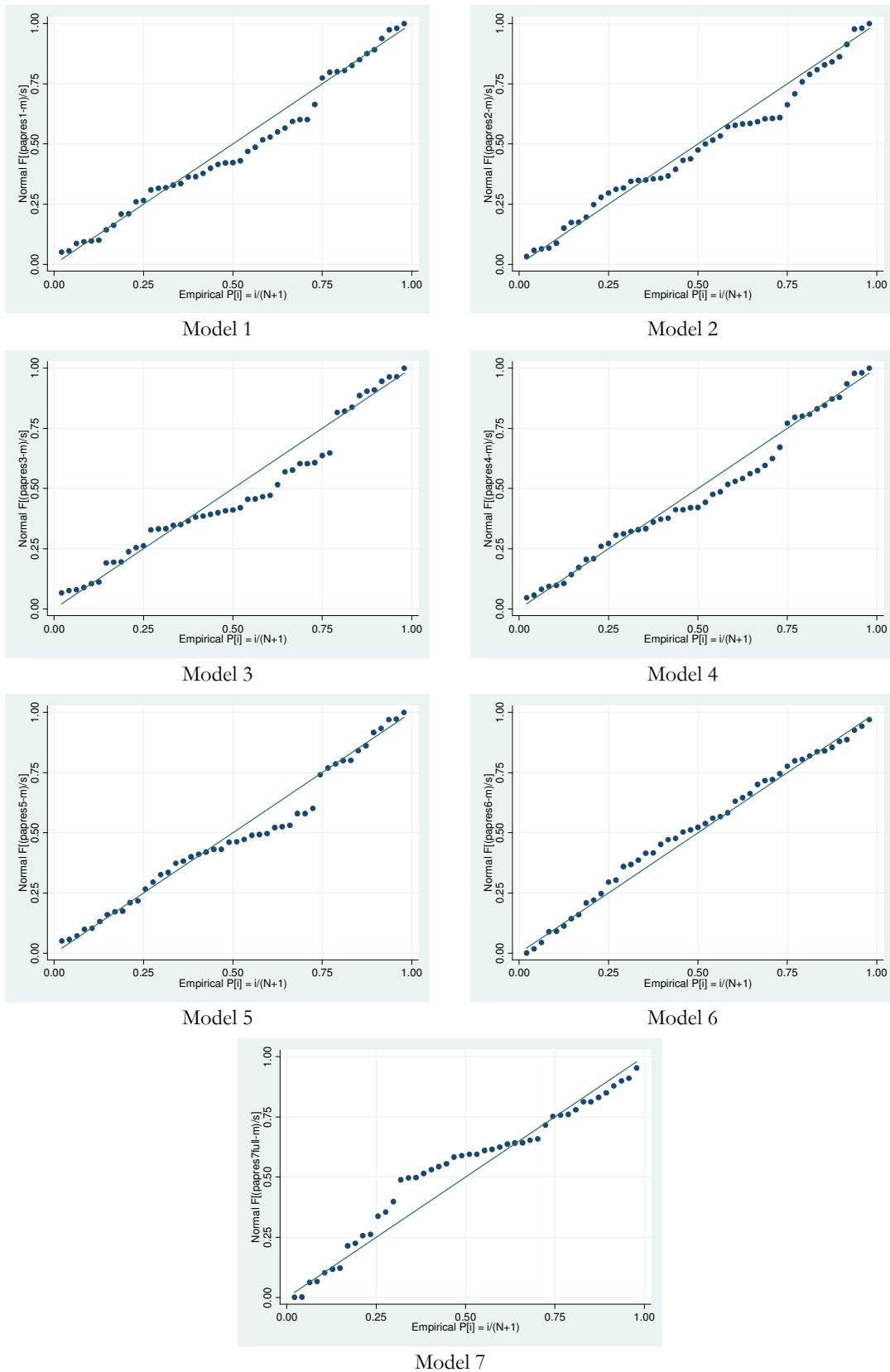


Model 4



Model 5

Figure A.2. Publications: Normal probability plots for regressions 1 to 7.



Appendix B: DEA scores

Table B.1. Results for the two DEA models tested.

University	Efficiency Scores (VRS) Contemporary model	Efficiency Scores (VRS) Lagged model
EHU	1.00000	1.00000
UAB	1.1037	1.00000
UAL	1.18229	1.20376
UAH	1.30982	1.28346
UALM	1.00000	1.00000
UAM	1.00000	1.00000
UB	1.00000	1.00000
UBU	1.00000	1.00000
UC3M	1.00000	1.03733
UCA	1.18842	1.20862
UCLM	1.03676	1.06714
UCM	1.00000	1.00000
UCN	1.37242	1.35105
UCO	1.05167	1.10208
UDG	1.00000	1.33237
UDL	1.47009	1.51850
UEX	1.00000	1.00000
UGR	1.00000	1.00000
UHU	1.14741	1.28055
UIB	1.16911	1.13549
UJA	1.00000	1.00000
UJCS	1.45009	1.23352
ULC	1.16815	1.24551
ULL	1.32124	1.02398
UMA	1.15302	1.15751
UMH	1.00000	1.00000
UMU	1.00000	1.00000
UOV	1.2317	1.03524
UPC	1.00000	1.00000
UPCT	1.00000	1.00000
UPF	1.20619	1.21505
UPM	1.44184	1.45067
UPN	1.28327	1.29853
UPO	1.44893	1.42852

Table B.1. Continued.

University	Efficiency Scores (VRS) Contemporary model	Efficiency Scores (VRS) Lagged model
UPV	1.24618	1.19750
URI	1.00000	1.00000
URJC	1.00000	1.11188
URV	1.00000	1.00000
USAL	1.00000	1.00000
USE	1.06896	1.06609
USC	1.05634	1.07828
UVEG	1.00000	1.00000
UVI	1.03922	1.00000
UZA	1.49694	1.41013
Mean	1.1283	1.1244
Bottom quartile	1.0000	1.0000
Median	1.0454	1.0517
Upper quartile	1.21257	1.21967
Std. Dev.	0.1609	0.1521
Highest inefficiency	1.4969	1.5185
# Efficient units	20	19
Total Obs.	44	44

Appendix C: Second-stage analysis of DEA scores

Despite the fact that the DEA approach provides information on how inefficient units can improve their production process and become more efficient, finding the environmental factors (generally uncontrollable) beyond those considered in the DEA is a complex task as there are just many determinants in the system level that condition the way HEIs perform. Trying to address this problem, and given the skewed and right-censored truncated distribution of the DEA scores, in a second step analysis we therefore applied a truncated regression.

Simar & Wilson (2007) listed a large number of recent papers where log-linear specifications (estimated by OLS), censored (i.e., Tobit) specifications (estimated by ML), or other particular parametric specifications were argued to be appropriate methods to be used in a second stage analysis (i.e. Hoff, 2007; McDonald, 2009; Ramalho, Ramalho & Henriques, 2010). In fact, particularising for the literature concerning the assessment of higher education institutions, we can find an important stream of research based on two-stage analysis, employing first a DEA methodology, and then using either ordinary least squares (OLS) or Tobit regressions in the second stage, relying on conventional methods for inference to explain the differences in the efficiency scores (Casu & Thanassoulis, 2006; Groot & García-Valderrama, 2006; Kempkes & Pohl, 2006; Tóth, 2008).

However, according to Simar & Wilson (2007), such structures (OLS, Tobit, ...) are not structural, but ad hoc, and are not valid because the estimates obtained are inconsistent for neglecting contextual variables due to the lack of a well-defined statistical model in which such structures would follow from the first stage where the initial DEA estimates are obtained.

The rationale behind this lies in three main arguments. First, (in)efficiency scores are calculated in relation to a particular technology, characterised in the DEA by the inputs

selected; however this technology might not entirely corresponds to the reality as it is an estimation based on a simplification. Second, the resulting efficient frontier is not the real one, but the image of the frontier calculated from the observations of the sample (and not the total population).¹⁷ And third, following the logic that efficiency is only approximated and not completely known, we can formulate that the output efficiency measure, γ_i , is assumed to be a function $\psi(Z_i, \beta)$ of environmental covariates Z_i and parameters β plus an independently distributed random variable ε_i representing the part of inefficiency not explained by Z_i (Farrell, 1957). Since $\gamma_i \geq 1$ by definition and ε_i is assumed to be distributed $N(0, \sigma_\varepsilon^2)$, the distribution of the error has to be left-truncated following the expression $1 - \psi(Z_i, \beta)$. After rearranging terms, we obtain $\varepsilon_i \geq 1 - \psi(Z_i, \beta)$, meaning that we always have inefficiency to explain (ε_i must be truncated on the left at $1 - \psi(Z_i, \beta)$), which does not happen when using Tobit or OLS.

Following the theoretical development of Simar & Wilson (2011) and its application in the higher education system by Wolszczak-Derlacz & Partera (2011) we used the truncated regression model in this second-stage analysis, paying special attention to the inference problem that arises from the inherent correlation amongst the DEA estimates in finite samples while obtaining coherent statistical models that lead to meaningful second-stage regressions. By carrying this analysis we aim to evaluate the determinants of university (in)efficiency, taking as a basis the efficiency measures derived from DEA estimation and employing as explanatory variables indicators not included in the DEA analysis. Standard errors of coefficients are estimated by bootstrapping technique (2,000 replications), and this leads to obtain more consistent errors compared to the case they are estimated by the standard maximum likelihood method.

¹⁷ Although our sample almost represents the entire population (44 out of 47 universities), this statement is also true in our case.

Considering the efficiency scores under the VRS assumption as the dependent variable, the independent variables chosen for the truncated regression included two dummy variables in order to control for the existence of a medical school or a polytechnic university, as previous studies found that these variables exert a positive and significant effect on the efficiency score (Kempkes & Pohl, 2006; Chapple et al., 2005). Likewise, we also examine the influence of having a business incubator within the university setting (Zi-yuan, 2010), as well as being settled in a science park (Siegel, Westhead & Wright, 2003). Thus, two extra dummy variables representing such advanced service infrastructures for the development of research and third stream activities were considered. Regarding the teaching mission, we included a fifth variable accounting for the number of students that abandon their studies without finishing them. This failure rate is quite meaningful as it can be understood as a proxy of the quality of the degrees offered by a university in relation to the level of exigency and difficulty. Finally, we controlled for size, age and educational diversity (Duch-Brown & Vilalta, 2010), operating similarly as for the regressions in Chapter 5. The resulting model is the one described in equation [7]:

$$DEA_i = \alpha_0 + \beta_1 \text{Size} + \beta_2 \text{Age} + \beta_3 \text{Academic Spread}_i + \beta_4 \text{Medicine}_i + \beta_5 \text{Polythechnic}_i + \beta_6 \text{Incubator}_i + \beta_7 \text{SciencePark}_i + \beta_8 \text{Failure rate}_i + \varepsilon_i \quad [7]$$

Descriptive statistics for all the variables and correlation matrix are shown in Tables C.1 and C.2, respectively. Looking at Table C.1 we can observe that more than 63% of the universities of the sample have a business incubator or a science park, meaning that such infrastructures are quite common amongst Spanish universities, and in particular 23 out of 47 universities do have both. The relationship between these two variables is confirmed in the correlation matrix (62.67%, p -value<0.000). Similar is the case of the presence of a medical school (proxied by the existence of degrees in the health sector), where only nine universities do not have any degree in this area of knowledge. This result is surprising because when considering the total number of degrees Spanish universities offer (2,396), only 7.14% are on health studies, meaning that universities do not really

focus on medical studies, but offers a few degrees as in any other area of expertise. The universities where medical degrees are more representative are the Universidad Rey Juan Carlos (16.67% of the total offer) and the Universidad Miguel Hernández (15.15%) with 5 degrees, and the Universidad de Zaragoza (13.89% of the total offer) with 10 degrees.

Table C.1. Descriptive statistics for the selected variables for the truncated regression.

Variable	Obs.	Mean	Std. Dev.	Min	Max
DEA scores	44	1.1244	0.1521	1	1.5185
Size (square meters)	47	282378.2	172166.8	88927	911740
Age (years)	47	133.6170	220.9353	11	791
Educational diversity	47	3.1671	0.8005	1.1011	4.2368
Medical school	47	0.8085	0.3977	0	1
Polytechnic university	47	0.0851	0.2821	0	1
Business incubator	47	0.63830	0.4857	0	1
Science park	47	0.6596	0.4790	0	1
Failure rate	46	0.1896	0.0501	0.0719	0.2988

Table C.2 also indicates a strong correlation between having a business incubator and concentration in medical and engineering degrees. In particular, incubators seem to be linked with universities with a medical school (30.89%) but not with polytechnic universities (-24.65%). This finding at first glance might be disconcerting, but can be easily explained by the elevated number of non-polytechnic universities having an incubator (26), becoming this not a distinctive infrastructure.

Although the truncated regression with a bootstrap model appears to fit the data well, the significance of parameters is relatively weak, with the exception of the polytechnic university dummy variable and the size. The effects of individual explanatory variables and combined models tested to explain the inefficiency scores under VRS assumption are given in Table C.3.

Table C.2. Correlation matrix of variables for the truncated regression.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1. DEA scores	1								
2. Size	-0.1363 (0.3778)	1							
3. Age	-0.1979 (0.1979)	0.6403 (0.000)	1						
4. Educational diversity	-0.1978 (0.1981)	0.2162 (0.1443)	0.3886 (0.0070)	1					
5. Medical school	-0.1661 (0.2812)	0.2431 (0.0997)	0.2718 (0.0646)	0.7407 (0.000)	1				
6. Polytechnic university	0.0792 (0.6092)	0.0776 (0.6039)	-0.0980 (0.5124)	-0.7425 (0.000)	-0.6267 (0.000)	1			
7. Incubator	0.0017 (0.9914)	0.1380 (0.3550)	0.0124 (0.9339)	0.1805 (0.2248)	0.3089 (0.0346)	-0.2465 (0.0949)	1		
8. Science park	-0.0171 (0.9120)	0.0971 (0.5162)	0.0002 (0.9988)	-0.0594 (0.6914)	-0.0073 (0.9612)	0.0582 (0.6976)	0.3002 (0.0403)	1	
9. Failure rate	-0.1899 (0.2225)	-0.0807 (0.5940)	0.1818 (0.2266)	0.1341 (0.3743)	-0.0738 (0.6260)	-0.0112 (0.9410)	0.1318 (0.3828)	-0.0338 (0.8237)	1

Significance level is presented in brackets.

Table C.3. Parameter estimates of truncated regression models explaining HEIs inefficiency.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Size	-0.1413 (1.0248)	-0.1611 * (0.0893)	-0.2141 ** (0.0846)	-0.1432 (0.0997)	-0.1454 (0.1049)	-0.1761 (0.1210)	-0.2048 (0.1277)	-0.2583 (0.1653)
Age	0.0044 (0.0628)	0.0373 (0.0633)	0.0218 (0.0612)	0.0060 (0.0631)	0.0094 (0.0676)	0.0253 (0.0758)	0.0621 (0.0832)	0.0463 (0.090)
Education diversity		-0.0719 (0.0646)					-0.0663 (0.6554)	0.0150 (0.1306)
Medical school			0.0442 (0.1277)					0.0157 (0.1746)
Polytechnic university			0.3283 * (0.1820)					0.3300 (0.2939)
Business incubator				0.0291 (0.0934)			0.0690 (0.0865)	0.0814 (0.1046)
Science park					0.0373 (0.0892)		-0.0031 (0.0798)	-0.0273 (0.1101)
Failure rate						-1.1505 (1.1385)	-1.309 (1.3095)	-1.2944 (1.3452)
Intercept	2.9083 ** (1.1513)	3.2624 *** (1.0081)	3.7002 *** (0.9566)	2.9067 *** (1.1219)	2.9194 ** (1.1628)	3.4859 ** (1.3976)	3.9077 ** (1.5282)	4.3343 ** (1.8702)
Sigma	0.1594 *** (0.0365)	0.1513 *** (0.0322)	0.1382 *** (0.0279)	0.1588 *** (0.0353)	0.1582 *** (0.0330)	0.1509 *** (0.0280)	0.1406 *** (0.0289)	0.1289 *** (0.0290)
Observations	44 (19 truncated)	44 (19 truncated)	44 (19 truncated)	44 (19 truncated)	44 (19 truncated)	43 (19 truncated)	43 (19 truncated)	43 (19 truncated)

Robust standard errors adjusted by heteroskedasticity are presented in brackets. *, **, *** indicate significance at the 10%, 5%, and 1%, respectively.

Results indicate a weak but significant decrease in efficiency for those universities with a presence of a polytechnic university. In the case of the existence of a medical school, although the sign of the relationship is clearly positive, the influence exerted appears not to be significant. The only other variable experiencing a significant influence is the size, suggesting that small universities might better administrate the relation between resources and outcomes, and thus, tend to be more efficient than larger ones. These results contradict in some way the theory of economies of scale, targeting that small universities are easier to manage, and that good results do not need to be accompanied by a large number of resources (specially material, financial or human), but by a competent mass.

The low explanatory power of the models tested suggested that other kind of studies should be carried in order to help us to understand differences in the performance of universities. As detailed in Chapter 7, the cluster analysis is chosen, which allows us to detect similar patterns of operating amongst universities, according to how each university orientates its strategy (i.e. more research oriented, more student oriented, etc.) regarding the general objective function.

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