Essays on universities and economic development

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Ph.D. Thesis
Programa de Doctorat en Economia, Bienni 2006-2008

ESSAYS ON UNIVERSITIES AND ECONOMIC DEVELOPMENT

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Barcelona, June 2012

A mis padres y hermanos

Acknowledgements

First and foremost I want to thank my supervisors Martí Parellada and Néstor Duch. I am indebted to them for their help. They have contributed with ideas and insights, not to mention helping me to find the funding needed to finish my Ph.D. I want to express my gratitude to Dr Parellada for his warm encouragement and thoughtful guidance. He has given me invaluable direction and helped me to think in new ways about many different aspects of the project. Dr Duch was not only an unsurpassed academic support, but my mentor and friend. I very much appreciate his enthusiasm, passion, determination, and his never-ending moral support.

The members of the Barcelona Institute of Economics (IEB) of the University of Barcelona have contributed immensely to my professional growth. In the IEB I found friends and excellent colleagues. I am especially grateful to Daniel Montolio and José García-Quevedo for helpful debates and valuable suggestions. Albert Solé, Alejandro Steller, Antoni Garrido, Elisabet Viladecans, José María Duran, Maite Vilalta, Maria Cubel, Marta Espasa, Montserrat Álvarez, Nuria Bosch, Pilar Sorribas and Toni Mora. Their constructive criticism and collaboration have been tremendous assets throughout my Ph.D.

My gratitude is also extended to Maria Àngels Gómez and Susana Cobos. They always had answers to my questions that I brought to them in all the intricate aspects of the administrative issues. They were always available to assist me, no matter the task or circumstance. I couldn't have completed all the required paperwork and delivered it to the correct place without their help.

I also owe a great deal of gratitude to a number of other friends and colleagues at the IEB: Elisa Trujillo, José Polo, Jordi Jofre, Marta Curto and Pere Arqué. They gave me valuable advices and friendly help, and most importantly, they were very supportive during the tough times. For this, I cannot thank them enough. Other past and present group members of IEB that I have had the pleasure to work with or alongside of are Albert Brue, Amedeo Piolato, Andreu Arenas, Elena Costas, Gabriele Pellegrino, Javier Vazquez, Luca Salvadori, Maria Sánchez, Raquel Marín, and Simon Planells. I have learned so much from all of them. I want to thank to Liam Seám Kely, Miriam Schindler and Kate Mackellar-Still. The help I received from them by correcting the English grammar in my drafts was priceless.

In the final phase of this dissertation, I enjoyed a very productive research visit to the Manchester Institute of Innovation Research (MIOIR) at the University of Manchester. My thanks goes to the MIoIR team for the nice environment they welcomed me into. Especially, Elvira Uyarra who was very supportive throughout my visit in Manchester. I would also like thank to Chiara Marzocchi, Deborah Cox, Fumi Kitagawa, Jacob Edler, Kieron Flanegan, Mercedes Bleda, and Piliph Shapira.

I gratefully acknowledge the funding sources that made my dissertation possible. For the first three years I enjoyed a grant from the Programme Alβan. For the subsequent three years, I had the support of the University of Barcelona and the Barcelona Institute of Economics (IEB).

I wish to thank my friends for all the emotional support, camaraderie, entertainment, and solidarity. Mentioning some names would be risky in case I accidentally omit some of them.

Of course no acknowledgments would be complete without giving thanks to my parents and siblings. They have always expressed how proud they are of me and how much they love me. I too am proud of them and love them very much.

Thank you

Javier García-Estévez
University of Barcelona
June 2012

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“Research-oriented universities are to the knowledge economy what coal and iron mines were to the industrial economy”

(Castells and Hall 1994)

Chapter 1

Introduction

The world economy has been undergoing a rapid structural transformation over the last few decades. This transformation is marked by a shift to more sophisticated skill- and technology-intensive sectors. Knowledge, science and innovation constitute the engine for economic growth in this scenario. This idea is largely supported by the endogenous growth theory. In particular, Romer (1990) developed an explanation in which agents optimally determine the resources allocated to research and development that lead to technological progress. In addition, Aghion and Howitt (1992) and Grossman and Helpman (1993) incorporated imperfect markets and R&D to the endogenous growth model.

A large consensus exists among scholars in relation to the role knowledge infrastructure plays as a driving force in the knowledge economy. Universities are an important component of that infrastructure. It is generally accepted that knowledge originating from universities as well as public research play a key role in technological change and economic growth (e.g., Jaffe, 1989; Adams, 1990; Salter and Martin, 2001). Accordingly, governments around the world are increasingly looking to universities as engines of economic growth and social development.

In recent years the European political agenda has focused intensely on higher education and its relation to economic growth. The conjunction of a growing importance of knowledge-led economies and the accelerated rate of global competition has generated 3 responses from the European Union: the Bologna Process and the strategies of Lisbon and Europe 2020. These responses have greatly shaped European higher education, and its response to new challenges. The Bologna process attempts to achieve transnational transparency of European Higher Education, while both the Lisbon agenda and Europe 2020 focus on economic growth, competitiveness and employability. Moreover, several European institutional initiatives are trying to understand the current role of universities and the future potential of universities in regional knowledge development. For example, the Programme on Institutional Management in Higher Education (IMHE) of the OECD conducted the project "Supporting the Contribution of Higher Education Institutions to Regional Development", in which a comparative review of how institutions, their regional stakeholders and partners interplay at different territorial levels. This review aimed to strengthen the contributions of Higher Education Institutions to regional economic, social and cultural development.

The changing roles of Universities

Although universities have long been recognized as key actors in economic development, there are an increasing number of additional roles they are expected to play (Uyarra, 2010). The past two decades have seen a growing emphasis on the need for universities to contribute to the environmental, social, and economic well-being of their home regions. More specifically, heightened demands are placed on universities to provide substantive value in terms of applied industrial research, talent development, technological discoveries, and knowledge transfer. In this context, universities are encouraged to play a new role as co-producers of knowledge in the innovation process of the regional business community. Hence, universities find themselves in a process of having to redefine their roles (Rutten and Boedema, 2009).

In addition, reforms have been introduced to help universities generate income for themselves and contribute to national wealth creation. For instance, public funding for university research in the UK has become dependent on the perception of whether it will make a direct contribution to the economy. The reduction in research funding available to universities has forced them to undertake activities that either attract industrial funding or generate income. This is particularly relevant in times, as those we are living today, in which the economic crisis puts a strong financial burden on the public resources devoted to higher education institutions (HEIs).

Universities have replied to the demands from their milieu by extending their classical role as a natural space for knowledge creation and sharing to perform other functions which are also playing an important role, for example, the creation of human capital, innovation and technology transfer, and regional leadership. From this perspective, universities have undergone two revolutions: first, the incorporation of research as an academic mission (Jencks and Riesman, 1968). Second, universities have assumed a role in economic development through extensions of both their research and teaching missions. Indeed, universities have increasingly expanded their activities further into the technology transfer mechanisms, identifying and filling gaps in the technology "push" process, establishing incubators to assist the formation of firms from campus research and venture capital arms to fill gaps in the availability of 'seed' funding (Etzkowitz et al., 2000).

According to Uyarra (2010), universities are perceived to play an increased number of key roles in economic development, besides the traditional role as producers of scientific knowledge ("Knowledge factory" role) namely: a "Relational" role involving knowledge sharing through university-industry interactions; an "Entrepreneurial" role based on the commercial exploitation of research; a role as boundary-spanning institutional "nodes" in innovation systems; and a "Developmental" role in relation to the regions in which they are located.

Consequently, the main outputs produced by modern universities can be summed up by: knowledge, human capital, know-how transfer, technological innovation, capital investment, provision of regional leadership, co-production of knowledge infrastructure and contribution to the regional milieu (Goldstein and Renault, 2004). In turn, the potential impacts of these outputs are productivity gains, business innovation, new business start-ups, increases in regional economic development capacity (for sustained, long-term development), regional creativity, and direct and indirect spending impacts. Diagram 1 shows a conceptual diagram of these outputs and impacts from universities.

Recently, knowledge is becoming an increasingly important part of innovation, and the university as the main knowledge-producing and disseminating institution should play a more prominent role in this process (Etzkowitz et al., 2000). The increased policy emphasis on the commercialisation of research and the creation of closer linkages between basic research and societal needs has raised substantial academic interest in this phenomenon. Over the last three decades, many countries have changed their legislation and created support mechanisms to encourage greater interaction between universities and firms, partly in the belief that industrial innovation had come to rely more heavily on academic research (Gulbrandsen et al., 2011). These initiatives stem from a belief that higher rates of innovation will result into higher rates of productivity growth and, therefore, socio-economic welfare (Deiaco et al., 2012).

Governments have usually supported R&D because of a desire to correct market failures in the private provision of new scientific knowledge. These market failures arise from two sources: firstly, high risk and sunk costs of conducting R&D discourages firms from engaging in R&D activity and secondly, the inability to appropriate all of the returns from R&D means that firms tend to invest below the socially optimum level (Hewitt-Dundas, 2012).

The need for commercially relevant university research expertise is reinforced further by the fact that companies are moving away from a system in which most of their research and development was done in their own laboratories, preferably in secret, to one in which they are actively seeking to collaborate with others in a new form of open innovation (Reichert, 2006).

In addition, over the last decade, many European governments have established university funds for innovation either in the form of research funds or university/business cooperation or in the form of a whole "third stream of funding" (in UK). This is attributed on the basis of a wider range of economically relevant engagement with non-academic partners. Such funding channels are intended to enhance the connectivity between universities and their milieu (Hewitt-Dundas, 2012). From an international perspective, regional authorities do not exert great influence on university behaviour through financing mechanisms or "hard" regulations. However, in some countries, regions have significantly greater means to influence such behaviour. For instance, the government in the UK and Spain grant certain autonomy to universities and provide specific regional (or "state") resources. In the UK, for instance, the government decided to increase the direct influence of regions on their skills and research base by giving them greater competence and the means to forge their own futures.

Universities and regional development

For example in Spain, the regional dimension has a particular relevance as a result of both the political and the administrative organisation of the State. Although most policies related to higher education institutions (HEIs) – hereafter referred to collectively as universities - are defined at national level, regions can influence and adapt them to achieve specific policy goals.

The relationship between universities and regional development has been analysed from several perspectives [See Drucker and Goldstein (2007) for an overview]. Some studies have analysed the role of universities as attractor, educator and retainer of students, shaping them into knowledge-based graduates for firms in the region (Boucher et al., 2003; Bramwell and Wolfe, 2008). According to these studies, the presence of a university affects the local labour market and contributes to the stock of tacit knowledge to provide formal and informal technical support.

A number of studies has aimed to quantify the effects that R&D activities have on the rise of productivity and economic growth. Goldstein and Drucker (2006) found out that the university activities of research, teaching, and technology transfer help raise regional economic development measured by average annual earnings. Sterlacchini (2008) confirmed the existence of a positive and significant relationship between the economic growth of European regions, and their knowledge base and human capital endowments, captured respectively, by the R&D expenditures and the proportion of adults with tertiary education. However, the impact of R&D is significant only for the regions that are above a given threshold of per capita GDP. Andersson et al. (2009) investigated the economic effects of the Swedish decentralization policy of post-secondary education on the level of productivity and innovation, and their spatial distribution in the national economy. Their model estimated the effects of university-based researchers on the productivity and innovation activity (award of patents) of local areas. They find a link between the number of university researchers in a community and the per worker output in that community.

This dissertation seeks to contribute to a better understanding of the roles that universities currently play in economic development. This topic is particularly relevant in the current situation, in the aftermath of the world financial crisis, when the leading industrial nations are increasing their support for universities and for scientific research in particular (Hughes and Mina, 2012). The main questions that this dissertation will deal with are therefore the following: How do universities affect economic development? To what extent do universities generate impacts on economic development that would otherwise not occur? These are big questions. We can start by answering smaller questions: What happens in a region in terms of firm creation when a university is created? What is the role of the universities in terms of creating of human capital? What are the effects of the universities on industrial innovation?

After discussing the main features of the relationship between universities and economic development, I proceed by briefly describing the contents of each of the chapters of this dissertation. Although the three main chapters of this dissertation are part of a common research project, each chapter is self-contained, meaning that can be read independently of the rest.

Chapter 2: **Does the presence of a university alter firm's location decisions? Evidence from Spain**

The existence of universities produces positive externalities both through performing knowledge-generating R&D activities and educating specialized human capital capable of absorbing such knowledge. Moreover, graduates may be important channels for disseminating the latest knowledge from academia to the local industry (Varga, 2000).

New firms take into account the additional factor of the existence of a university in a region when deciding on their location.

A myriad of empirical studies have confirmed that knowledge spillovers are geographically restricted (Jaffe, 1989; Anselin et al., 1997). Knowledge spillovers appear to significantly determine the location decision of new firms, including specialized human capital and institutions performing R&D activities (Audretsch et al., 2005). Moreover, the tendency to cluster geographically should be more common in industries where new knowledge plays a more important role because such knowledge is less likely to be codified and is simpler to transmit over great distances (Baptista et al., 2011)

This chapter evaluates the effects of the establishment of new universities by measuring its impact on the formation of new firms. I study this effect making use of the differences-in-differences methodology. I create a quasi-experimental design based on the enacting of the Spain's 1983 University Reform Act (LRU), which opened the door to the foundation of new universities and faculties.

The results indicate that the establishment of a new university has a positive and significant effect on new firm start-ups. When the analysis is carried out at faculty level, the findings indicate that the foundation of science and social science faculties has had a marked impact on the creation of firms. Finally, when new firms are grouped according to their technological level (i.e. high, medium or low), faculties of social sciences are found to be an important additional factor in the creation of firms in medium tech sectors.

Chapter 3: **Student graduation: To what extent university's expenditure matter?**

Since the pioneering studies of Schultz (1961) and Becker (1964), human capital (hereinafter, HC) has become a significant factor in the economics literature, and it has reached a key role in neo-classical endogenous growth models. The influential studies of Lucas (1988), Romer (1990), and Barro (1991) identify the accumulation of HC as the main source of productivity growth, while a related research line reports that a large stock of HC makes it easier for a country to absorb new products and ideas discovered elsewhere (Nelson and Phelps, 1966). These perspectives assume education to be a direct input into production, and consider growth rates to be related to increasing endowments of various inputs. Thus, changes in the HC stock are a decisive explanatory factor of growth (Mankiw et al., 1992; Hanushek and Kimko, 2000). Here, as Becker (1964) suggested, education is an investment of time and foregone earnings in exchange for higher rates of return at a later date. Two main mechanisms account for the accumulation of HC, namely, schooling (Lucas 1988) and learning-by-doing (Arrow, 1962).

Seen from another perspective, the skill-biased technological change hypothesis affirms that there is considerable complementarity between new technologies and skilled labour. Hence, the recent increase in demand for highly skilled workers in developed countries is mainly driven by technological change (Acemoglu, 1998; Piva et al., 2005). Hence, there is a constant upskilling of the workforce across developed countries.

As a result, HC is not just a key element for economic growth but at the same time it is experiencing a rise in demand. Universities play a fundamental role in the creation of HC. Diagram 2 shows the main effects that universities produce as a consequence of their teaching activities. For instance, recruitment of skilled students would be of great interest for firms that need specific university knowledge to be able to absorb it in their products, processes, and organization.

This chapter aims to analyse university characteristics that affect the graduation rate, and to determine whether regional characteristics influence university performance in terms of graduation. The results show that university expenditure has been a key determinant of the graduation rate in Spain over the last decade. Moreover, results obtained through quantile regression analysis show that a policy of increasing university expenditure only makes sense for universities with low graduation rates. However, universities whose graduation rates do not belong to the 20th percentile can improve their ranking by raising financial-aid to students.

Chapter 4: **On the effects of University-Industry interactions**

Are universities producing and disseminating really the kind of knowledge that is most needed in the knowledge economy? Businesses ask universities to provide relevant research expertise in order to become or remain globally competitive, and innovative. This expertise can be transferred directly through both collaboration agreements and other open science channels, or indirectly through recruitment of their graduates. The fourth chapter attempts to understand how universities and firms establish well-functioning formal and informal flows of explicit and tacit knowledge.

Of key relevance in this context is therefore the need to expand our understanding of the factors that differentiate universities as partners in the innovation process from other external alliance partners (Bercovitz and Feldman, 2007). The purpose of this chapter is to gain a better understanding of university-firm collaboration and the effects this collaboration has on firm’s innovation performance.

In the current context of the knowledge-based economy, the rapid pace of technological change exerts significant pressure on enterprises to expand their innovative capabilities. From an organisational perspective, carrying out R&D activities and/or intensifying them is one of the firms' most strategic decisions. In doing so, firms have designed new R&D practices to undertake them. The next decision that firms should make is ***how*** to perform R&D i.e. through internal process or through cooperation with partners. This decision depends on the characteristics of the technologies involved, as well as on the characteristics of firm's competencies (Miotti and Sachwald, 2003). Thus, firms conducting expensive, risky or complex research will seek R&D cooperation.

The major motives for firms to become involved in R&D cooperation have been grouped into different classes: Cost and risk sharing, complementarities or skill sharing, and factors related to the absorptive capacity of the firm (Tether, 2002; López, 2008). In turn, the effects of cooperation can be summarized as firstly, it augments and extends firm’s internal efforts to achieve strategic objectives (Bercovitz and Feldman, 2007) and, secondly, it enables firms to internalise the knowledge spillovers and eliminate the disincentive effect of spillovers on R&D (Belderbos et al. 2004).

Finally, the choice of an R&D partner with a specific profile (***with who***) depends on the type of complementary R&D resources firms seek to access. Often R&D cooperation is classified as either vertical (clients, suppliers and competitors) or horizontal (universities, public institutes) (Miotti & Sachwald 2003). Firms decide to interact with universities motivated by factors such as obtaining knowledge of scientific and technological advances, getting access to highly trained human capital and solving specific problems (Mansfield, 1995). Moreover, the set of reasons for UIIs also contains access to instruments, experimental materials, and research techniques (Cohen et al., 2002).

The universities' roles in industrial innovation are tested in this chapter. Four different roles of universities are analysed: 1) as source of information, 2) as a partner of cooperation, 3) as an agent helping to enhance absorptive capacity and, 4) as a supplier of R&D services. The effect of the universities roles in industrial innovation is captured through three measures: 1) the share of sales with significantly improved products or products new to the firm (but not new to the market), 2) the share of sales due to products new both for the firm and the market, and 3) patent applications.

The main findings can be summarised as follows. Firstly, the role of universities as a source of information and knowledge is found to be a very important channel in enhancing firms' innovative performance. Secondly, carrying out formal collaboration with universities in order to perform research is a very effective mechanism for improving firms' innovation outcomes. Moreover, the effect of collaborating with universities over four years is found to have a strong and positive impact on firm innovative performance. Thirdly, universities as a creator of highly skilled workers are found to be one of the natural and most important mechanisms through which they boost innovation. Finally, universities play another role in the innovation process as suppliers of R&D services. It is confirmed that firms that undertake the development of complex innovations buy R&D services from universities.

In general, the contribution of universities is very helpful in terms of getting new products to market and for generating patents, while it is less important for conducting innovations new to the firm.

The following chapters are concerned with questions of universities and economic development. The first two of them with a regional perspective - firm location and creation of human capital - and the other deals with the links between universities and industry. Overall, this dissertation provides strong evidence for the importance of universities and demonstrates the wide range of mechanisms by which universities influence economic development.

Diagram 1 Relationship between University and Regional Development (Short and Long-term Effects)

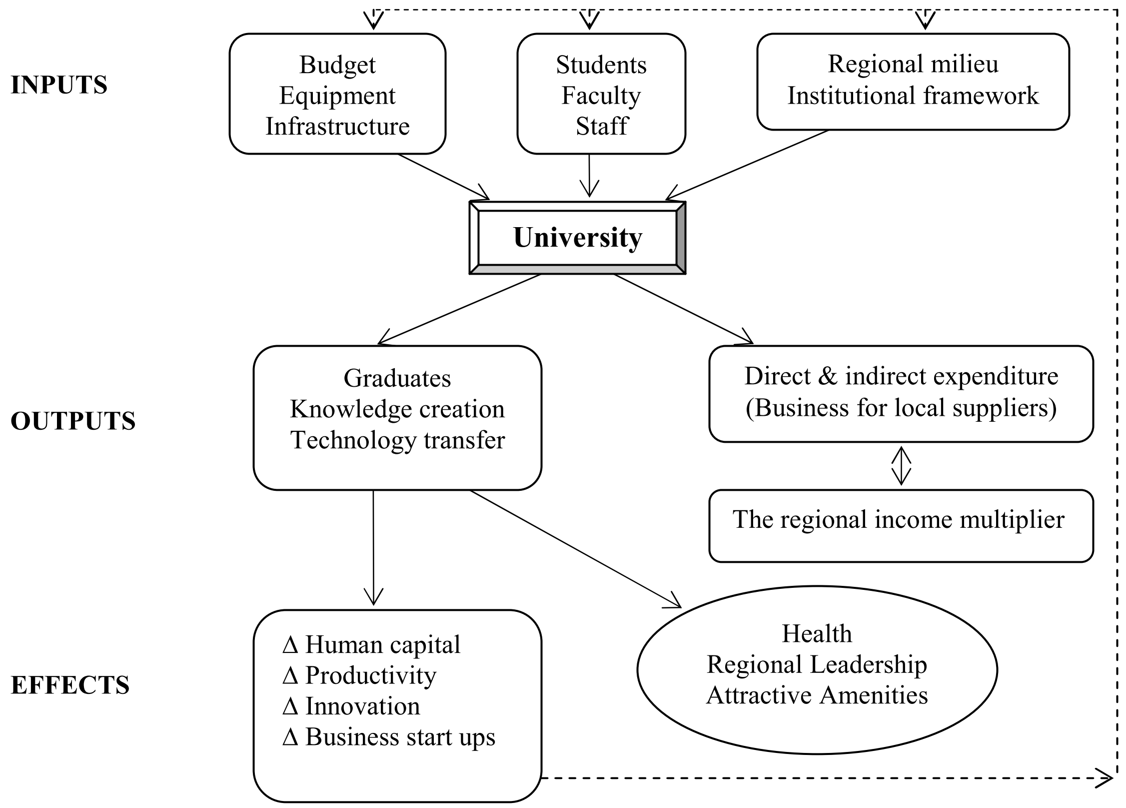
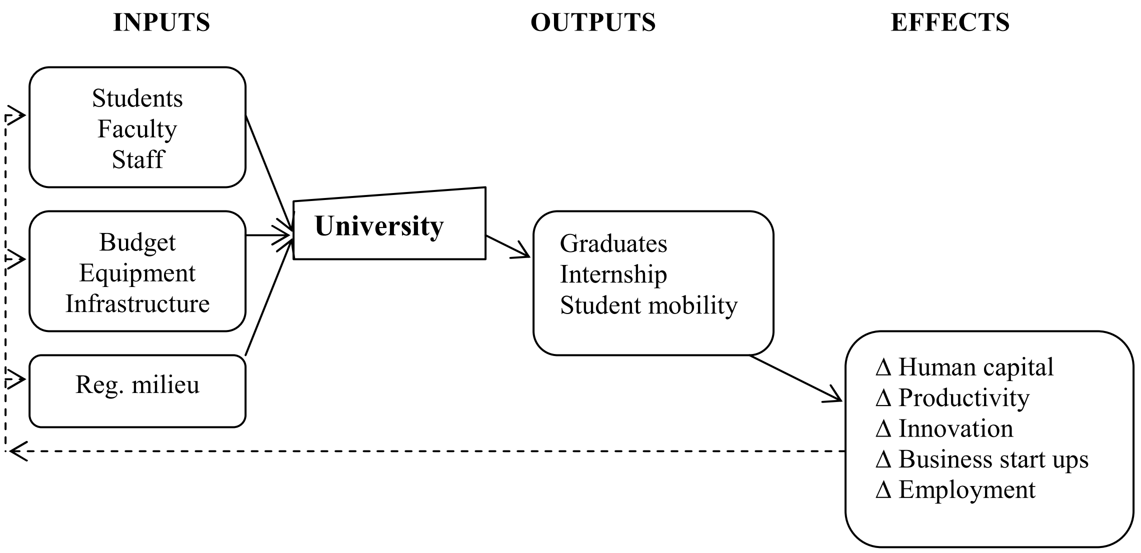


Diagram 2 Universities and the creation of Human capital



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“The consequences for human welfare involved in questions like these are simply staggering: Once one starts to think about them, it is hard to think about anything else.”

(Lucas, 1988)

Chapter 2

Does the presence of a university alter firm's location decisions? Evidence from Spain

1. Introduction

Universities have long been recognized as key actors in technological change and economic development. In recent decades, many countries have increased both incentives to, and the pressure on, universities to become more involved with their wider regions. Most universities reacted by offering more market-oriented programmes and by building closer links with business[1]. A leading issue in this relationship between universities and regional government has been the fostering of entrepreneurship and the creation of firms. To achieve these goals, regional policy has typically sought to lever the presence of local research universities, increase the availability of venture capital, encourage a culture of risk taking, and create strong local informational and business development networks (Feldman, 2001).

The literature on firm's location points out the existence of agglomeration economies as the main factor for understanding the location decision. The literature on the New Economic Geography, for instance, provides a theoretical framework for explaining the

[1] See Drucker and Goldstein (2007) for an overview of the literature discussing the relationship between universities and regional development.

spatial distribution of economic activity by analysing the interaction of transport costs and firm-level scale economies (Krugman, 1991). In turn, such interaction creates spatial demand linkages that further agglomeration. Thus, firms are attracted to cities where they might serve large local markets from just a few plants while incurring low transport costs (Fujita et al. 1999). In these models, however, the degree of geographic concentration is limited by rising congestion costs.

The empirical literature, meanwhile, traditionally focuses on Marshallian micro-foundations of agglomeration economies i.e. knowledge spillovers, labour market pooling and input sharing (Rosenthal and Strange, 2001). The evidence is that knowledge spillovers (measured in terms of industry R&D, university research and skilled labour) are key drivers of agglomeration (Audretsch and Feldman, 1996; Glaeser, 1999).

Another stream of literature seeks to understand the universities' contribution to the generation of knowledge spillovers. Varga (2000) characterized three kinds of university spillovers: information transmission through personal networks of university and industry professionals; technology transfer via formal business relations; and spillovers promoted by universities' physical facilities. Audretsch et al. (2004), in testing whether knowledge spillovers generated by universities are homogeneous with respect to two scientific fields (namely, natural and social sciences), provided strong evidence of the generation of knowledge spillovers in the German university system. Audretsch and Lehmann (2005) further corroborated that new knowledge and technological-based firms have a high propensity to locate close to universities. They reported that the two main types of spillovers are research and human capital, proxied by scientific research published in scholarly journals and human capital embodied in students graduating from a university. It has also been demonstrated that university spillovers occur through geographically localized mechanisms, the impact being significantly greater for firms that are technologically closer to research universities (Jaffe et al. 1993, Kantor and Whalley, 2009), and over longer distances through collaborative research (Ponds et al. 2009).

Such studies have also been concerned with analysing the fundamental factors involved in the formation of an entrepreneurial culture. Feldman (2001) summarises these as supportive social capital, venture capital, entrepreneurial support services and actively engaged research universities. Thus, the birth of new firms, mainly in high-tech sectors (HT hereafter), should be positively associated with higher levels of educational attainment (Acs and Armington, 2002), university R&D expenditure (Woodward et al., 2006; Kirchhoff et al., 2007) and university research (Bania et al. 1993; Colombo et al. 2010). In the Spanish case, Acosta et al. (2009) reported that the main source of university spillovers that accounted for new HT-business location close to universities was the number of graduates.

The literature tended to consider only homogeneous spillovers. However, universities carry out activities (both research and teaching) in many scientific disciplines with a highly varied degree of industrial and commercial applicability. As such, it is of interest to identify any underlying differences that might exist between the types of knowledge generated by universities. To date, only Audretsch et al. (2004) has conducted such a differentiated analysis (see discussion above). Here, we adopt a similar approach and distinguish between three different fields of knowledge: 1) sciences and engineering, 2) social sciences and humanities, 3) health. Moreover, we are able to take our analysis one step further by incorporating recent changes in the university regulatory framework operating in Spain.

The paper has two main goals: first, to contribute to the empirical literature on the relationship between universities and regional economic development, more specifically to analyse the effect of the presence of a university on the creation of new firms; and second, to identify more precise modes of knowledge spillover mechanisms by differentiating between the academic fields through which a university might influence the region in which it is located.

We focus on a period in which significant university reforms were made. Spain's 1983 University Reform Act (LRU) encouraged regions to expand their existing universities and to create new institutions. As a result, the public university system underwent considerable territorial expansion. As such, the legislation represents a natural experiment that serves to estimate the effects of university spillovers on the creation of new firms, all the more so because any shifts in entrepreneurial activity before and after the introduction of the law can be compared.

By distinguishing between university faculties in terms of the main academic studies being offered, we are better able to identify more specific knowledge spillover mechanisms. We are also interested in observing which industrial sectors are influenced most. Thus, we seek to determine whether the creation of faculties has had an effect on new firm start-ups in high, medium, and low technology sectors. The main findings can be summarized as follows: the creation of faculties in academic fields such as the sciences and social sciences has had a positive effect on the creation of new firms.

The paper is organized as follows: section 2 describes the main features of the 1983 University Reform Act and its implications for the creation of new universities and faculties; section 3 describes the data and outlines the empirical strategy; section 4 presents the results; section 5 concludes.

2. The University Reform Act (LRU)[2] of the early 1980s.

In the late 1970s and during the 1980s, Spain implemented a number of significant institutional changes derived from the transition to democracy. Among them, the higher education system was subject to substantial political and economic reforms. The first milestone was the inclusion in the Spanish Constitution of the three basic principles on which university legislation was to be based; the right of all Spaniards to education, academic freedom, and the autonomy of the universities (OECD, 2008). Later, in 1983, the enactment of the LRU sought to modernize the university system, improve its quality and enhance its competitiveness.

The Act introduced several radical changes, focussing primarily on the social embeddedness of the universities, their democratic organisation, and the need for a far-reaching modernisation of their scientific capabilities. Three aspects of this reform are of specific interest to us here.

[2] *Ley de Reforma Universitaria* henceforth LRU, in its Spanish acronym.

First, we examine the devolution of powers for the planning and administration of higher education, from the 1980s until the mid-1990s, from central to regional governments. The LRU introduced a decentralised model of governance for managing higher education organized in four tiers; the state, the autonomous regions, local governments and educational institutions. Today central government, through its Ministry of Education, controls the legal framework that guarantees the homogeneity and unity of the education system. The government elected in each autonomous region regulates and administers the higher education institutions (HEIs hereafter) within its territory. It has the jurisdiction to establish, authorise and supervise the running of public and private institutions, academic and administrative staff, and to build new educational facilities and renovate existing ones. The Act granted regional governments the power to implement their own higher educational policy, including decisions to create new universities. As a result, many regions created new universities in their provinces, and others opened at least one new faculty (See Figure 1), and hence bringing about a marked rise in the number of such institutions. Since 1983, a total of forty new HEIs (new universities or new campuses) have been created.

The Spanish Constitution allows for the public and private ownership of universities. Public universities can be established either by law enacted in the national parliament in agreement with the local regional governments, or by legislation drawn up directly by the legal assemblies of the autonomous regions. With the approval of the autonomous government, any person or legally recognized entity can found a private university, which can either be owned and run by the Catholic Church or have lay university status. Although the number of private universities has increased since the 1990s, Spain's university system is still largely dominated by public institutions. Between the introduction of LRU and 1994, twenty-two universities were founded, i.e. 32% of all institutions were created during our period of analysis. At the same time, most of the existing universities increased their operations, expanding into new territories. Thus, during the 1980s, the number of students enrolled at Spain's universities rose rapidly. In 1970 the number of university students stood at 352,000, by 1980 it had risen to 698,000, and by 1985 935,000 students were enrolled (Hernández, 1983). The university system underwent unprecedented expansion (see Table 2).

Second, the LRU ushered in much greater university autonomy. It granted university governing bodies control over their own planning and management, including financial autonomy. This autonomy means they are entitled to draw up their own statutes and choose, designate, and change their governing and representative bodies. The third consequence of the reform was the universities adopted a clearly defined dual-dimension - teaching and research - in line with their European counterparts. Incentives to encourage joint R&D projects involving universities and the private sector were also introduced. Consequently, university R&D expenditure increased from 0.11% of GDP in 1983 to 0.28% in 1994.

3. Data and estimation strategy

In order to determine the impact of the presence of a university on the creation of new firms, we assembled a data set for the Spanish provinces (NUTS 3) for the period 1980 to 1994. Below we describe the database and define our variables. We then outline our estimation strategy and include a brief explanation of our empirical approach. Finally, we present the specification adopted for conducting the econometric analysis.

Spain has 50 public universities located in 43 of its 52 provinces[3]. This public university system comprises 470 faculties operating across the range of academic fields (INE, 2009). Our analysis does not take into consideration universities (or faculties) created after 1994 and before 1980. We have obtained information for 224 of these faculties, 38% of which were founded after the enactment of the LRU[4]. Our study exploits the differential timing of faculty foundations in each academic field across Spanish provinces, to identify how the presence of a university can affect new firm start-ups.

[3] Some of the largest Spanish universities have campuses in different provinces. For instance, the Universidad de Castilla-La Mancha has four campuses across four different provinces: Albacete, Ciudad Real, Cuenca and Toledo.
[4] The missing faculties correspond to regions that already had a university before LRU. Therefore, according to our methodology, this missing information does not compromise our estimations.

3.1 Data

As noted, because our main hypothesis assumes that the relationship between universities and the creation of firms depends on the academic disciplines being offered by that institution, the presence of a university is classified in accordance with three broad fields: sciences and engineering (*SCI+Eng*), social sciences and humanities (*SSCI+Hum*), and health sciences (*HEALTH*)[5]. For each province, we noted the year in which the faculties dedicated to each of these fields were founded. We were only interested in those faculties founded during the period of analysis[6]. As such, this particular setting provides a unique opportunity to analyse the linkages between the presence of a university and new firm start-ups.

Our main outcome variable is the creation of industrial firms throughout the Spanish provinces in a given year. The database on new firm formations comes from the Register of Industrial Establishments (RIE), constructed by the Spanish Ministry of Industry and Energy. It provides administrative information about the opening of industrial establishments by sector, their initial investment, number of workers, electrical power supplied, and geographical location. Unlike other sources, the RIE takes the establishment as its unit of information, rather than the company - an attribute that allows us to be more geographically accurate. During the period considered 124,957 new establishments were created in the Spanish manufacturing sector, 14% of which were in medium and high-tech (MHT) industrial sectors. A notable feature of these enterprises is that 87% of them started with fewer than 10 workers, and that 99.4% of them started with fewer than 100 workers[7].

We further complement our panel with a set of variables that allows us to study agglomeration economies. First, we include the Herfindahl index and the population of each province. Second, to test the role of the market on the location of a new firm, a market potential measure is introduced. The exact definition of variables is described

[5] The category includes medicine, pharmacy, and nursing.
[6] This information was, in most cases, complemented and confirmed by faculty staff via email.
[7] This is consistent with the size distribution of firms in Spain, a country with a traditionally high share of SMEs.

below. These data were obtained from the National Institute of Statistics (INE) and the BBV foundation (1999). Table 1 provides descriptive statistics of the data.

3.2. Estimation strategy

One of the main empirical challenges faced in identifying the impact of a new faculty on the creation of new firms is the fact that the opening up of new faculties is usually endogenous to the economy, in the sense that the strongest economic agglomerations constitute the demand for founding new faculties. The LRU radically changed the framework regulating Spain's universities. In methodological terms, the Act represents an exogenous source of variation, because the establishment of a new university, which is the central causal parameter of interest in this study, derives from a political decision.

Following the enactment of the LRU, most provinces founded at least one new faculty in each of the three academic fields defined. However, the exact year of foundation of each new university varied from province to province, as did that of their new faculties (Table 2). Exploiting this geographical and temporal variation in the foundation of faculties, we were in a position to compare the creation of firms before and after the foundation of the faculty in the different provinces. Hence, we used a difference-in-differences approach (DD) to estimate the effect that the foundation of faculties had had on the creation of new industrial firms in the period. By adopting this strategy we were able to avoid the endogeneity problems that typically arise when making comparisons between heterogeneous individuals (Bertrand et al., 2004).

The fundamental ideas underpinning the DD-estimator can be summarised as follows. First, the DD-estimator takes the "normal" difference between the treatment and control group and estimates the treatment effect. Here, the underlying assumption is that the trend in the variable of interest is the same in both treatment and control groups. Second, the DD-estimator assumes that any differences in the change in means between treatment and control groups are the result of the treatment. Finally, the DD method is based on the idea that the unobserved provincial component does not vary over time within a group[8].

The DD-estimator has the following form:

$$Y_{it} = \beta_0 + \beta_1 X_i + \beta_2 T_t + \beta_3 X_i * T_t + \varepsilon_{it} \qquad (1)$$

Where X_i is a dummy variable taking the value 1 if the individual is in the treatment group, 0 if it is in the control group, and T_t is a dummy variable taking the value 1 in the post-treatment period and 0 in the pre-treatment period. In this specification, the DD-estimator is β_3, the coefficient on interaction between X_i and T_t. It is a dummy variable that takes the value 1 only for the treatment group in the post-treatment period. In addition, the DD approach is based on the assumption that the influence of other factors can be controlled for by a comparison with a province that is similar in every aspect as regards effects on firm formation, but which has not created a faculty.

In our econometric framework only the foundation year of each faculty is assumed to be exogenous. We have two groups of provinces: control and treatment. The first one is composed of provinces which did not have a faculty at the start of the period of analysis and did not experience changes over time. Instead, the treatment group comprises those provinces that created at least one faculty after LRU. Provinces which held a faculty before 1980 are excluded.

According to Varga (2000), Audretsch et al. (2005) and Acosta et al. (2009) the main source of university spillovers is the number of graduates, hence, it is fair to assume that the effects of university presence on regional economy occur at least five years after its foundation.

[8] If any of the assumptions listed above do not hold then we have no guarantee that the DD-estimator is unbiased. For example, one of the most common problems with DD estimates is the failure of the parallel trend assumption (Figure 2 illustrates the performance of this assumption for our data). One way to help avoid this problem is to obtain more data for other time periods before and after treatment to determine whether there are any other pre-existing differences in trends.

The DD equation, for our panel data for the creation of firms in 50 provinces over 15 years, is given in equation (2)

$$Y_{ijt} = \alpha_{ij} + \beta_1 Fac_{i,\, t+5} + \beta_2 lnMP_{i,\, t} + \beta_3 lnPop_{i,\, t-1} + \beta_4 HI_{i,\, t} + \gamma_t + \varepsilon_{ijt} \qquad (2)$$

The dependent variable is the number of new industrial establishments in province *i*, year *t* and industrial sector *j*. The main explanatory variable is the dummy variable $Fac_{i,\, t+5}$, which equals one for province *i* in year *t+5* (where t is the year when a faculty was founded), and zero otherwise. As one objective of this study is to analyze whether the kind of science matters in the production of knowledge spillovers, the variable *Fac* alternates between the three academic fields (*SCI+Eng, SSCI+Hum,* and *HEALTH*).

As discussed above, agglomeration forces are a key factor affecting the choice of a firm's location. We include urbanization and localization economies proxied by a province's population ($lnPop_{i,\, t-1}$) and employment specialization index ($HI_{ij,\, t}$), respectively. As in Rosenthal and Strange (2003), the diversity of economic activity is incorporated using a Herfindahl index of employment by 11 two-digit manufacturing industries, defined as

$$HI_{ij,t} = \sum_s \left(\frac{e_{si}}{e_i} \right)^2$$

Where $HI_{ij,\, t}$ is the Herfindahl index for province *i* and year *t*. e_{si} is the employment in sector s in province *i*, e_i is the total employment in province *i*. An increase in $HI_{i,\, t}$ reflects less diversity in the environment. Duranton and Puga (2001) suggested that if diversity plays a more important role for firm births, the coefficient for this index is expected to be negative and significant.

Furthermore, agglomeration forces draw firms towards places characterized by better access to customers ('demand or backward linkages') and suppliers ('cost or forward linkages') (Ottaviano and Pinelli, 2006). An empirical way to introduce this effect is a market potential measure. Harris (1954) proposed a classic gravity-type measure, in which the potential between two locations is positively related to their size and negatively related to the distance between them. Market potential is given by the following expression[9]:

$$MP_{j,t} = \ln\left[\sum_k \frac{M_{k,t}}{d_{jk}}\right] \text{ for } j \neq k. \text{ When } j=k,\ d_{jk}=1$$

Where $M_{k,t}$ is a measure of the market size of the destination k (e.g. measured in terms of population or GDP), d_{jk} is the distance between origin j and destination k. These variables are expressed as a logarithm to reduce heterogeneity and to detect non-linear relationships.

Finally, the panel specification includes annual time dummies[10] (γ_t) and in order to control for unobserved regional heterogeneity, province and industrial fixed effects (α_{ij}) are also introduced. We use 34 industry sectors to better control aggregation effects in provinces with a different distribution of industries. Industry codes are based on the two-digit National Classification of Economic Activities (NACE 93 Rev.1).

Arauzo et al. (2010) synthesize in two categories the basic econometric tools adopted in empirical studies on industrial location: Discrete Choice Models (DCMs) and Count Data Models (CDMs). Thus, when the unit of analysis is the firm/plant and the main concern is how its characteristics (size, sector, etc.) and/or those of the chosen territory (population, infrastructures, etc.) affect location decisions, DCMs are used. When the unit of analysis is geographical (municipality, county, province, region, etc.), and the factors that affect location decisions therefore refer to the territory, then CDMs are used.

From a statistical viewpoint, given that the dependent variable has the features of count data, it can be assumed that this variable follows a Poisson distribution. That is, it has

[9] Head and Mayer (2005) calculate and compare complex alternative measures of market potential. However, the results are very similar to the specification suggested by Harris (1954).

[10] We also estimated a version of the model by including an interactive term between annual and industrial sector dummies, in order to better absorb specific shocks for industrial sector and year. The results are very similar to those reported below.

large numbers of the smallest observation and remaining observations taking the form of small positive numbers[11].

A key issue in count data models is the presence of overdispersion, and therefore, the choice between the Poisson model and the negative binomial model. In order to solve this, Cameron and Trivedi (2009) suggest that the Poisson panel estimators rely on weaker distributional assumptions - mainly, correct specification of the mean - and it may be more robust to use it with cluster-robust standard errors, than with the negative binomial estimators[12]. Figure 3 shows the distribution of the dependent variable.

4. Results

The first set of regressions estimates the effect of university creation on new firm start-ups. As discussed above, the assumption is that the effect takes place five years after the creation of the university, when the first year intake graduates. Thus, this specification includes a dummy that takes the value one commencing five years after the foundation of the university[13]. In all regressions, we include cluster-robust standard errors so as to account for both overdispersion and serial correlation. Other empirical issues should be mentioned: First, to avoid multicollinearity problems between population and market potential, the latter was calculated with provincial GDP rather than population. Second, we did not include spatial econometric techniques because Moran's I statistic rejected the presence of spatial autocorrelation in the geographic distribution of new firms in Spain in our period of analysis. Third, since our unit of analysis is both the province and the industrial sector, the adoption of fixed effect (FEs hereafter) estimation helps to control

[11] Following Arauzo et al. (2010), the underlying assumptions in empirical studies on industrial location using count data models imply the existence of an equilibrium allowing the derivation of the number of new firms/plants created in a given region over a given period. This equilibrium results from the existence of stochastic, unobservable, and location-specific demand and supply functions of potential entrepreneurs.

[12] In order to rule out overdispersion from our data, after applying this specification a test was computed, and the null hypothesis of no overdispersion was accepted.

[13] Or faculty, in the case of subsequent specifications.

for unobserved heterogeneity specific to each province and to each sector[14]. A Hausman test was performed, indicating that the differences between the fixed and random effects' coefficients are not systematic. Therefore, both procedures are appropriate, and for brevity only FE estimations are reported[15]. Finally, it is also interesting to examine whether the university founded (or later, the kind of faculty) has a specific impact on a particular industrial sector. In order to test this link, we split the sample into three industrial groups; high (HT), medium (MT), and low tech (LT).

Table 3 shows the results from this first model. When all industrial sectors are included, the effect of university foundation on firm creation is positive and statistically significant (see column 1). Likewise, the coefficient of market potential is positive and significant. Columns 2 and 3 report the regressions for HT and MT sectors. In these cases, the foundation of a university does not have any effect on the dependent variable. The coefficient of specialization index is positive and has a significant effect on the creation of new firms in HT sectors. On the contrary when MT sectors are analysed, that coefficient, although again statistically significant, it is negative. Finally, we can see in column 4 that the university creation has a positive and significant effect on the formation of firms in LT sectors. Also the coefficient of the lagged logarithm of province population is positive and statistically significant.

The following step on the analysis investigates whether the kind of faculty founded has any differentiated effect on the creation of firms. The results are presented for separate regressions for each academic field. For instance, columns 1 to 3 of table 4 present the results for the whole sample and column (1) includes the dummy for the creation of *SCI+Eng* faculties. Similarly, in columns (2) and (3) the specifications alternate the variable *Fac* for the rest of academic fields.

The results present two patterns. In the first of these, including *SCI+Eng* and *SSCI+Hum*, the foundation of this type of faculties has a positive and statistically significant effect on the creation of industrial establishments. Regional and national market access, proxied by

[14] Particularly, we expect that FEs capture province specific determinants of location such as regional policy, institutional framework, and remoteness.
[15] Results of random-effects are available from the authors upon request.

a market potential measure, produces ambiguous results. In the case of *SCI+Eng*, it is revealed to have a substantial positive influence on firm location, whereas for *SSCI+Hum* it is not statistically significant. We find no evidence to support the presence of localization economies (the coefficient of the specialization index is not statistically significant). This outcome is probably due to the fact that FEs absorb all the explanatory power, as industrial structure shows only small variability across time.

As for urbanization economies, when the regression includes the *SCI+Eng* faculties, the coefficient of the lagged logarithm of population is not statistically significant. We obtain statistical evidence of the presence of urbanization economies when the faculty of *SSCI+Hum* is included. Nevertheless, this result should be taken with caution because population and establishment of faculties are correlated - the probability of creating a faculty is as large as the size of the province's population. Despite this, we wish to control for this key variable and so have kept it in our analysis for two reasons: first, both the magnitude and the statistical significance of coefficients are very similar when the variable of urbanization economies is dropped from the regressions; and second, the variable is introduced in a logarithm in order to reduce collinearity.

In the second pattern presented by the results, the creation of health faculties seems to have no statistically significant impact on new firm start-ups (see column 3, Table 4). It could well be argued on this point that the number of health faculties founded during the period of analysis was smaller than for those created in other academic fields, and that influence of health faculties on regional development occurs through other channels. As the OECD (2008) suggested, HEIs have actively taken part in promoting community service in areas such as public health and the arts throughout history. In this model, the market potential does not have a significant effect on the dependent variable either. Only the coefficient of the variable for urbanization economies is positive and statistically significant.

When the sample is split according to technological levels, the following results are found. Regarding creation of HT firms, it was not possible to determine whether the foundation of faculties had any effect (see columns 4 to 6 at Table 4). Three arguments can help explain this result. First, our data only include firms from the industrial sector, and perhaps this linkage is strongest in service sector firms. Second, the period under analysis could be characterized by a lower dynamism in the creation of HT industries. In fact, during the period analyzed only 2,620 firms were created in HT sectors, representing just 2% of total firms. Third, only recently has the creation of science parks or the increase in the volume of contracts of the Offices for the Transfer of Research Results (OTRI) shown an expansion of the relationship between the universities and the firms in the transmission of knowledge (Barrio and García-Quevedo, 2005).

Columns 1 to 3 of Table 5 show the results for MT sectors. Only the faculty variable *SSCI+Hum* yields a statistically significant coefficient. The coefficient for the specialization index is negative and statistically significant, when *SCI+Eng* and *Health* are included. On the contrary, this index is systematically positive in the HT sample.

The regressions for LT industrial sectors are shown in columns 4 to 6 of table 5. In general, the results are similar to those of the whole sample. Two patterns also emerge: the faculties of *SCI+Eng* and *SSCI+Hum* have a significant positive effect on firm formations (see columns 4 and 5), but health faculties have no significant effect on the dependent variable (see column 6). Both market potential and urbanization economies show similar results to those of the whole sample.

5. Concluding comments

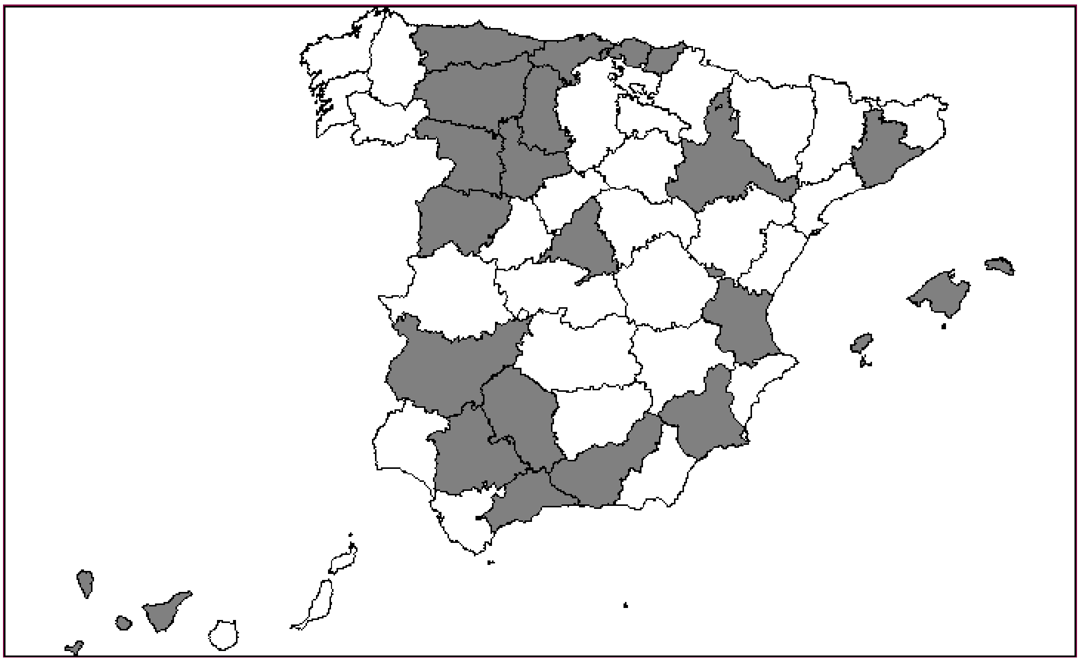
Universities have long been recognized as a key element in regional economic development. In more recent years, universities have increased their attempts at raising regional entrepreneurial culture, above all by generating knowledge spillovers. As a result, an understanding of these spillover mechanisms has become an issue of increasing interest in the literature. In this paper, we have sought to explore this field further by incorporating a new methodological approach that has allowed us to examine, more accurately, the effect of the foundation of new universities on new firm start-ups. Thus, by taking into consideration the exogenous changes in the foundation of university faculties ushered in with the Spanish University Reform Act of 1983 (LRU), this paper has analysed the linkage between the presence of a university and new firm formations. By drawing on data from the register of new industrial establishments and faculty foundation dates, it has been possible to examine the effect of knowledge spillovers on the creation of new firms in Spain.

Our results show that the creation of universities had a marked impact on new firm start-ups, with the foundation of SCI+Eng and SSCI+Hum faculties presenting a positive effect on firm formations. For these two academic fields, therefore, we confirm the central hypothesis of this paper. By contrast, the creation of health faculties did not have a significant effect on new firm start-ups during the period analysed. In short, the Spanish case presents strong evidence that the presence of a university is a key factor taken into account by firms when reaching their locational decisions.

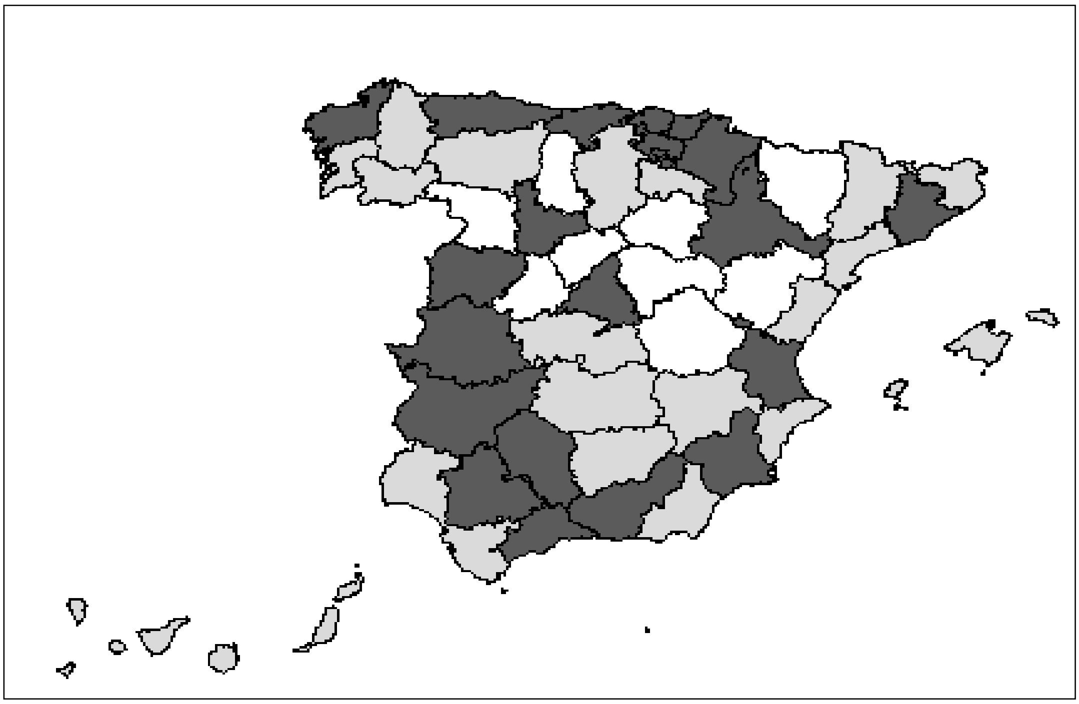
Furthermore, it has been possible to validate that the most important effect of the universities on the economy occurs via human capital. Future research might seek to analyse other important mechanisms promoting knowledge spillovers from universities to firms such as scientific research and technology transfer.

Figure 1
Change in the geographic distribution of Spain's University System 1980 - 1994.

1980



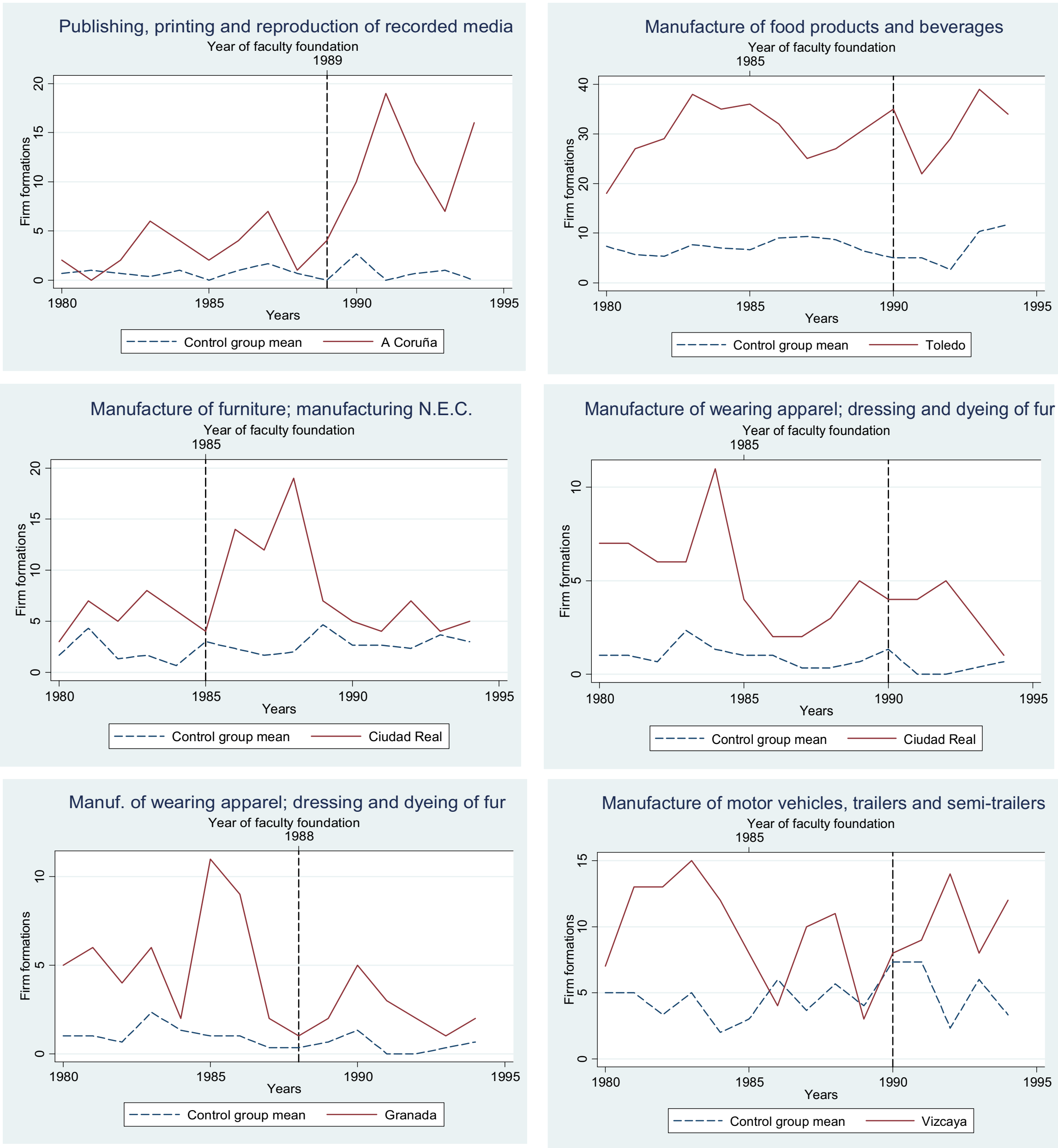
1994



Control group: Provinces without universities
Treatment group: Those provinces that created at least one university during the period of analysis
Provinces drop out analysis because they already had universities at the beginning of period.

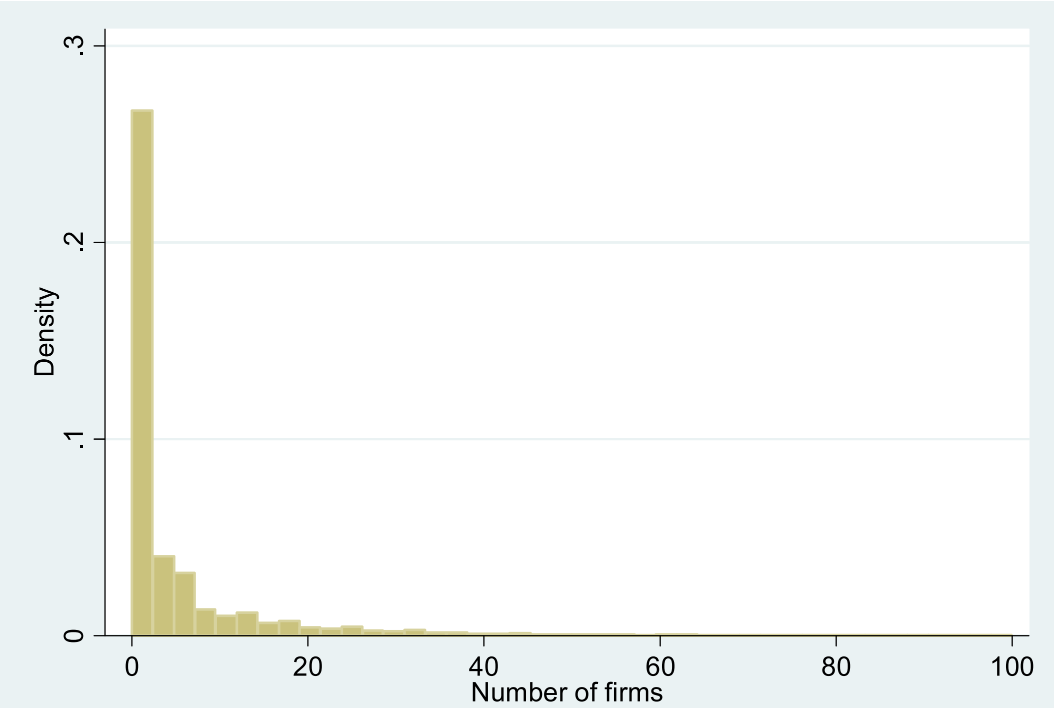
Figure 2
Treatment trends in firm formations in selected treated provinces and control group, at the time of the creation of faculty.

a) at time of the creation of faculty b) five years after the creation of faculty



Notes: Figures illustrate the trend in firm formations.
(1) Control group comprises provinces such as Avila, Segovia, Soria, Huesca, Teruel.

Figure 3
Histogram of firm formations across industrial sectors and provinces



Note: Figure illustrates the distribution of the dependent variable for values lower than 100.

Table 1
Descriptive Statistics

Variable		Mean	SD	Min	Max	Observations
Number of firms	overall	4.143637	10.93148	0	408	N = 11355
	between		9.290478	.0666667	173.6	n = 757
	within		5.769817	-168.4564	207.5436	T = 15
Foundation Of University	overall	.7375678	.4399677	0	1	
	between		.3763957	0	1	
	within		.2280357	.0042344	1.337568	
SCI+Eng	overall	.5433514	.49813	0	1	
	between		.4412997	0	1	
	within		.2313631	-.1233153	1.476685	
Health	overall	.5414924	.4982883	0	1	
	between		.4603435	0	1	
	within		.1911237	-.2585076	1.474826	
SSCI+Hum	overall	.5802221	.4935352	0	1	
	between		.428789	0	1	
	within		.2446424	-.2864446	1.513555	
ln Market potential	overall	7.562391	.4607638	6.493721	8.741614	
	between		.4381802	6.727322	8.563071	
	within		.1434158	7.285204	7.826928	
ln Specialization index	overall	5.53748	2.174278	.6692958	14.81977	
	between		2.161573	1.36072	13.33459	
	within		.4217585	1.605853	8.716178	
ln $Population_{t-1}$	overall	12.86498	.631305	11.45558	15.37233	
	between		.6279346	11.49133	14.02586	
	within		.0687777	11.256	15.52807	

SCI+Eng = Fac. of Sciences and Engineering, *SSCI+Hum* = Fac. of Social Sciences and Humanities, Health = Faculties of medicine, pharmacy, etc.

Table 2
Faculties founded during the period 1980 - 1994.

University	Province	Year of university foundation	Year of foundation by faculties		
			Health	Social Sciences and Humanities	Sciences and Engineering
U. Carlos III de Madrid	Madrid	1989		1989	
U. Castilla-La Mancha	Albacete	1985	1985	1989	
U. Castilla-La Mancha	Ciudad Real	1985		1985	1985
U. Castilla-La Mancha	Toledo	1985	1985	1985	1985
U. de Alicante	Alicante	1979	1984		1979
U. de Almería	Almería	1993	1994		1993
U. de Burgos	Burgos	1994	1994	1994	1994
U. de Cádiz	Cádiz	1979	1979	1990	1990
U. de Cantabria	Cantabria	1985		1985	
U. de Extremadura	Badajoz	1968			
U. de Extremadura	Cáceres	1973	1983		
U. de Girona	Girona	1992	1992	1992	1992
U. de Granada	Granada	1531			1988
U. de Huelva	Huelva	1993			1993
U. de Jaén	Jaén	1993	1993	1993	1993
U. de La Coruña	Coruña (A)	1989	1990	1994	1989
U. de La Rioja	Rioja (La)	1992		1992	1992
U. de Las Palmas de Gran Canaria	Palmas (Las)	1989	1989	1989	1989
U. de Lleida	Lleida	1991	1992	1991	
U. de Málaga	Málaga	1972			
U. de Murcia	Murcia	1915			
U. de Santiago	Lugo	1495	1983		1991
U. de Vigo	Ourense	1990		1990	1994
U. de Vigo	Pontevedra	1989		1994	
U. del País Vasco	Vizcaya	1980		1981	
U. Jaume I de Castellón	Castellón	1991		1991	1991
U. Politécnica de Cataluña	Barcelona	1971			1992
U. Politécnica de Valencia	Valencia	1971			1986
U. Pompeu Fabra	Barcelona	1990		1990	
U. Pública de Navarra	Navarra	1987		1987	
U. Rovira I Virgili	Tarragona	1992		1992	

Table 3
Does the foundation of Universities affect the creation of firms?
OLS estimation

VARIABLES	All sectors (1)	High-tech sectors (2)	Medium-tech sectors (3)	Low-tech sectors (4)
Foundation of university $_{i,\, t+5}$	0.146**	0.112	0.404	0.116*
	(0.067)	(0.481)	(0.257)	(0.068)
Market potential $_{i,\, t}$	1.029**	1.421	2.977	0.726
	(0.519)	(2.868)	(2.256)	(0.464)
Specialization index $_{i,\, j,\, t}$	-0.037	0.433**	-0.283***	-0.028
	(0.040)	(0.178)	(0.078)	(0.048)
Population $_{i,\, t-1}$	0.420	-6.741	-0.873	0.523**
	(0.265)	(5.637)	(1.543)	(0.256)
Year fixed effects	Yes	Yes	Yes	Yes
Province and industrial sector fixed effects	Yes	Yes	Yes	Yes
Observations	8,229	1,004	1,510	5,715
Number of industrial sectors x province	555	68	106	381
Wald test	1172.97	91.15	390.62	919.50
Log likelihood	-13497.98	-455.4943	-2398.96	-10612.48

Notes: 1) The endogenous variable is the number of new firm formations in province *i*, industrial sector *j*, and year *t*. 2) The variable of university foundation is a dummy that takes the value one beginning from five years after the date the university was created, and is zero otherwise. 3) Estimation based on OLS. 4) Market potential, specialization index and population are expressed in logarithms. 5) Cluster-Robust Standard Errors (in parentheses) are clustered at the (two-digit) industry and province level. 6) Statistical significances reported by *** p<0.01, ** p<0.05, * p<0.10.

Table 4
Does the foundation of faculties affect the creation of firms?
All and high tech sectors. Count model, Poisson regressions.

	All sectors			High tech sectors		
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	SCI+Eng	SSCI+Hum	Health	SCI+Eng	SSCI+Hum	Health
Faculty $_{i, t+5}$	0.138**	0.143***	0.014	-0.227	0.098	-0.252
	(0.063)	(0.055)	(0.075)	(0.322)	(0.349)	(0.340)
Market potential $_{i, t}$	2e-05**	1e-04	-2e-04	2.4e-06	2e-05	8e-04
	(9.97e-06)	(1e-04)	(1e-04)	(3e-05)	(4e-04)	(5e-04)
Specialization index $_{i, j, t}$	-1e-04	-0.045	-0.035	0.345**	0.322*	0.269**
	(0.033)	(0.038)	(0.039)	(0.160)	(0.185)	(0.132)
Population $_{i, t-1}$	0.185	0.651***	0.584**	-3.537	-3.586	-4.745
	(0.413)	(0.247)	(0.274)	(3.516)	(5.269)	(3.732)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Province and industrial sector fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12475	9697	10830	1634	1244	1394
Number of industrial sectors x province	840	654	730	110	84	94
Wald test	3297.49	1045.67	2370.72	156.81	52.23	110.58
Log likelihood	-23182.65	-15797.60	-19591.63	-1110.40	-644.19	-778.23

Notes: 1) The endogenous variable is the number of new firm formations in province *i*, industrial sector *j*, and year *t*. 2) The faculty variable for every academic field is a dummy that takes the value one beginning from five years after the date the faculty was created, and is zero otherwise. 3) Market potential, specialization index and population are expressed in logarithms. 4) Cluster-robust standard errors (in parentheses) are clustered at the (two-digit) industry and province level. 5) Statistical significances reported by *** p<0.01, ** p<0.05, * p<0.10.
SCI+Eng = Faculties of sciences and engineering.
SSCI+Hum= Faculties of social sciences and humanities
Health= Faculties of medicine, pharmacy, etc.

Table 5
Does the foundation of faculties affect the creation of firms?
Medium and low tech sectors. Count model, Poisson regressions.

	Medium tech sectors			Low tech		
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	SCI+Eng	SSCI+Hum	Health	SCI+Eng	SSCI+Hum	Health
Faculty $_{i, t+5}$	0.064	0.281**	0.146	0.150**	0.128**	0.004
	(0.124)	(0.142)	(0.149)	(0.069)	(0.060)	(0.082)
Market potential $_{i, t}$	3e-05	4e-04	1e-04	2e-05*	2e-04	-2e-04
	(2e-05)	(4e-04)	(3e-04)	(1e-05)	(1e-04)	(2e-04)
Specialization index $_{i, j, t}$	-0.147**	-0.089	-0.256***	0.012	-0.063	-0.014
	(0.058)	(0.068)	(0.069)	(0.038)	(0.045)	(0.046)
Population $_{i, t-1}$	1.176	1.269	-0.308	0.159	0.629**	0.661**
	(1.261)	(1.490)	(1.035)	(0.436)	(0.249)	(0.271)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Province and industrial sector fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2622	2034	2251	8219	6419	7185
Number of industrial sectors x province	182	142	157	548	428	479
Wald test	646.60	278.81	430.46	2771.16	871.91	2046.87
Log likelihood	-3992.78	-2836.29	-3426.17	-18103.40	-12341.8	-15386.39

Notes: 1) The endogenous variable is the number of new firm formations in province *i*, industrial sector *j*, and year *t*. 2) The faculty variable for every academic field is a dummy that takes the value one beginning from five years after the date the faculty was created, and is zero otherwise. 3) Market potential, specialization index and population are expressed in logarithms. 4) Cluster-robust standard errors (in parentheses) are clustered at the (two-digit) industry and province level. 5) Statistical significances reported by *** p<0.01, ** p<0.05, * p<0.10.
SCI+Eng = Faculties of sciences and engineering.
SSCI+Hum= Faculties of social sciences and humanities
Health= Faculties of medicine, pharmacy, etc.

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Chapter 3

Student graduation: To what extent does university expenditure matter?

1. Introduction

The creation of human capital is one of the most important channels via which universities positively affect economic development (Acosta et al., 2009; Audretsch et al., 2005; Hanushek and Kimko, 2000; Mankiw et al., 1992). Thus, it is interesting to analyse the factors that determine its production, and the strategic role played by universities in this process.

The literature on Higher Education Institutions (hereinafter, HEIs) has been mainly concerned with distributional questions related to access and cost faced by different groups. There have also been some attempts to model universities from other perspectives. Just and Huffman (2009) adopt a theoretical approach to model universities as behavioural institutions making decisions as regards tuition rates, research and teaching incentives, that follow from utility maximization subject to production technology and resource/budget constraints.

From an empirical perspective, the estimation of university efficiency has been a highly fertile field. For instance, Archibald and Feldman (2008) and Johnes (2006) use non-parametric techniques, while other papers employ parametric methodologies to analyse the presence of economies of scale and scope in the universities of various countries, e.g. the US (Groot et al., 1991; Dundar and Lewis, 1995), the UK (Glass et al., 1995; Izadi et al., 2002; Johnes and Johnes, 2009), Japan (Hashimoto and Cohn, 1997), China (Longlong et al., 2009), and Spain (Duch et al., 2010).

As one of the most valued outcomes of the universities is degree completion, i.e. their contribution of high-skill workers to the labour force, much of the research has been concerned with estimating the impact of expenditure on student persistence and graduation rates (Ryan, 2004; Webber and Ehrenberg, 2010), student engagement (Pike et al., 2006), and calculating the time-to-degree using duration models (Lassibille and Navarro (2011). Others, such as Berger and Kostal (2002), Perna and Titus (2004), Sá et al (2004), and Bedard and Herman (2008) analyse the determinants of enrolment in HEIs.

We seek to contribute to this body of literature in a number of ways. First, while previous studies have tended to use cross section estimations, in this paper we adopt a panel model in order to better control for unobserved university characteristics[1]. By observing the same university over time, we can control the factors that make a university permanently more productive in terms of the number of graduates. Second, the previous literature on graduation rates has mostly sought explanations at the individual (student) level; nonetheless, student achievements are equally attributable to the institutional features. The possible impact of these factors is, therefore, considered in our analysis.

Finally, we analyse a new case study, namely, the entire public university system in Spain. At least two traits of the Spanish case make it an interesting object of study. First, since the 1980s Spain has undergone fundamental economic and social changes. One of the most significant has been the substantial increase in the educational achievement of its labour force. Over the last four decades, the share of the economically active population attaining tertiary education rose from 1 to 9.4% (IVIE, 2010). Second, the Spanish university system is characterised by a number of specific features that make its analysis of particular interest. While in most OECD countries, public expenditure per student on HEIs declined between 1995 and 2004, in Spain, it increased appreciably by

[1] Besides controlling more effectively for unobserved heterogeneity, panel estimations are clearly more efficient than pooled ones, providing smaller standard errors and narrower confidence intervals.

71%. In parallel, Spain was the only OECD country in which the absolute number of tertiary students fell (by 7%) between 2000 and 2005 (OECD, 2008).

Two main research questions have guided this study: (1) What factors determine the creation of human capital in universities? (2) How do regional characteristics affect university performance in terms of human-capital creation?

This issue is especially relevant for the following reasons. First, human capital plays a key role in the well-known models of endogenous growth (Lucas, 1988; Romer, 1990; Barro, 1991). Second, there has been a steadily increase in demand for highly skilled workers mainly driven by technological change (Acemoglu, 1998; Piva et al., 2005)[2]. In this setting, HC is not just a key element for economic growth but at the same time it is experiencing a rise in demand. While we are aware of several studies that discuss the effects of HC accumulation on, for example, wage premiums in a microeconomic context (Mincer, 1974; Moretti 2004; Ciccone and Peri 2006), regional income disparities (Coulombe and Tremblay 2007), regional development (Florida et al., 2008), regional productivity (Ramos et al., 2010), regional employment (Mollick and Mora, 2010) and the level of economic activity (Abel and Gabe, 2010)[3], relatively little is known about the factors that determine the production of human capital.

The rest of this paper is organized as follows. The next section describes the Spanish university framework. Section 3 provides details of the data and describes the empirical strategy. Section 4 reports our results. A robustness check using unconditional quantile regression is conducted in Section 5. Section 6 concludes.

[2] This idea is known as the skill-biased technological change hypothesis, which affirms that there is considerable complementarity between new technologies and skilled labour.

[3] Table A3 in the appendix provides a review of recent studies on the relationship between regional development and human capital.

2. Spanish university framework

Over the last three decades, the Spanish university system has increased three-fold in terms of the number of students enrolled[4]. The number of HEIs has evolved in parallel, with the establishment of universities in all the state's cities and major towns. Along with this expansion process, a major transformation has taken place in the university system. Two reform measures introduced changes resulting in its political and administrative decentralisation. The first of these was the University Reform Act (LRU), which came into force in 1983, and was concerned with the organization of the universities and the modernization of their scientific work. The second was the Universities Act (LOU) introduced in 2001, which sought to implement quality assurance policies and prepare the Spanish university system for entry into the European Higher Education Area (EHEA). In 2007, the modification of the LOU made changes to the rectoral election procedures, faculty accreditation and selection, and the coordinating bodies of university policy.

The governance structure of the Spanish university system is based on a decentralised model that comprises three levels: the state, the autonomous regions, and the educational institutions[5]. The central government is responsible for its overall co-ordination, its international representation under a unique voice, and the control of scholarships and grants. Likewise, through the Ministry of Education, it establishes the regulatory framework for obtaining, issuing and validating academic degrees.

The regional government is responsible for administering the HEIs within its territory. It establishes directives regarding staff (teaching and administrative) qualifications, quality measurement, salaries and the recruitment system[6]. The building of new educational facilities and the renewal of existing ones also fall under the control of the autonomous regions. Mechanisms of university funding are one of the main issues at this level of

[4] Since 2000, the Spanish university system has been one of the largest in Europe in terms of number of enrolled students, surpassed only by Germany, the UK, France and Poland.
[5] In specific instances, the central government and the autonomous regions have delegated powers to city councils. This includes a wide range of responsibilities from providing information on the city's educational institutions to the management of non-university institutions.
[6] The central government also has a voice in the definition of categories and personnel salaries.

government.[7] Although over recent years there has been a convergence in the regional funding mechanisms, differences persist[8]. However, two common types of funding can be identified across regions: 1) basic funding, which considers variables related to both demand and costs of production factors and 2) non-recurrent funding, which supports program-contracts tied to output-performance, e.g. in terms of research outputs or graduation rates (Consejo de Coordinación Universitaria, 2007). In order to illustrate the main regional features of budget allocation we describe two examples - Madrid and Catalonia, which represent about 34.6% of Spanish university expenditure and account for 31% of its university students. The Autonomous Community of Madrid allocates resources to universities according to the following model: 59.5% to teaching[9], 25.5% to research, 10% to enhance aspects such as teaching performance, undergraduate job placement, quality of services, and finally, 5% to accomplish other objectives. In turn, Catalonia's funding model comprises five elements: 1) *Fixed* - lump-sum payment for each university, 2) *Basic* - linked to scale of university activity, 3) *Derivative* - policy promoting academic personnel, 4) *Strategic* – linked to objectives, and 5) *Competition* - through official announcements.

Higher education regulations have granted autonomy to universities. This autonomy embraces the following powers: 1) drawing-up their statues and electing their institutional governing and representative bodies, 2) definition of their own structure, 3) organisation of educational programmes, 4) preparation and management of their own budgets, and 5) administration of assets.

Given its importance for this study, mention should also be made of the way in which Spanish universities structure their degree courses. Prior to the Bologna reform, the degree structure included both short (first) and long (first and second) cycle courses. Short, first cycle programmes were more vocationally oriented with a duration of two to three years and led to a Diploma degree. About 35% of students were enrolled on short-

[7] In 2005, for instance, 91.8% of public spending on tertiary education was allocated as direct subsidies to institutions, with only 8.2% going to student financial-aid (OECD, 2010).

[8] The existence of several models of funding across regions implies differences in the mechanisms of university expenditure allocation, which we take into account in the econometric analysis.

[9] The amount of resources allocated to teaching corresponds to demand. Hence, degrees with low demand and high dispersion are penalized.

cycle programmes in 2007[10] (INE, 2009). Second cycle courses, lasting a further two years, commenced on completion of short programmes, and led to the awarding of a Bachelor's degree. These long-cycle programmes were more academic, preparing students for entry into the professions (law, engineering, medicine, etc.). Third cycle courses are equivalent to the current PhD programmes.

3. Data description and empirical strategy

The empirical analysis is carried out at the university level for the period 1998-2008. We use data on the Spanish public university system, collected biannually by the Rector's Conference of Spanish Universities (RCSE)[11]. This database contains detailed information on university performance such as enrolment, graduation, expenditure, investment, and faculty, among others. Private universities are excluded from our analysis for two reasons. First, the information available is more recent and, then, scarcer, which could give lead to degrees of freedom problems. Second, as Just and Huffman (2009) noted, there are major differences between public and private universities in terms of their funding, management structure, resource/budget constraints, social issues, and so forth. Therefore, in trying to avoid these problems and to reduce those associated with heterogeneity, our sample is restricted to the state's public university system, i.e. 47 universities. In 2008, 86% of students were enrolled in public universities. A major advantage of the data is that they offer a wide perspective of the Spanish University system, especially with regard to post-graduate students.

[10] This percentage has changed very little over the years.
[11] Although this represents an attempt to build a systematic database for the Spanish university system, and one that has improved over time, there are many missing values in the first years of data collection, which does not allow us to obtain more degrees of freedom.

3.1. Dependent variable

The dependent variable is the overall weighted graduation rate[12], which is calculated using the following expression

$$WGR_{it} = \sum_{j=1}^{3} \frac{G_{ijt}}{E_{ijt-m}} . S_{jit}$$

Where WGR_{it} = overall weighted graduation rate[13] of university i in year t, G_{ijt} = number of graduates of university i, cycle j and year t. E_{ijt} = number of students enrolled in first year of university i cycle j and year $t-m$[14]. S_{ijt} = share of graduates of university i, cycle j and year t[15]. i = university, j= cycles (undergraduate – long and short cycle - and PhD), t = year.

The mean graduation rate during the period analysed was 66.2%. The minimum and maximum values were 32.2% and 98.4%, respectively. This measure showed huge variation both across universities and regions. Indeed, although there was a trend towards convergence across universities, the ratio between the highest graduation rate and the lowest during the whole period was three. In the case of the regions, two (Catalonia and Madrid) consistently performed better than the others, while the Balearic Islands and the Canary Islands were placed at the other end of the distribution. Despite the general convergence noted - with very few variations, there was considerable persistence in the ranking occupied by each university over the period in terms of their graduation rates.

[12] The cohort-graduation rate is the usual measure of degree completion in the literature. For instance, Webber and Ehrenberg (2010) use the six-year graduation rate for students who entered the institution as full-time first-year students six years earlier. Other alternatives of widespread use are net or gross graduation rates, and Graduation/Successful completion. Calculation details can be seen in the OECD publication “Education at a Glance”.

[13] Henceforth, graduation rate.

[14] When j= short cycle, m=3; if j= long cycle, m=5; when j= MSc, m=2; finally, if j=PhD, m=3.

[15] $S_{ijt} = \frac{G_{jit}}{G_{it}}$, G_{jit} = number of graduates in cycle j, at university i in year t; G_{it} = number of graduates at university i in year t. This term seeks to weight the duration of the different cycles.

3.2. Explanatory variables

The explanatory variables can be classified into four groups: 1) expenditure variables, 2) university characteristics related to scale and technical orientation, 3) measures of input quality, and 4) proxies of other university activities besides teaching[16]. In the first group we consider both the effect of total expenditures and their three main components on the graduation rate. These expenditure categories constitute the core of educational and general expenditures within the Spanish public universities[17]. The first category is made up of personnel expenditures, including total salary outlays and the fringe benefits of faculty and administrative staff. The average personnel expenditure per student enrolled in the sample was 3,053 € each year. This category grew steadily during the period of analysis, and represents 55.85% of total expenditures.

The second category is made up of financial aid to students, including scholarships and fellowships awarded to students such as grants-in-aid, trainee stipends, tuition and required fee waivers, and other monetary subsidies given to students. As discussed earlier, Spain's Ministry of Education promotes and manages these grants, which are paid to the university or directly to the student. These expenditures averaged an annual 327.9 € per student enrolled. The third category comprises research and development (R&D) expenditures, including charges for activities specifically organized to produce research outcomes. The mean level of these expenditures was 918.2 €, representing 12% of total university expenditures. Finally, total expenditures are the sum of these three categories plus investment, capital transfers and financial operations. The mean level was 5,659.4 € per student enrolled each year. This variable presented a sustained increase during the period analysed (See Figure 1)[18].

In the case of the second group of variables, previous studies often include the number and the square of the number of undergraduate ($Undergra\_stu_{it}$) and graduate students ($Grad\_stu_{it}$) enrolled at the university (Groot et al., 1991; Longlong et al., 2009; Webber

[16] Table A1 depicts the details used to build the explanatory variables.
[17] All financial data used in the study are expressed in per enrolled-student terms and have been adjusted to 2001 values.
[18] In turn, Figure 2 shows the relationship between graduation rate and total expenditure per student enrolled in 2004 and 2008.

and Ehrenberg, 2010). These variables are introduced separately to control for differences in costs of undergraduate and graduate education, and their squared terms to allow for economies of scale[19]. In addition, as a measure of family effort, the tuition fees ($fees_{it}$) paid by students are included. These fees are fixed by the regional governments and are the same for all universities in that region, but vary across academic fields. We introduce a simple average of the public price of the teaching credit by university. Similarly, we include a further two variables to control for university characteristics: the share of students receiving financial support from the Ministry of Education ($Supp\_stu_{it}$) and the share of students enrolled on science and engineering courses (Sci_stu_{it}). The former is included to control for differences in the number of fellowship recipients across universities, which are assigned according to family income and other socioeconomic characteristics; and, the latter in order to take into account the fact that each academic field has different associated costs.

According to Dolan and Schmidt (1994), a model of higher education should reflect the broader perspective that the quality of output can influence the quality of inputs, and that certain institutional resources may themselves enhance the quality of the inputs. Hence, the third group of variables includes measures of student ability and faculty quality. The $student\ ability_{it}$ is introduced through the minimum score required to gain admission to the university[20]. As a control for faculty quality, we use the ratio of the number of scientific articles published in JCR journals to full-time faculty ($publi_{it}$)[21].

The last group of explanatory variables refers to university activities. These are generally classified into three main categories; teaching, research, and technology transfer (TT). Depending on its specific profile, each university assigns a different weight to each, which correlates with the amount of resources allocated. We introduce different indicators for each of these activities: the number of patent applications (Pat_{it}) for TT,

[19] Alternatively, some specifications include the total number of student (tot_stu_{it}) which is the sum of $Undergra\_stu_{it}$ and $Grad\_stu_{it}$.
[20] An average of the 75th percentile of scores or those entering a first-year class was calculated. Data come from the Ministry of Education. Figure 3 provides scatter-plots of graduation rate and student ability in 2000 and 2002.
[21] These data come from the information provided by the institute of documentary studies on science and technology.

and the above variable $publi_{it}$ for research. Table A2 presents descriptive statistics for the variables used.

3.3. Empirical strategy

In order to estimate the relationship between university characteristics and graduation rate, we specify a panel structure to reduce unobserved heterogeneity. A problem that can be addressed in this way is, for instance, the fact that the estimated effects of financial resources may be confounded by unobserved institutional characteristics. The function to be estimated can be written as:

$$WGR_{it} = \alpha_i + \tau_t + \lambda_j + \beta_1 Expenditures_{it} + \beta_2 Undergra\_stu_{it} + \beta_3 Undergra\_stu^2_{it} + \beta_4 Grad\_stu_{it} + \beta_5 Grad\_stu^2_{it} + fees_{it} + \gamma_2 Sci\_stu_{it} + \gamma_3 Supp\_stu_{it} + \gamma_1 ability_{it} + \gamma_4 publi_{it} + Pat_{it} + \mu_{it}$$

i=1,2,..., N universities, and t=1998, 2000, ..., 2008.

$Expenditures_{it}$ refer to the three expenditure categories mentioned above, which are expressed in terms of enrolled students. The inclusion of university fixed effects (α_i) minimizes the influence of any unobserved variables that may be correlated with both the dependent variable and the disturbance term. Finally, τ_t and λ_j are time and regional dummies, N= 47 is the cross section and T= 6 the time-series sample size.

Considerations of multicollinearity among different categories of expenditure preclude any attempt at including them within the same specification; hence, we run separate regressions for each. Panel estimations with both fixed (FEs) and random effects (REs) were carried out. A Robust-Hausman test was performed, indicating that differences between the coefficients of fixed and random effects are not systematic. Therefore, both procedures are appropriate. Since university policy varies across regions (i.e. the budget is allocated by the regional government), we prefer REs because they are more efficient and allow us to include a set of regional dummies[22].

Other empirical issues should be mentioned. First, the graduation rate is measured at three- and five-year intervals, but the resources required achieving this outcome span multiple periods. In order to control for this and to capture the dynamic nature of the graduation rates, we consider resources expended over multiple years, as well as graduation rates from multiple cohorts. Second, all specifications include both year and university fixed effects. Hence, any university permanent characteristics, e.g. infrastructure quality, are controlled for by a set of university dummies. Third, data on personnel expenditure do not enable us to separate items out between teachers and administrative staff. In order to obtain reliable results, the student-teacher ratio is adopted, which is a cleaner measure of university effort in terms of teaching personnel. Finally, information on R&D expenditures contains many errors and missing values. Conversely, the information on research outcomes - by which R&D activity can be assessed - is accurate. Therefore, the effects of university R&D on graduation rate are analysed through research outcomes such as patents and publications.

4. Results

4.1. University characteristics

Two specifications are included. Regressors from two groups of explanatory variables are included in the first specification, i.e. expenditures and university characteristics. The other groups are introduced in the second specification (i.e. measures of input quality and proxies of other university activities). In addition, the number of students enrolled is divided between undergraduates and graduates and their square terms are also included.

[22] For sake of brevity some FE estimations are not reported here. They are, however, available from the authors upon request.

We present results separately for total expenditure (Table 1), student-teacher ratio (Table 2) and financial-aid to students (Table 3). The first general finding is that all regressors in the group of expenditure variables have a statistically significant effect on the graduation rate. Aside from the financial-aid results, the magnitude of the aforementioned coefficients is held relatively stable across specifications. Likewise, the student-teacher ratio coefficient is negative and always statistically significant at least at the one-percent level (see Table 2). Second, the total number of students (*tot_stu)* consistently shows a positive and statistically significant effect on the graduation rate. Third, the share of students on science and engineering courses (*Sci_stu)* and the measures of input quality (*student ability and public*) do not have any effect on the dependent variable. This last result might indicate that student ability is randomly distributed and plays no role in the determination of graduation rates. This being the case, graduation rates should be explained by university characteristics.

Since the column 7 specification in Tables 1, 2 and 3 includes all the groups of regressors and a set of regional dummies[23], the following remarks and the calculations on the magnitude of impact are based on that specification. In the case of the relationship between total expenditure and the graduation rate, the estimated coefficient is positive and statistically significant across specifications (see Table 1). Hence, a one standard deviation increase in total expenditures leads to a rise in the graduation rate of about 4.8 percentage points. *Supp_stu* has a positive and significant effect on the dependent variable. Regressors from the other groups of variables do not have any effect on graduation rates. Although this might seem somewhat unusual, it is, in fact, in line with previously reported findings (Weber, 2010).

When the student-teacher ratio is included, a negative and statistically significant coefficient is obtained (see Table 2)[24]. An increase by one standard deviation reduces the graduation rate by about 9.5 percentage points. *Undergad_stu*^{2} and *pat* show a positive and statistically significant effect on the graduation rate.

[23] As mentioned, these dummies seek to control for differences in university policy across regions.
[24] The variable *fee* was dropped from the regressions in Table 2 due to problems of collinearity.

Finally, expenditure on student financial-aid presents the following features[25]. First, the estimated coefficient suggests that a one standard deviation increase in this item leads to a rise in the graduation rate of about 4.9 percentage points. Second, the number of undergraduate students *(Undergrad_stu)* and its squared value *(*$Undergrad\_stu^2$*)* are statistically significant, and their signs (negative and positive, respectively) present a U-shape (See column 7, Table 3). It would seem, therefore, that there are two ranks of university size at which the graduation rate presents higher levels. Moreover, in the case of small universities, increasing the number of undergraduate students leads to a reduction in the graduation rate. By contrast, at larger universities, increasing the number of students can lead to a rise in the graduation rate. Third, in line with the results in Table 2, *pat* is again positive and statistically significant at least at the 10 percent level. This result can be interpreted as showing the complementarity effect among university tasks.

4.2. Regional characteristics

The expansion of the Spanish university system and its geographical distribution has sought to introduce regional balance. As discussed, universities can make a significant contribution to the regional economies by generating human capital, since better regional economic performance is expected as a result of graduates joining the labour force. At the same time, features of the regional economy can affect university performance. This section analyses the impact of regional context on graduation rates. The key point is that, since the university framework remains unchanged across the period of analysis, regional socio-economic characteristics, together with university characteristics, might explain differences between university outcomes. We assume that the graduation rate (*GR*) of university *i* in year *t* is modelled as a function of university characteristics *U* and regional characteristics *R*.

$$GR_{it} = f\,(U_{it}\,,\, R_{it})$$

[25] *fees* and *supp_stu* were excluded because of collinearity.

The difficulty lies in the fact that it is not easy to find regional variables that are not correlated with university characteristics. We perform this analysis focusing solely on regional characteristics. Furthermore, total university expenditure, the number of students enrolled and university fixed-effects are included.

We add associated variables to two groups of regional features: demographic structure and labour market[26]. In the case of the latter, we introduce regional employment since it influences enrolment and persistence (Bedard and Herman, 2008; Mollick and Mora, 2010). Although it is likely that students (and families) consider the unemployment rate when making decisions over education plans, it is no less likely that the level of employment is a good indicator of labour market performance and, therefore, it is taken into account by families. The assumption here is that once students have started higher education, the probability of persistence, and then graduation, correlate highly with the level of employment in the economy. To capture this effect, we use the employment in province i in year t, for 16- to 24-year-olds[27].

The graduation rate could be affected by the regional demographic structure through the following mechanism. Moretti (2004) indicates that the US labour force is characterized by a long-run trend of increasing education, with younger cohorts being better educated than their older counterparts[28]. In addition, Ciccone and Peri (2006) argue that cities with a larger share of older workers in a certain decade will experience a greater increase in average schooling in subsequent years. In line with these arguments, we use the share of population with tertiary education[29] (*40Greater*) and the share of old workers in the previous decade (*OLD*). Here the expected effect is that provinces in which these shares are higher will obtain a higher graduation rate. Finally, as in the preceding analysis, a set of regional dummies is included.

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[26] A third variable related to the standard of living was also considered, namely, per capita GDP. Nonetheless, it was excluded for problems of collinearity.
[27] These data are taken from the Economically Active Population Survey conducted by the INE.
[28] OECD data (*Education at a Glance, 2010*) show that in Spain, the proportion of people aged 25 to 34 that have attained tertiary education qualifications more than doubles the number in the 55- to 64-year-old cohort (39% and 16% in Spain compared to the OECD average of 35% and 20% respectively).
[29] Specifically, we include the share of population with higher education and aged over 40.

To deal with collinearity between *Employment* and *40Greater* two specifications were introduced. The main findings can be summarized as follows. After controlling for regional characteristics in the model, the total university expenditure maintains a positive and statistically significant relationship with the graduation rate. In keeping with this, the total number of enrolled students once again positively affects the dependent variable (see Table 4).

In the case of the influence of regional characteristics on the graduation rate, three results are worth stressing. First, the coefficient of *40Greater* is negative and statistically significant (See columns 1 to 3 in Table 4). Second, *Employment* has a negative and statistically significant effect on the dependent variable. This suggests that once students enrol at university, the probability of persistence, and subsequently of graduation, will be lower if regional employment presents a good performance. Finally, *OLD* seems to have no effect on the graduation rate, being significant only in the case of the random-effect model without regional dummies (see column 5) [30].

5. Empirical Extensions

OLS estimates provide the average effect of an explanatory variable over the entire distribution of an outcome variable. Nonetheless, in some contexts, this summary statistic may not be representative of the relationship in any one part of the outcome distribution. To look beyond the underlying questions of economic and policy interest concerning graduation rates, we use a quantile framework to characterize their entire distribution. Quantile regressions are often used to show differential impacts of the variables of interest throughout the outcome distribution.

[30] In a second step, to reduce any suspicions of endogeneity problems, we re-estimated this last specification introducing the share from the previous decade. Our results were very similar and are not reported here for reasons of space.

We apply a new unconditional quantile estimation technique for panel data based on Powell (2011) and Firpo et al. (2009)[31]. The method consists of running a regression of a transformation - the Recentered Influence Function (RIF) - of the outcome variable on the explanatory variables. The basic difference between conditional quantile treatment effects (QTEs) and unconditional QTEs is that the former are defined conditionally on the value of the regressors, whereas unconditional effects summarize the causal effect of a treatment for the entire population (Frölich and Melly, 2010).

Two categories of university expenditure were analysed through unconditional QTEs: total and financial-aid to students. We introduce a fixed-effect model to control for time-invariant unobserved university heterogeneity.

The results show that the relationship between total university expenditures and the graduation rate is only statistically significant at the low quantiles i.e. q=0.20, 0.40 (see Table 5). In turn, estimates of the coefficient of financial-aid to students lead us to conclude that, aside from the lowest quantile i.e. q=0.20, there is a strong relationship with the graduation rate, across the distribution (see Table 5). Likewise, the magnitude of coefficients presents an inverted-U shape when we move to the right-hand side of the distribution. A further pattern that emerges from this exercise is that the standard errors are smaller for lower quantiles than they are for the upper ones, reflecting greater precision in that part of the distribution.

These findings can be attributed to following circumstances. First, the results seem to show that that there is a point up to which the graduation rate can be increased via university expenditure. From that point, expenditure has a reduced capacity to bring about better outcomes. Here, any possible advances are determined by the students themselves and may be triggered by financial support to the students. Therefore, a well-designed fellowship program seems to play an important role in degree completion.

Second, from a regional perspective, we identify a weak level of persistence among universities occupying the lowest ranks (in terms of graduation rates). It would seem

[31] We adopt the second estimator (RIF-Logit regression), its main advantage being that it allows heterogeneous marginal effects.

feasible for them to escape from these positions by adopting a policy that combines elements of university expenditure and student fellowship programs. This would seem to constitute a more effective strategy for reduce disparities between regions in terms of their university performance.

Like the current national fellowship program run by Spain's ministry of education, financial support to students should be tied to educational achievements as well as regional socio-economic characteristics.

6. Concluding remarks

Graduation rates remain one of the most frequently applied measures of institutional performance and continue to draw the attention of both academics and policymakers. This paper has sought, in the first place, to analyse university characteristics that affect the graduation rate, and secondly, to determine whether regional characteristics influence university performance in terms of graduation. To the best of our knowledge, this is the first economic study conducted in Spain to consider institutional characteristics and regional features.

The answers to the research questions formulated here help further our understanding of the ways in which institutional and regional features can affect university outcomes. Our results are largely consistent with findings in recent studies in related fields. University expenditure has been a key determinant of the graduation rate in Spain over the last decade. Moreover, results obtained here through quantile regression analysis show that a policy of increasing university expenditure only makes sense for universities with low graduation rates. Universities whose graduation rate does not belong to the 20th percentile can though improve their ranking by raising financial-aid to students. Yet, these questions require more careful attention since any expenditure increase needs to be tied to improvements in quality and efficiency.

The analysis also shows that it is not only the amount of university expenditure that is important, but also university research performance. Indeed, there would seem to be a complementarity effect between their teaching and research activities.

Future research might take the following directions. First, although high graduation rates have been viewed as a good indicator of institutional excellence, it should also be recognized that they reflect admission standards, the academic strength of the enrolled students, and the resources that institutions can devote to instruction, remediation, and retention. The influence of these factors should, therefore, be taken into account. Second, measuring the quality of both inputs and outputs is important when analysing higher education; thus, quality measures need to be incorporated. Third, when the data sources so allow it, information at the institutional level could be expanded to include a student-level component, which would serve to unite the two types of study currently in vogue.

Figure 1

Evolution of University total expenditure per enrolled student[32]

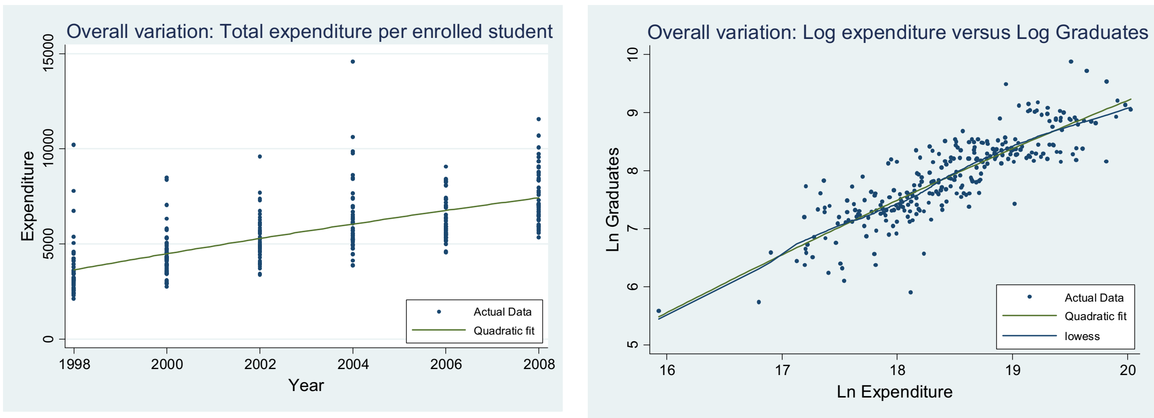


Figure 2 Graduation rate and per capita expenditure

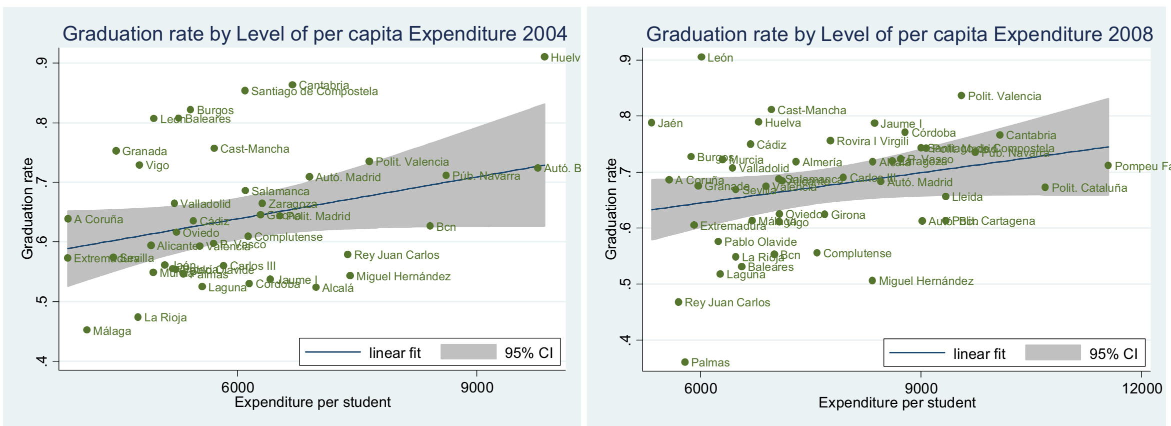
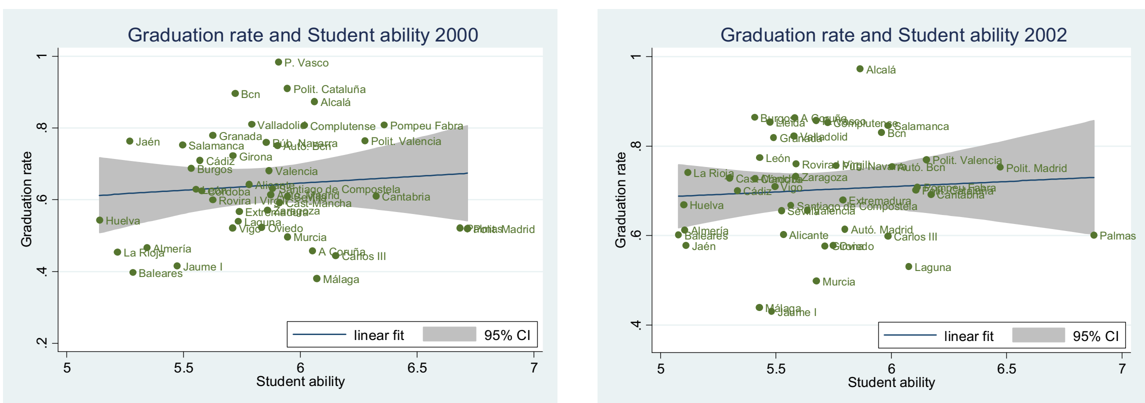


Figure 3 Graduation rate and student ability



[32] Each point in this figure represents an individual-year pair

Table 1 Econometric estimates: Total expenditure and graduation rate

	Pooled		Panel				
VARIABLES	(1)	(2)	(3) FE	(4) RE	(5) RE	(6) RE	(7) RE
Total expenditure $_{it}$	0.024***	0.023**	0.023*	0.024***	0.022**	0.027***	0.022**
	(0.009)	(0.009)	(0.013)	(0.009)	(0.010)	(0.009)	(0.010)
Sci_stu $_{it}$	0.036	0.056	-0.253	0.026	0.024	0.126	0.053
	(0.055)	(0.070)	(0.427)	(0.071)	(0.056)	(0.082)	(0.071)
Supp_stu $_{it}$	0.662*	0.813**	0.483	0.204	0.584	0.447	0.792**
	(0.355)	(0.323)	(0.522)	(0.258)	(0.356)	(0.278)	(0.331)
Fees $_{it}$	-0.049	-0.044	-0.069*	0.002	-0.056	0.014	-0.045
	(0.035)	(0.029)	(0.036)	(0.011)	(0.036)	(0.010)	(0.029)
Undergra_stu $_{it}$		-0.007				-0.005	-0.007
		(0.005)				(0.004)	(0.005)
Undergra_stu$^2_{it}$		0.106				0.101	0.109
		(0.068)				(0.067)	(0.069)
Grad_stu $_{it}$		0.021				0.013	0.016
		(0.023)				(0.022)	(0.023)
Grad_stu$^2_{it}$		-2.265				-2.752	-2.056
		(2.193)				(2.216)	(2.231)
Student Ability $_{it}$		-0.003				-0.011	0.001
		(0.021)				(0.022)	(0.022)
Publi $_{it}$		0.065				0.016	0.066
		(0.079)				(0.075)	(0.081)
Pat $_{it}$		0.002				-0.000	0.002
		(0.002)				(0.002)	(0.002)
Tot_stu $_{it}$	0.017***		0.113*	0.016**	0.018***		
	(0.006)		(0.059)	(0.007)	(0.006)		
Constant	0.702**	0.736**	1.022**	0.387**	0.849**	0.282	0.736**
	(0.297)	(0.291)	(0.484)	(0.164)	(0.347)	(0.196)	(0.297)
University fixed-effects	Not	Not	Yes	Not	Not	Not	Not
Regional dummies	Yes	Yes	Not	Not	Yes	Not	Yes
Adj. R-squared	0.39	0.41	0.16	0.13	0.39	0.21	0.41

Notes: the dependent variable is the graduation rate at university *i* in year *t*. *Total expenditure* $_{it}$ is the sum of expenditures of personnel, financial-aid to students and R&D, plus investment, capital transfers and financial operations. *Sci_stu*$_{it}$ is the share of students in science and engineering. *Supp_stu*$_{it}$ is the share of students with financial support from the Ministry of Education. *fees*$_{it}$ are tuition fees. *Undergra_stu*$_{it}$ and *Undergra_stu*$^2_{it}$ are the number and the square of undergraduate students. *Grad_stu*$_{it}$ and *Grad_stu*$^2_{it}$ are the number and the square of graduate students enrolled at the university. *student ability*$_{it}$ is the minimum score required to gain admission to the university. *publi*$_{it}$ is the ratio of the number of scientific articles published in JCR journals to full-time faculty. *Tot_stu* $_{it}$ is the sum of *Undergra_stu* $_{it}$ and *Grad_stu* $_{it}$. *Pat* $_{it}$ is the number of patent applications.

Robust standard errors clustered at university level are shown in parentheses. *,**,*** denote the significance at 90%, 95% and 99%, respectively. Number of observations: 217. Number of Universities: 46. Year effects are included in all models. The expenditure variables are expressed in 2001 Euros and per student enrolled.

Table 2 Econometric estimates: Personnel expenditure and graduation rate

	Pooled		Panel				
VARIABLES	(1)	(2)	(3) FE	(4) RE	(5) RE	(6) RE	(7) RE
Student-teacher ratio $_{it}$	-0.017***	-0.021***	-0.021***	-0.018***	-0.017***	-0.027***	-0.024***
	(0.006)	(0.006)	(0.006)	(0.004)	(0.005)	(0.006)	(0.007)
Sci_stu $_{it}$	0.019	0.045	-0.317	-0.007	0.006	0.070	0.040
	(0.043)	(0.069)	(0.235)	(0.057)	(0.040)	(0.077)	(0.068)
Supp_stu $_{it}$	0.326	0.553*	0.189	0.225	0.255	0.439**	0.460
	(0.346)	(0.310)	(0.423)	(0.179)	(0.313)	(0.207)	(0.357)
Undergra_stu $_{it}$		-0.007*				-0.005	-0.007
		(0.004)				(0.004)	(0.004)
Undergra_stu$^2_{it}$		0.116*				0.114*	0.123*
		(0.066)				(0.066)	(0.071)
Grad_stu $_{it}$		0.003				-0.018	-0.009
		(0.022)				(0.021)	(0.022)
Grad_stu$^2_{it}$		-1.590				-0.864	-1.008
		(2.082)				(2.186)	(2.153)
Student Ability $_{it}$		0.002				0.001	0.007
		(0.020)				(0.021)	(0.022)
Publi $_{it}$		0.105				0.099	0.114
		(0.070)				(0.068)	(0.075)
Pat $_{it}$		0.003*				0.002	0.003*
		(0.002)				(0.002)	(0.002)
Tot_stu $_{it}$	0.014***		0.100***	0.016**	0.016***		
	(0.005)		(0.034)	(0.007)	(0.005)		
Constant	0.875***	0.901***	0.853***	0.906***	0.876***	0.904***	0.829***
	(0.152)	(0.218)	(0.195)	(0.079)	(0.156)	(0.169)	(0.234)
University fixed-effects	Not	Not	Yes	Not	Not	Not	Not
Regional dummies	Yes	Yes	Not	Not	Yes	Not	Yes
Adj. R-squared	0.35	0.41	0.14	0.14	0.35	0.23	0.41

Notes: the dependent variable is the graduation rate at university *i* in year *t*. *Student-teacher ratio* $_{it}$ is the ratio of full-time equivalent students and the number of full-time equivalent teachers. *Sci_stu*$_{it}$ is the share of students in science and engineering. *Supp_stu*$_{it}$ is the share of students with financial support from the Ministry of Education. *Undergra_stu*$_{it}$ and *Undergra_stu*$^2_{it}$ are the number and the square of undergraduate students. *Grad_stu*$_{it}$ and *Grad_stu*$^2_{it}$ are the number and the square of graduate students enrolled at the university. *student ability*$_{it}$ is the minimum score required to gain admission to the university. *publi*$_{it}$ is the ratio of the number of scientific articles published in JCR journals to full-time faculty. *Tot_stu* $_{it}$ is the sum of *Undergra_stu* $_{it}$ and *Grad_stu* $_{it}$. *Pat* $_{it}$ is the number of patent applications.
Robust standard errors clustered at university level are shown in parentheses. *,**,*** denote the significance at 90%, 95% and 99%, respectively. Number of observations: 217. Number of Universities: 46. Year effects are included in all models. The expenditure variables are expressed in 2001 Euros and per student enrolled.

Table 3 Econometric estimates: Financial-aid to student and graduation rate

	Pooled		Panel				
VARIABLES	(1)	(2)	(3) FE	(4) RE	(5) RE	(6) RE	(7) RE
Financial-aid $_{it}$	0.257*	0.470***	0.359**	0.116	0.294**	0.137	0.323***
	(0.131)	(0.171)	(0.147)	(0.097)	(0.125)	(0.104)	(0.116)
Sci_stu $_{it}$	0.052	0.044	-0.332	0.054	0.040	0.140	0.027
	(0.051)	(0.087)	(0.316)	(0.074)	(0.048)	(0.096)	(0.080)
Undergra_stu $_{it}$		-0.011**				-0.011**	-0.009*
		(0.005)				(0.005)	(0.005)
Undergra_stu^2 $_{it}$		0.135*				0.156**	0.123*
		(0.069)				(0.078)	(0.071)
Grad_stu $_{it}$		0.044				0.028	0.028
		(0.031)				(0.027)	(0.028)
Grad_stu^2 $_{it}$		-4.159				-3.716	-3.176
		(2.714)				(2.705)	(2.649)
Student Ability $_{it}$		-0.003				0.018	0.008
		(0.023)				(0.027)	(0.026)
Publi $_{it}$		-0.082				0.100	0.018
		(0.136)				(0.088)	(0.093)
Pat $_{it}$		0.002				0.001	0.003*
		(0.002)				(0.002)	(0.002)
Tot_stu $_{it}$	0.012*		0.051	0.013	0.014**		
	(0.006)		(0.039)	(0.008)	(0.006)		
Constant	0.477***	0.533***	0.551***	0.553***	0.461***	0.495**	0.462**
	(0.076)	(0.176)	(0.176)	(0.063)	(0.073)	(0.203)	(0.200)
University fixed-effects	Not	Not	Yes	Not	Not	Not	Not
Regional dummies	Yes	Yes	Not	Not	Yes	Not	Yes
Adj. R-squared	0.34	0.38	0.10	0.09	0.33	0.14	0.40

Notes: the dependent variable is the graduation rate at university *i* in year *t*. *Financial-aid* $_{it}$ refers scholarships and fellowships awarded to students such as grants-in-aid, trainee stipends, tuition and required fee waivers, and other monetary subsidies given to students. Sci_stu_{it} is the share of students in science and engineering. $Undergra\_stu_{it}$ and $Undergra\_stu^2_{it}$ are the number and the square of undergraduate students. $Grad\_stu_{it}$ and $Grad\_stu^2_{it}$ are the number and the square of graduate students enrolled at the university. $student\ ability_{it}$ is the minimum score required to gain admission to the university. $publi_{it}$ is the ratio of the number of scientific articles published in JCR journals to full-time faculty. Tot_stu_{it} is the sum of $Undergra\_stu_{it}$ and $Grad\_stu_{it}$. Pat_{it} is the number of patent applications. Robust standard errors clustered at university level are shown in parentheses. *,**,*** denote the significance at 90%, 95% and 99%, respectively. Number of observations: 217. Number of Universities: 46. Year effects are included in all models. The expenditure variables are expressed in 2001 Euros and per student enrolled.

Table 4 Panel estimations: Regional characteristics and graduation rate

VARIABLES	FE (1)	RE (2)	RE (3)	FE (4)	RE (5)	RE (6)
Total expenditure $_{it}$	0.019**	0.029***	0.028***	0.018*	0.026***	0.026***
	(0.009)	(0.007)	(0.008)	(0.009)	(0.007)	(0.008)
Tot_stu $_{it}$	0.084**	0.022***	0.022***	0.086**	0.022***	0.024***
	(0.037)	(0.007)	(0.005)	(0.042)	(0.006)	(0.005)
40greater $_{it}$	-0.662**	-0.237***	-0.512**			
	(0.307)	(0.081)	(0.215)			
OLD $_{it}$				0.582	1.259***	0.998
				(2.085)	(0.422)	(0.720)
Employment $_{it}$				-0.139**	-0.015	-0.043**
				(0.060)	(0.011)	(0.018)
Constant	0.401***	0.432***	0.443***	0.359	0.235***	0.296**
	(0.125)	(0.062)	(0.066)	(0.425)	(0.082)	(0.136)
Regional dummies	Not	Not	Yes	Not	Not	Yes
Adj. R-squared	0.12	0.20	0.33	0.11	0.21	0.34

Notes: the dependent variable is the graduation rate at university *i* in year *t*. *Total expenditure* $_{it}$ is the sum of expenditures of personnel, financial-aid to student and R&D, plus investment, capital transfers and financial operations. *Tot_stu* $_{it}$ is the sum of *Undergra_stu* $_{it}$ and *Grad_stu* $_{it}$. *40greater* $_{it}$ is the share of population with tertiary education and aged over to 40 at province i. *OLD* $_{it}$ the share of old workers in the previous decade. *Employment* $_{it}$ is the employment at province i.
Robust standard errors clustered at university level are shown in parentheses. *,**,*** denote the significance at 90%, 95% and 99%, respectively. Number of observations: 217. Number of Universities: 46. Year effects are included in all models. The expenditure variables are expressed in 2001 Euros and per student enrolled. Columns 1 and 4 show fixed-effect models, other columns show random-effect ones.

Table 5 Fixed-effects quantile regression results

	20^{th} (1)	40^{th} (2)	60^{th} (3)	80^{th} (4)
Total expenditure	0.011*	0.013*	0.002	0.024
Std. Error	(0.006)	(0.007)	(0.013)	(0.016)
Financial-aid to student	0.146	0.448**	0.573***	0.388**
Std. Error	(0.150)	(0.172)	(0.176)	(0.194)

Notes: the dependent variable is the graduation rate at university *i* in year *t*.
Robust standard errors clustered at university level are shown in parentheses. *,**,*** denote the significance at 90%, 95% and 99%, respectively. Number of observations: 217. Number of Universities: 46. Year effects are included in all models. The expenditure variables are expressed in 2001 Euros and per student enrolled.

Appendix

Table A1 List of variables

Variable	Description
Overall Weighted-Graduation rate $_{it}$	Overall Weighted-Graduation rate of university *i* at year *t*
Total expenditure $_{it}$	Sum of personnel, financial-aid to student and R&D, plus investment, capital transfers and financial operations
Personnel expenditure $_{it}$	Total salary outlays and fringe benefits of faculty and administrative staff
Financial-aid $_{it}$	Refers scholarships and fellowships awarded to students such as grants-in-aid, trainee stipends, tuition and required fee waivers, and other monetary subsidies given to students.
R&D expenditure $_{it}$	charges for activities specifically organized to produce research outcomes
Student-teacher ratio $_{it}$	is obtained by dividing the number of full-time equivalent students by the number of full-time equivalent teachers
Undergra_stu $_{it}$	Undergraduate students
Undergra_stu^2 $_{it}$	Squared of undergraduate students
Grad_stu $_{it}$	Graduate students
Grad_stu^2 $_{it}$	Squared of graduate students
Tot_stu $_{it}$	Sum of *Undergra_stu* $_{it}$ and *Grad_stu* $_{it}$
Fees $_{it}$	Weighted average of tuition fees by university
Supp_stu $_{it}$	Student percentage with financial support of ministry of education
Sci_stu $_{it}$	Share of students in science and engineering degrees
Student Ability $_{it}$	Minimum score to access to the university. Average of the 75th percentile of scores by university's entering first-year class
Publi $_{it}$	the ratio of the number of scientific articles published in JCR journals to full-time faculty
Pat $_{it}$	The number of patent applications

Table A2 Descriptive statistics

		Standard Deviation				
	Mean	**overall**	**between**	**within**	**Min**	**Max**
Overall Weighted-Graduation rate $_{it}$	0.6625	0.1525	0.0828	0.0955	0.3219	0.9846
Total expenditure $_{it}$	5.6594	2.1749	1.3422	1.7207	2.1239	21.9961
Personnel expenditure $_{it}$	3.0537	0.9510	0.5107	0.8051	0.7892	5.8690
Financial-aid to student $_{it}$	0.3279	0.1531	0.1463	0.0715	0.0248	0.9322
R&D expenditure $_{it}$	0.9182	0.6244	0.4898	0.3968	0.1426	3.4925
Student-teacher ratio $_{it}$	15.5202	3.9594	2.3347	3.2129	9.1824	51.5857
Undergra_stu $_{it}$	24.3505	16.0573	15.9428	2.8615	3.2230	82.5000
Undergra_stu^2 $_{it}$	849.8688	1133.1630	1115.4510	248.9346	10.3877	6806.2500
Grad_stu $_{it}$	1.4041	1.5132	1.4828	0.3549	0	11.0620
Grad_stu^2 $_{it}$	4.2531	13.2817	12.6018	4.4635	0	122.3679
Fees $_{it}$	10.3834	1.4475	1.0995	0.9512	0	15.1156
Supp_stu $_{it}$	0.1672	0.0537	0.0504	0.0195	0.0135	0.3459
Sci_stu $_{it}$	0.4478	0.1875	0.1873	0.0269	0.0097	1
Student Ability $_{it}$	6.5767	0.5576	0.4817	0.2867	5	7.9950
Publi $_{it}$	0.3305	0.1531	0.1346	0.0751	0.0601	0.8880
Pat $_{it}$	7.2128	7.5168	6.6258	3.6538	0	41

N = 271, n = 47, T=6. All financial data used in the study are expressed in terms of per enrolled student and have been adjusted to 2001 values.

Table A3 Recent studies on the relationship between regional development and human capital

Studies	***Dependent variables***	***Explanatory var.***	***Methodology***	***Unit of analysis***	***Period***
Artís et al. 2010	1. Δ Productivity 2. Δ GDP per capita	Stock of physical capital, Stock of human capital (primary, high school, Tertiary)	Spatial panel data. Weighted matrix (distances between province capitals)	Spanish provinces	1980 – 2007
Abel and Gabe 2010	GDP per capita (average 2000 – 2005)	Human Capital = The proportion of each metropolitan area's working-age population with a college degree, Physical capital investment.	Cross section, Instrumental Variables: Land-grant university.	US Metropolitan areas	2000 - 2005
Coulombe and Trembaly 2007	Provincial Per capita income	HK measured by: 1. University achievement 2. Indicator of skill based on literacy test scores. Year of Schooling	Mincerian estimates. Time series and cross section. GLS, FGLS. Instrumental variables.	Canadian provinces	
Ciccone and Peri 2006	Average-schooling externalities	Δ in average schooling Δ in av. experience	Theoretical model, Mincerian approach (identifying HK externalities)	US City	1970-1990
Florida et al. 2008	1. Productivity (measure by Wages) 2. Income	Human capital, creative class, technology variables, tolerance and related variable, universities (# of university faculty per capita), consumer services (amenities).	Cross section, Structural equation model. What are the factors that shape the distribution of human capital in the first place?	US metropolitan regions (331)	2000
Hanushek and Kimko 2000	Productivity and economic growth.	Labour force quality (based on student cognitive performance)	Equation system to explain: 1. Economic growth. 2. Resources devoted to schools and human capital production. 3. labour-force quality	Countries (drop out)	
Mollick et al. 2010	Δ population (or employment) County logarithmic	Share of individuals in the county: Youth, Mid, Old. Argument: Cities with a larger share of	IV, Cross section.	Texas counties (254)	1980, 1990, 2000

Studies	***Dependent variables***	***Explanatory var.***	***Methodology***	***Unit of analysis***	***Period***
	population density growth between 1980-1990 and between 1990-2000	older workers in 1970 experienced a greater increase in average schooling in subsequent years.			census
Moretti 2004	Wages		Cross section and panel data. IV: 1. Lagged of age structure, 2. Land-grant university	US cities (201) NxT= 44891	1979 - 1994 census
Shapiro 2006	Growth in: Productivity, employment, wage, rental price, house value.	Share college educated. Dependent variables alternate as explanatory in other regressions. (a simple neoclassical growth model is calibrated)	IV: Land-grand colleges and Universities (1862), compulsory schooling laws.	US Cities	

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Chapter 4

On the effects of University-Industry interactions

1. Introduction

University-industry interactions (UIIs henceforth) take place through a wide variety of mechanisms, from the so-called open-science[1] to more formal ones such as consultancy, contract research, joint research, training – lifelong learning in general, and in-company training in particular -, patenting and spin-out activities (D'Este and Patel, 2007). Studies have found that open-science mechanisms are, in general, far more relevant to industrial R&D laboratories than the commercial activities of universities, such as licensing or co-operative ventures (See e.g. Cohen et al., 2002).

The difficulty in the organization of UIIs arises from the highly uncertain and non-codifiable nature of scientific know-how, which results in high transaction costs and systemic failures in the market for this know-how (Veugelers and Cassiman, 2005). This is one of the basic justifications to government intervention. As such, a growing amount of resources (public and private) has been allocated to promote UIIs related to R&D activities over the past two decades. As a result, UIIs have grown very rapidly.

[1] Open science channel refers to knowledge-sharing mechanisms based on the traditional conventions in science, i.e. the free sharing of knowledge unhindered by commercial considerations (e.g. publications and informal interaction) (Perkmann and Walsh, 2007).

The burgeoning relevance of UIIs has motivated researchers to investigate empirically their causes and effects. The determinants of UIIs have been extensively studied in the literature. Among the factors that have been identified are firm and industry characteristics (Laursen and Salter, 2004; Fontana et al., 2006; López, 2008; Segarra and Arauzo, 2008; Arvanitis and Woerter, 2009), geography of the cooperation (Hewitt-Dundas, 2011; Laursen et al., 2011), and identification of the main form in which UIIs are practiced (Perkmann and Walsh, 2007). However, little is known about the results (or effects) of the university-industry relationships. This paper aims at contributing to the understanding of UIIs and their effects on firms' innovative performance.

The objective of this paper is to review the university role in the innovation process. We build upon Polo (2011) whom explores the effects UIIs on firms' innovative performance in Spain. More specifically, we assess the different ways through which universities positively affect the innovative output of firms i.e. creator of human capital, provider of research findings, partner in R&D projects, and supplier of R&D services. Data is used from the Technological Innovation Panel dataset – PITEC (for its Spanish acronym). The PITEC is built on the responses to the Spanish part of the Community Innovation Survey (CIS), and provides data for a large sample of firms over the period 2004 - 2009. The panel structure of PITEC enables the use of panel data techniques which control for individual unobservable heterogeneity which is not controlled for cross sectional data. On balance, the data provides quantitative evidence suggesting that universities' contribution is rather helpful in terms of new products to market and for generating patents, while it is less important for conducting innovations new to the firm.

The Spanish case has the following features. Firstly, the Spanish business sector plays a smaller role in R&D activities than in other EU countries, while Spanish universities are carrying out more R&D activities than in the EU (Segarra and Arauzo, 2008). In 2009, universities performed about one third of total R&D expenditures, and hired 47% of researchers (COTEC, 2011)[2]. Secondly, regarding innovation activities, Spanish firm cooperation with universities is much lower than the EU average. While only 17.3% of

[2] In 2009, the figures for the UE 17 were: universities performed 23% of of total R&D expenditures and hired 35% of researchers (EUROSTAT, 2011).

Spanish firms engaged in research cooperation with universities in 2009, in the EU this figure was almost double (31%) (EUROSTAT, 2011).

The paper is structured as follows: Section 2 provides the background to this paper by examining previous studies on the effects of UIIs on firms' innovative performance. Section 3 discusses the hypotheses to be tested and is followed by Section 4, in which the methodology and data used are described. Section 5 presents the results, while Section 6 summarizes the findings with some concluding remarks.

2. The reasons for UIIs and their effects on firms' innovative performance

What do enterprises seek when they cooperate with universities?

UIIs are mostly motivated by factors other than immediate commercial outcomes. These include obtaining knowledge of scientific and technological advances, getting access to highly trained human capital and solving specific problems (Mansfield, 1995). The set of reasons for UIIs also contains access to instruments, experimental materials, and research techniques (Cohen et al., 2002). From the universities' point of view, the most important incentives for collaborating with industry are 1) to provide their students and faculties with practical problems related to technological areas, 2) to create employment opportunities for their graduates, 3) to access additional funds specifically for research, 4) to access industry skills and facilities and 5) to keep abreast of industry problems (García-Aracil and Fernández De Lucio, 2008; Caniëls and van den Bosch, 2011).

When do firms cooperate with universities?

R&D cooperation with universities is more likely to be chosen by R&D intensive firms in sectors that exhibit faster technological and product development (Belderbos *et al*. 2004). Moreover, cooperation with universities is a complementary component within a firm's overall innovation strategy. The literature has highlighted that universities are the preferred partners in two cases.

Firstly, in order to carry out basic research (often long-term orientated), which is generally more aimed at innovations that may open up entire new markets or market segments (Monjon and Waelbroeck, 2003). In addition, public research carried out by universities is used not just to help generate new ideas, but also to help in completing existing R&D projects (Cohen et al., 2002).

Secondly, when there are concerns about the perceived ability to fully appropriate the results (Veugelers and Cassiman, 2005; Bercovitz and Feldman, 2007). Most public research institutions and universities do not seek commercial applications and tend to focus on the more generic or basic end of the R&D complex, and co-operation with public partners which does not involve commercial risk (Miotti and Sachwald, 2003). As a result, university-firm agreements are formed whenever risk is not an important obstacle to innovation and typically serves to share costs.

Firms often choose to undertake R&D projects with university through a *cooperative agreement* when the project embodies basic R&D activities and tends to be strategically less important. In contrast, when R&D projects are strategic and include developing novel knowledge, the firm is more likely to resort to *formal contracting* with a university (Cassiman et al., 2010).

***Effects of UIIs*[3]**

The relationship between universities and industrial firms is mediated by a complex set of overlapping interactions and institutions. This fact hinders the ability to empirically trace the direct effects of universities on industrial innovation (Salter and Martin, 2001). Still, no consensus is found on the role of universities in the development of industrial innovations, or on the channels through which knowledge flows between universities and industrial firms (Bekkers and Bodas Freitas, 2008). In addition, most empirical studies have dealt with input-related motives for and effects related to R&D cooperation at the firm level, which include knowledge spillovers, access to complementary knowledge, or cost- and risk-sharing in innovation projects (Aschhoff and Schmidt, 2008).

Commonly used indicators of innovation outcomes include sales of products that are new-to-market (or new-to-firm, or significantly improved) compared to sales of other products. The main advantages of these indicators are that they provide a measure of the economic success of innovations, are applicable to all sectors, and allow types of innovations to be distinguished (Negassi, 2004). On the contrary, their main limitation is that they are sensitive to product life cycles and markets, which may differ in the context of competing companies (Frenz and Ietto-Gillies, 2009).

3. Hypotheses

A framework is built which thoroughly takes into account the wide range of mechanisms that UIIs influence firms' innovative performance. Certainly, some of these hypotheses have been discussed separately in the literature. The purpose is to assemble an integrated framework, which relates the various methods through which firms benefit from interactions with universities, such as via use of information sources, cooperation agreements, buying R&D services, and hiring highly-skilled workers to augment the absorptive capacity. The following set of hypothesis is tested.

[3] Table A1 in the appendix offers a review of recent studies analyzing the effects of UIIs on firm innovation performance.

University as a source of information

The channels via which useful information moves from universities to industrial R&D facilities include patents, informal information exchange, publication and reports, public meetings and conferences, recently hired graduates, licenses, joint or cooperative ventures, contract research, consulting and temporary personnel exchanges (Cohen et al., 2002). It is still small the number of firms drawing directly from universities as a source of information or knowledge for their innovative activities. Likewise, compared to clients or suppliers, universities are only moderately important. But that does not imply that universities make little or no contribution to industrial innovation. This feature suggests that the direct contribution of universities to industrial practice is likely to be highly concentrated in a small number of industrial sectors (Laursen and Salter, 2004). The hypotheses can be stated as:

Hypothesis 1. Enterprises using universities as a source of information have a higher innovative performance. Hence, the application of knowledge generated by universities is positively associated with innovation performance.

University-industry formal collaboration

UIIs have been identified as an important factor affecting firms' innovative performance. Moreover, the most important benefits for firms from interaction with universities come from formal collaboration (Monjon and Waelboreck, 2003). Usually, formal collaboration is done through: 1) *Collaborative research*, which is research jointly pursued by university and industrial partners, commonly with public funding (Perkmann and Walsh, 2007). It aims at developing new knowledge as opposed to applying existing knowledge to a new problem or 2) *Contract research*, which involves experimental projects carried out by universities, which are commissioned and funded by industries. In this mode, knowledge is typically produced early on in the project (D'Este and Patel, 2007; Cassiman et al., 2010). Collaboration and contracting have been generally considered in the literature as strictly alternative organizational forms. However, in reality the two may coexist (Cassiman et al., 2010). These arguments lead towards the following hypothesis.

Hypothesis 2. Firms that have incorporated mechanisms of formal collaboration with universities within their R&D strategies have a higher innovation performance compared with those that do not.

In addition, a full examination of the impact of R&D cooperation should be done over a longer period of time. Consequently, the following hypotheses can be stated as:

Hypothesis 3. Permanent R&D collaboration with universities positively influences innovative performance.

Absorptive capacity

In many studies, the firms' absorptive capacity[4] is an important determinant for R&D performance. In turn, absorptive capacity depends on the firm's specific investment, including the existence of an R&D department and enough qualified personnel (Arvanitis and Woerter, 2009; de Faria et al., 2010). Hence, one of the most important contributions universities provide to industrial innovation is the production of skilled graduates. By hiring new graduates, firms acquire knowledge of recent scientific research and the ability to solve complex problems, perform research, and develop ideas (Salter and Martin, 2001). The hypothesis can be stated as:

Hypothesis 4. Firms with a higher proportion of skilled workers, and therefore with higher absorptive capacity, have better innovative performance.

The firms' strategy for carrying out R&D activities comes from a combination of a wide variety of innovation sources both internal and external (Veugelers and Cassiman, 1999).

[4] This term was introduced by Cohen and Levinthal (1989). It refers to the firm's ability to identify, assimilate, and exploit knowledge from the environment. It raises the dual role of R&D as both a producer of new information and a tool of a firm's ability to learn from existing information.

Firms acquire much external knowledge via the purchase of technological consulting services and by acquiring incorporated technology and technical assistance. Universities are one of the alternatives that firms have for obtaining external R&D. This idea leads towards the last hypothesis:

Hypothesis 5. Buying R&D services from universities is positively associated with innovative performance.

4. Data and model specification

4.1 Data

This paper uses the Technological Innovation Panel dataset (PITEC) which is a subsample of the Spanish Community Innovation Survey (CIS)[5], organized as a balanced panel-data. Using four years of the PITEC database (2006-2009), a sample of 8,551 firms is assembled[6]. 78% of the sampled firms carried out some type of innovation (product or process)[7]. Moreover, 36.8% of the innovative firms carried out innovative activities through collaboration with other agents. The firms' most preferred collaborators were firms belonging to the same group (15.7%). The same proportion was found when

[5] In Spain, the Instituto Nacional de Estadística (INE) carried out the CIS under the name *Encuesta de Innovación Tecnológica en las Empresas*.

[6] 3652 in Manufacturing (NACE Rev.2 10–33), 4341 in Services (NACE Rev.2 from 45 to 96), and the rest in Mining and quarrying (NACE 5–9), Electricity, gas and water supply (NACE Rev.2 35–39) and Building (NACE Rev.2 41-43).

[7] Product innovation refers to the introduction of goods or services into the market, or the significant improvement over basic features, technical specifications, incorporated software or other intangible components, and benefits of existing products. Process innovation consists of the implementation of new or improved manufacturing method, logistic systems, and support activities. Product and process innovations must be for the firm, and not necessarily for the economic sector or market (INE 2011, Community Innovation Survey).

collaborating with universities and suppliers (17.3%), and lower proportions were seen with competitors (11.9%) and clients (9.7%)[8].

Regarding the characteristics of innovative firms engaged in R&D cooperation activities with universities, the firm size -in terms of number of employees - is twice the size of other innovative firms (see Table 2). 57% belong to a group, spend on average 21% of their total sales in R&D and export 8% of their total sales. About 38% of firms have personnel with a higher level of education than the sample average.

4.2 Variables description[9]

Dependent variables: measures of innovative performance

The dependent variables are relative to firm innovation performance in a specific period t. In order to test the hypotheses developed in Section 2 and to capture the different innovation dimensions, along with the distinct levels of complexity, three separate measures were used: 1) the share of sales with significantly improved products or products new to the firm (but not new to the market), 2) the share of sales due to products new both for the firm and the market, and 3) patent applications[10].

Explanatory variables

Key regressors: *University's roles in industrial innovation*

1) University as a source of information

[8] See Table 1.
[9] A detailed description of the construction of the variables included in our empirical model can be found in appendix Table A2.
[10] This variable is an effective way of capturing the achievement of more significant and complex innovations. In fact, the requirements to register a patent are usually more stringent than for other innovations (Beneito, 2006).

The CIS asks each firm to rate on a Likert scale (1–4) the importance of various external sources of information in terms of the "effectiveness in the firms' innovation process" in the past 2 years. Hypothesis 1 is tested by reviewing the answers to the CIS's question about how important each information source is to the enterprise's innovation activities. One of those information sources is universities.

The assessment of knowledge produced by universities as an input for the innovation process widely varies across industries. Table 3 shows inter-industry variation in the importance of universities to innovation. The top five industries with the highest share of firms assessing universities as a highly important source of information are: Extraction of crude petroleum and natural gas (33.3%), Research and development (32%), Mining and quarrying (24.2%), Agriculture, forestry and fishing (22.5%). Overall, 9.5% of firms assessed information from universities as highly important, while 15.4% reported as it as moderately important.

In addition, the assessment by firms on the usefulness of knowledge created by universities has shown very little variation over time (see Table 4). About 26% of firms assess information and knowledge from universities as being of high and medium importance. By contrast, more than half of firms (about 55%) have not used or considered universities as a "not relevant" source of information and knowledge.

The role of universities as a source of information is proxied by a dummy variable, which takes on the value one if information produced by universities is deemed to be important or very important to an enterprise, and zero otherwise. This variable should be seen as a proxy for the importance of universities to the firm's innovative activities, reflecting the judgment of members of the firm concerning the value of universities to its activities (Laursen and Salter, 2004).

2) University as a partner of cooperation:

The following key regressor in the empirical analysis is the university role as co-operator in R&D activities. Usually cooperation firm-university is a complementary strategy in the innovation process. Only about 17% of firms cooperated with universities, which suggests that cooperative arrangements are far from the norm among innovative Spanish firms.

The questionnaire only contains information on whether firms cooperate with universities or not. No information was available on the importance, the duration, or the number of cooperative agreements. Hypothesis 2 was tested through a dichotomous variable that takes a value = 1 when firm has cooperated with university; and otherwise 0.

Hypothesis 3 (persistence in R&D collaboration with universities) was tested through a dummy variable that takes a value =1 if the firm cooperated with a university in the last 4 waves of PITEC data.

3) University as a supplier of highly skilled workers

Firms hiring highly-skilled workers enhance their absorptive capacity, which correlates with better outcomes from innovation activities. Absorptive capacity is often measured through qualification of human resources i.e. the employee education level. Hypothesis 4 was tested through the dummy variable which is equal to 1 if the firm has a share of employees with higher education above the average of the sample (0.27).

4) Universities as suppliers of R&D services:

The questionnaire asks firms for the amount of external R&D expenditures including contracts for acquiring the R&D services of other firms, universities or public research centres. Hypothesis 5 was tested with answers to this question, in particular, the amount of R&D expenditure that was carried out with universities.

Controls

Control variables included in the analysis reflect differences in R&D intensity, incoming spillovers and appropriability, belonging to a group, obstacles to innovation, the level of exports, and industry and associated technological level.

Further control variables include a set of 2-digit industry dummies (56 industries are distinguished) and firm size (the logarithm of the number of employees). The correlation matrix is presented in Table 5. Correlations are generally low to moderate, which indicates that there is a low risk of facing collinearity issues.

4.3 Method and estimation strategy

The functional form of the econometric model to assess the university role in the innovation process is given as

$$Y_{it} = f\,(U_{it}\,,\, Z_{it})$$

Where

- Y_{it} represents the three measures of innovation performance: 1) the share of sales with significantly improved products or products new to the firm (but not new to the market), 2) the share of sales due to products new both for the firm and the market, and 3) patent applications.
- U_{it} denotes the several mechanisms through which universities influence industrial innovation: information source, cooperation partner, creator of human capital, and supplier of R&D services.
- Z_{it} is a vector of control variables: R&D intensity, incoming spillovers and appropriability, belonging to a group, obstacles to innovation, the level of exports, and industry and associated technological level.

Two dependent variables are censored - i.e. restricted to the interval between 0% and 100% – therefore, in order to test the hypotheses developed in Section 2, a censored regression or Tobit estimation procedure is used. Likewise, when the propensity to patent is the dependent variable a Probit model is used.

Other methodological issues should be mentioned. First, unobservable individual heterogeneity has an effect on a firm's decision to invest in innovation (Peters, 2009). Hence, it seems reasonable to assume that it could affect their decision to interact with universities and subsequently the firm's innovation outcomes. To take account for this issue into account, panel techniques are used along with pooled regressions. Furthermore, in all estimations, the error terms were clustered at the firm level to control for intra-firm serial correlation.

Second, because only dependent variables for innovation-active firms are observed, the coefficients in the outcome regression may be biased. Thus, in line with recent econometric studies into innovation performance, a Heckman selection model is estimated (Veugelers and Cassiman, 2005; Lööf and Broström, 2008; Hewitt-Dundas, 2011) next to the Tobit model. The identification variables included in the selection model are firm size and obstacles to innovation (related to lack of information). Both are considered in the selection model as a likely influence on the decision to carry out innovation activities, but not as determinants of innovation performance[11].

The formal definition and further details about the econometric models involved in the empirical strategy are presented below.

The Tobit Model

This model, also called a censored regression model, is designed to estimate linear relationships between variables when there is either left (below) or right (above) censoring in the dependent variable. Censoring from above takes place when cases with a value at or above some threshold, all take on the value of that threshold, so that the true value might be equal to the threshold, but it might also be higher. In the case of censoring from below, values those that fall at or below some threshold are censored.

The formal Tobit model in our case is given by $Y_i^* = \beta x_i + \mu_i, \ \mu_i \sim N(0, \sigma^2)$, where Y_i^* is a latent variable.

[11] The sample selection is for whether firms introduced a product or process innovation, or not. In the first stage, the innovation equation is estimated.

The observable variable is defined to be equal to the latent variable whenever the latent variable is above zero and zero otherwise.

$$Y_i = \begin{cases} Y_i^* & \text{if } Y_i^* > 0 \\ 0 & \text{if } Y_i^* \leq 0 \end{cases}$$

The likelihood function for the Tobit model takes the form:

$$log\ L = \sum_{Y_i>0} -\frac{1}{2}\left[log(2\pi) + log\ \sigma^2 + \frac{(Y_i - \beta x_i)^2}{\sigma^2}\right] + \sum_{Y_i=0} log\left[1 - F\left(\frac{\beta x_i}{\sigma}\right)\right]$$

The estimated Tobit coefficients are the marginal effects of a change in x_i on y^*, the unobservable latent variable and can be interpreted in the same way as in a linear regression model. However, that interpretation may not be useful since we are interested in the effect of X on the observable y (or change in the censored outcome).

It can be shown that change in y is found by multiplying the coefficient with $\Pr(a<y^*<b)$, that is, the probability of being uncensored. Since this probability is a fraction, the marginal effect is actually attenuated. Here, a and b denote lower and upper censoring points. For example, in left censoring, the limits will be: a =0, b=+∞.

The probit model

Probit and logit are the two most common techniques for estimation of models with a dichotomous dependent variable. The Probit is similar to a Tobit model in the sense that a latent variable is estimated. Probit model is estimated using maximum likelihood procedure.

For a sample of N independent observations, the maximum likelihood estimation, $\hat{\beta}$, maximizes the associated log-likelihood function

$$Q(\beta) = \sum_{i=1}^{N} [y_i lnF(x_i'\beta) + (1 - y_i)\ln\{1 - F(x_i'\beta)\}]$$

The maximum likelihood estimation is obtained by iterative methods and is asymptotically normally distributed.

Heckman model

The Heckman selection model can be presented as follows

Selection equation

$$z_i^* = w_i'\alpha + \xi i$$

$$z_i = \begin{cases} 1 & \text{if } z_i^* > 0 \\ 0 & \text{if } z_i^* \leq 0 \end{cases}$$

- z_i^* = latent variable, -think of this as the propensity to be included in the sample
- w_i' = vector of covariates for unit *i*
- α = vector of coefficients
- ξ_i = random disturbance for unit *i*

Outcome equation

$$y_i = \begin{cases} x_i' \beta + u_i & \text{if } z_i^* > 0 \\ - & \text{if } z_i^* \leq 0 \end{cases}$$

- y_i = Dependent variable
- x_i' = vector of covariates for unit *i*
- β = vector of coefficients
- u_i = random disturbance for unit *i*

The following assumptions are typically made about the distribution of, and relationship between, the error terms in the selection and outcome equation:

$u_i \sim N(0,1)$

$\varepsilon_i \sim N(0,\sigma^2)$

corr $(u_i\, 1) = \rho$

In other words, the Heckman selection model typically assumes a bivariate normal distribution with zero means and correlation ρ.

Heckman (1979) suggests that selection bias can be thought of as a form of omitted variable bias. Specifically we can model the omitted variable by:

$$E[(\varepsilon_i | u_i > -\mathbf{Z_i}\gamma)] = \rho_{\varepsilon u}\sigma_\varepsilon \lambda_i(-\mathbf{Z_i}\gamma) = \beta_\lambda \lambda_i(-\mathbf{Z_i}\gamma)$$

where $\lambda_i(-\mathbf{Z_i}\gamma)$ is the inverse Mill's ratio evaluated at the indicated value and β_λ is and a unknown parameter ($=\rho_{\varepsilon u}\sigma_\varepsilon$).

The maximum likelihood estimator takes the form

$$Ln\, L = \sum_{z=0} Ln\,\{1-\phi(w_i\alpha)\} + \sum_{z=1} Ln\,\langle\frac{1}{\sqrt{2\pi\sigma_u^2}}\rangle + \sum_{z=1}\frac{1}{2\sigma_u^2}(Y_i - x_i'\beta)^2 + \sum_{z=1} Ln\,\phi\left[\frac{w_i\alpha + \rho\left(\frac{(Y_i - x_i'\beta}{\sigma_u}\right)}{\sqrt{(1-\rho)^2}}\right]$$

5. Results and discussion

This section discusses the results of the analysis, firstly with regards to the effects of UIIs on the sales of innovative products (both to the firm and to the market) and secondly, to the propensity to patent.

5.1 The effect of UIIs on sales of innovative products

Table 6 presents the first set of regressions testing the hypotheses. Mixed support has been found about the university role as a source of information and knowledge to industrial innovation (hypothesis 1). On the one hand, when the innovative performance is measured through the share of sales with products new to the market, the university role as a source of information is positive and statistically significant, supporting hypothesis 1 (see columns 1 and 2). Hence, it seems particularly important in this type of innovation that firms combine their own know-how with expertise and knowledge from universities. On the other hand, when innovative performance is the share of sales with products new to the firm, the mentioned university role has no effect (see columns 3 and 4). One explanation might be that the knowledge required for this type of innovation can be obtained through other channels.

The results broadly support hypothesis 2, suggesting that formal collaboration with universities improves firms' innovative performance.

These findings are in line with previous studies; firstly, universities are important sources of knowledge for firms, which facilitates growth in innovative sales in the absence of formal R&D cooperation. Secondly, university cooperation is instrumental in creating and bringing to market radical innovations, generating sales of products that are novel to the market, and hence improving the growth performance of firms (Belderbos et al., 2004; Bishop et al., 2011).

Hypothesis 4 is also strongly supported when the dependent variable is the share of sales with products new to the market. Accordingly, firms with a higher proportion of skilled workers, and therefore with higher absorptive capacity, have better innovative performance. On the contrary, when the share of sales with products new to the firm is the dependent variable, the relationship with employees' education is not statistically significant. Our results indicate that firms showing a relatively higher share of high-skilled workers do not perform better that the rest of firms in the sample.

A new variable was introduced in order to test hypothesis 3. It is a dummy variable which takes value 1 if the firm has cooperated with universities in t-2 and t-4, and 0 otherwise. The results show in table 7 support the idea that permanent R&D formal collaboration with universities positively influences the innovation performance.

The results obtained when running a Heckman selection model are presented in Table 8. In columns (1) and (3) the selection variable is whether a firm has introduced a process or product innovation or not. Having accounted for potential selection bias in the model, the first finding that can be drawn from the results is that hypothesis 1 and 4 are reinforced when the dependent variable is the share of sales with products new to the market. In addition, a new result is that hypothesis 5 is now confirmed, since in previous regressions any evidence could not be achieved[12] (see column 2). By contrast, when the dependent variable is the share of sales with products new to the firm any hypothesis on the contribution of university to industrial innovation is supported (see column 4).

A concern still subsisting in the estimations is related to issues of endogeneity. While selection would bias Tobit estimates towards zero, endogeneity affecting the innovation variables leads to a positive bias in the estimates for innovative performance. This is addressed by introducing a time lag in the regressions. Following Belderbos et al. (2004), it can be assumed that innovation activity requires some time to translate into innovation output. Thus, the impact of university roles on a firm's innovative performance should become more obvious in the subsequent three or four years. The chosen lag structure between universities roles and its effects on innovative outcome is based on a four-year delay: university variables are captured in t-4 (2006), and innovation outcomes in t (2009).

Table 9 shows results when the mentioned lag structure is introduced. The hypotheses 1 and 3[13] are only supported when the innovative outcome is measured through the share of sales new to the market. In contrast, hypothesis 2 which states that formal collaboration

[12] In unreported regressions this variable was converted to a dichotomous variable which takes value 1 if firm buys R&D services to university, and 0 otherwise. The results are pretty similar to those shown here.

[13] Hypothesis 1 affirms that information and knowledge from universities is an important input for industrial innovation. Hypothesis 3 states that firms with a higher proportion of skilled workers, and therefore with higher absorptive capacity, have better innovative performance.

with universities positively affects the firms' innovative performance is confirmed for all innovative outcomes.

5.2 The effect of UIIs on the propensity to apply for patents

In this section the dependent variable is patent application. If the firm replied that it did at least one patent application, the variable takes the value of 1, and it takes the value of 0 otherwise. This variable can be seen as an indicator for more complex innovations.

Table 10 displays the results. Columns (1) and (2) present the results from pooled and panel random effects, respectively. Columns (3) and (4) present the estimates of the corresponding Heckman probit model. The significance of Athrho implies that there is sample selection effect; consequently a sample selection model should be used.

Considered together, the estimated results tell a similar story to the one for the share of sales new to the market. All proxies used to test the hypotheses have a positive and statistically significant effect on the patent application. The main difference detected being that hypothesis 5 is confirmed even when sample selection bias is corrected. Hence, this result broadly supports the idea that firms developing complex innovations use the universities as suppliers of R&D services.

6. Conclusions

This paper studies the effects of UIIs on firms' performance in terms of innovation in Spain. Following the literature that seeks to analyse the nature of UIIs and the studies that focus on the effects that UIIs produce on innovation activities, a framework is established to analyse the several roles and channels by which firms may benefit from interacting with universities.

Universities help firms to innovate through a wide range of mechanisms. From access to new ideas through open-science channels, which contribute to the development of learning capabilities, to formal collaboration for conducting research, which could contribute to solving complex problems. The significance of this study stems from its consideration of the several roles that universities play in the innovation process.

This study uses specific innovation outcome measurements to describe new results on the effects from UIIs. Innovation is measured through three variables: 1) sales of innovative products new to the firm, 2) sales of innovative products new to the market, and 3) propensity to patent. Based on firm-level innovation data for Spain and having corrected econometric issues such as selection bias and endogeneity, new empirical evidence is provided about the multiple types of benefits for firms from interaction with universities.

Four mechanisms are analysed through which universities can influence industrial innovation. Firstly, the role of universities as a source of information and knowledge is found to be a very important channel enhancing firms' innovative performance. In particular, firms benefit from this channel when complex innovations are being carried out. Secondly, formal collaboration with universities in order to perform research is a very effective mechanism for improving firms' innovation outcomes. Since innovation is a multifaceted process, the effects of collaborating with universities might materialize only years later after signing the agreement. Hence, the importance of continuity or persistence in formal collaboration between universities and firms is also taken into account. The effect of collaborating with universities over four years is found to have a strong and positive impact on firm innovative performance.

Thirdly, universities as a creator of highly skilled workers are found to be one of the natural and most important mechanisms through which they boost innovation. It is shown that firms with a larger than average share of highly-skilled workers have a better innovative performance. Finally, universities play another role in the innovation process as suppliers of R&D services. It is confirmed that firms that undertake the development of complex innovations buy R&D services from universities.

Overall the results suggest that the contribution of universities is very helpful in terms of getting new products to market and for generating patents, while it is less important for conducting innovations new to the firm. We conjecture that firms combine their own know-how with expertise and knowledge from universities when they undertake highly complex innovations. Hence, the University-Industry relationship tends to gravitate to the interaction type that has potentially the highest value in terms of incoming knowledge, and tends to be related directly to the introduction of higher-level innovations, as in the results for patent applications. More importantly, the results obtained here show the multifaceted features of UIIs and their potential to contribute to business innovation, and competitiveness.

Another major issue is the simple ignorance by firms of what universities do and what they could provide in terms of knowledge and support. Only about 17% of firms cooperated with universities, which suggests that cooperative arrangements are far from the norm among innovative Spanish firms. Hence, firms in Spain seem to lack the knowledge about what universities have to offer them in terms of research and innovation.

In line with some findings of Howells et al. (2012) in the UK, features and results obtained in this paper also show that Spain is also undergoing three paradoxes of University-Industry interactions: (i) firms rate universities very low as sources of information, knowledge and partners, but actual impact for innovative outcomes is much higher than for other sources; (ii) the actual impact of universities and research does not necessarily equate with how firms value and appreciate university collaborations; and (iii) there appears to be little or no difference between formal and informal linkages in terms of impact on innovative outcomes.

To conclude, a comment can be made about the structural changes that universities are undertaking. Since ancient times, education has been the benchmark for progress for any civilization. Nowadays, higher education is on the brink of its own revolution. It is dealing with complex major changes that must be directed toward optimal outcomes if universities are to continue as major players in the rapidly changing global economy. The role of universities is evolving from providing industry and the public sector with trained personnel and transferring knowledge in the form of research results for industry to draw upon, to becoming a structural factor in the science-based innovation process and encouraging industry–university collaboration. Indeed, over the past few decades, new determinants and social demands on universities have emerged.

Universities have responded by starting several initiatives such as technological and scientific parks, technology transfer offices (TTOs), long-life learning projects, university-enterprise cooperation, and applied research, etc. There never was a "golden age of independence from external forces" and indeed, many university forms appeared specifically to interact with external organisations or to act strategically in relation to economic development or industrialisation. Universities have always received many pressures from society, but those pressures differ for different geographical and time periods (Martin, 2012). Finally, it is important notable that there are important normative issues to be addressed about what roles universities should and should not undertake in the knowledge economy, as well as issues about whether we truly understand the diverse and multiple impacts that they actually do have.

Table 1
Propensity to co-operate on R&D among innovating firms by type of partner (%)

Partners	Firms' characteristics				
	All firms [a]	Groups	>500	In High-tech sector	Patent
All types of partners	36.8	39.9	49.9	45.1	57.9
Within groups	15.7	18.0	20.3	18.9	33.8
Clients	9.7	11.9	17.6	17.5	24.9
Suppliers	17.3	20.0	25.5	29.8	38.5
Competitors	11.9	14.8	23.1	16.7	25.5
Universities	17.3	21.6	33.3	18.0	29.5
Private labs	17.0	20.0	23.8	23.0	31.3
Public Institutions	11.3	24.6	26.7	16.4	22.6
Number of firms [a]	6661	3063	772	366	881

[a] Innovative firms of the survey with more than 10 employees. The propensity to co-operate is the ratio of the number of firms that co-operate over the total number of innovative firms.

Table 2
Cooperation among firms engaged in innovation activities (descriptive statistics) (Data to 2009)

Variables	All innovative firms		Firms engaged in innovation cooperation activities		Firms not engaged in innovation cooperation activities		Firms engaged in innovation cooperation activities with universities	
	Mean	Std. dev	Mean	Std. dev	Mean	Std. dev	Mean	Std. dev
Number of employees	361. 01	1692.84	530.57	2264.27	262.22	1234.03	792.31	2994.45
Number of employees (log)	4.41	1.44	4.65	1.54	4.28	1.36	4.98	1.65
Exports share	7.09	15.07	8.12	16.28	6.49	14.28	8.22	16.56
Part of a group	0.45	0.49	0.53	0.49	0.41	0.49	0.57	0.49
Engagement R&D	0.65	0.47	0.83	0.37	0.56	0.50	0.82	0.38
Employees' education	0.33	0.47	0.42	0.49	0.28	0.45	0.38	0.48
Innovation intensity	0.18	2.72	0.32	3.61	0.11	2.01	0.21	1.84
Incoming knowledge spillovers	0.32	0.32	0.40	0.31	0.28	0.31	0.41	0.32
Appropriability	0.44	0.79	0.59	0.88	0.35	0.72	0.63	0.90
Low-tech firm**	0.39	0.48	0.35	0.48	0.41	0.49	0.36	0.48
Medium-tech firm	0.32	0.47	0.33	0.47	0.32	0.46	0.32	0.47
High-tech firm	0.08	0.28	0.11	0.31	0.07	0.26	0.09	0.29
knowledge intensive service firm	0.65	0.47	0.76	0.42	0.59	0.49	0.71	0.45
Non-knowledge intensive service firm								
Number of observations	6661		2452		4209		1147	

Sample includes firms with more than 10 employees.
See Table A2 in the Appendix 1 for the description of the variables.

Table 3
How important do firms (within 43 industries) indicate universities to be as an information and knowledge source for technological innovation during the period 2007–2009?

	High (%)	Moderate (%)	Low (%)	Not relevant (%)	Row (%)	No. Of firms
Agriculture, forestry and fishing	**22.5**	**26.1**	13.5	37.8	1.4	111
Mining and quarrying	**24.2**	12.1	9.1	54.5	0.4	33
Extraction of crude petroleum and natural gas	**33.3**	**33.3**	0.0	33.3	0.0	3
Food, beverages and tobacco products	10.1	17.6	21.1	51.2	7.4	592
Textiles	3.1	4.3	24.2	68.3	2.0	161
Wearing apparel	4.8	6.3	12.7	76.2	0.8	63
Leather and related products	4.7	7.0	16.3	72.1	0.5	43
Wood and of products of wood and cork	4.2	15.5	16.9	63.4	0.9	71
Paper and paper products	4.8	9.6	19.3	66.3	1.0	83
Printing and reproduction of recorded media	3.7	5.6	14.8	75.9	0.7	54
Chemicals and chemical products	9.6	16.1	25.4	48.8	6.3	508
Pharmaceutical	**23.0**	**29.1**	24.3	23.6	1.8	148
Rubber and plastics products	3.8	11.4	20.4	64.4	3.6	289
Other non-metallic mineral products	9.4	13.9	19.3	57.4	3.0	244
Basic metals	3.7	14.2	27.6	54.5	1.7	134
Metal products, except machinery and equip.	5.5	11.8	17.5	65.2	5.6	451
Computer, electronic and optical products	10.0	19.0	22.3	48.7	3.3	269
Electrical equipment	8.5	14.5	23.9	53.0	2.9	234
Machinery and equipment n.e.c.	6.3	8.6	21.4	63.6	7.5	602
Motor vehicles, trailers and semi-trailers	2.2	17.4	25.4	54.9	2.8	224
Building of ships and boats	**18.8**	12.5	25.0	43.8	0.2	16
Manufac. of air and spacecraft and related mach.	5.3	**36.8**	26.3	31.6	0.2	19
Other transport equipment	8.0	12.0	28.0	52.0	0.3	25
Furniture	1.3	10.0	18.0	70.7	1.9	150
Other manufacturing	6.4	16.5	24.8	52.3	1.4	109
Repair and installation of machinery and equip	4.4	13.2	17.6	64.7	0.8	68
Energy and water	**17.2**	**43.1**	10.3	29.3	0.7	58
Waste collect., treatment & disposal act.; materials recovery	**14.9**	13.4	16.4	55.2	0.8	67
Construction	**13.8**	18.3	17.9	50.0	3.0	240
Wholesale and retail trade	5.1	9.3	16.9	68.7	6.1	492
Transportation and storage	4.6	13.1	11.5	70.8	1.6	130
Accommodation and food service activities	0.0	0.0	7.3	92.7	0.5	41
Telecommunications	**15.0**	**35.0**	17.5	32.5	0.5	40
Computer programming, consultancy and related act.	9.4	18.4	21.3	50.9	6.4	511
Information service activities	6.6	15.6	19.0	58.8	2.6	211
Financial and insurance activities	2.2	3.9	18.9	75.0	2.2	180
Rental and leasing activities	7.7	3.8	19.2	69.2	0.3	26
Research and development	**32.0**	**35.7**	21.2	11.2	3.3	269
Other professional, scientific and tech. act.	**16.1**	**20.6**	18.4	44.8	7.7	620
Administrative and support service act.	5.0	9.9	12.4	72.7	2.0	161
Education	12.2	14.6	12.2	61.0	0.5	41
Human health and social work activities	11.2	13.2	17.8	57.9	1.9	152
Arts, entertainment and recreation	10.0	10.0	15.0	65.0	0.2	20
Other service activities	**21.3**	13.3	17.3	48.0	0.9	75
Column (%)	9.5	15.4	19.9	55.3	100.0	
No. Of firms	760	1236	1599	4443		8038

All innovative firms of the sample regardless size are included.

Table 4
How important do firms indicate universities to be as an information and knowledge source for technological innovation during the period 2004–2009

	2004		**2005**		**2006**		**2007**		**2008**		**2009**	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
1	703	9.67	932	9.65	832	8.82	834	9.4	812	9.69	760	9.46
2	1,169	16.08	1,470	15.22	1,411	14.96	1,309	14.76	1,303	15.55	1,236	15.38
3	1,403	19.29	1,931	20	1,987	21.07	1,803	20.32	1,727	20.61	1,599	19.89
4	3,997	54.96	5,323	55.13	5,202	55.15	4,925	55.52	4,536	54.14	4,443	55.27
Total	7,272	100	9,656	100	9,432	100	8,871	100	8,378	100	8,038	100

1= High, 2= medium, 3=low, 4=not relevant/ not used.
All innovative firms of the sample regardless size are included.

Table 5
Correlation of the independent and control variables.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Dependent vars.														
(1) Newmarket_sh	1.00													
(2) Patent	0.12	1.00												
(3) Newfirm_sh	-0.08	0.00	1.00											
Univ. vars.														
(4) Coop with U	0.04	0.14	0.00	1.00										
(5) U source info	0.10	0.16	-0.01	0.19	1.00									
(6) Buy R&D servi to Univ	0.04	0.09	0.00	0.07	0.34	1.00								
(7) Employ' edu	0.12	0.07	0.00	0.07	0.17	0.10	1.00							
Controls														
(8) Exports sh.	0.01	0.02	0.01	0.03	0.01	0.00	0.00	1.00						
(9) Group	-0.04	0.05	-0.03	0.24	0.06	0.02	0.02	0.04	1.00					
(10) Engage R&D	0.15	0.19	0.05	0.16	0.24	0.18	0.16	0.02	0.03	1.00				
(11) Intensity	0.04	0.02	0.02	0.01	0.03	0.02	0.05	0.00	-0.02	0.03	1.00			
(12) Spillovers	0.11	0.14	0.03	0.14	0.27	0.10	0.10	0.00	-0.01	0.29	0.02	1.00		
(13) Appropriab	0.13	0.69	0.00	0.12	0.14	0.08	0.08	0.01	0.02	0.20	0.02	0.17	1.00	
(14) Firm size	-0.08	0.05	-0.06	0.21	0.04	0.00	-0.14	0.09	0.47	-0.02	-0.03	-0.01	0.05	1.00
(15) Cost_obsta	0.07	0.05	0.04	0.00	0.08	0.04	0.05	-0.02	-0.18	0.14	0.01	0.14	0.06	-0.23

Number of observations 31804
See Table A2 in the Appendix 1 for the description of the variables.

Table 6
Estimates results: Tobit model

VARIABLES	*The share of sales due product new to the market*		*The share of sales due product new to the firm*	
	Pooled (1)	Panel RE (2)	Pooled (3)	Panel RE (4)
University as a source of info	0.051***	0.036***	-0.014	-0.008
	(0.012)	(0.009)	(0.011)	(0.011)
Cooperation with universities	0.042***	0.035***	0.031***	0.020*
	(0.011)	(0.011)	(0.011)	(0.010)
Employees' education	0.086***	0.062***	-0.003	-0.008
	(0.011)	(0.009)	(0.011)	(0.009)
Buying R&D services to Univ	-0.012	0.008	-0.024	-0.013
	(0.020)	(0.017)	(0.020)	(0.018)
Exports share	0.051	0.033	0.103**	0.085*
	(0.050)	(0.042)	(0.044)	(0.048)
Part of a group	-0.012	-0.002	-0.018*	-0.022**
	(0.011)	(0.009)	(0.011)	(0.010)
Engagement R&D	0.198***	0.150***	0.091***	0.074***
	(0.013)	(0.011)	(0.012)	(0.010)
Innovation intensity	0.139	0.161	0.108	0.069
	(0.145)	(0.297)	(0.119)	(0.270)
Incoming knowledge spillovers	0.123***	0.106***	0.071***	0.043***
	(0.016)	(0.012)	(0.015)	(0.015)
Appropiability	0.076***	0.055***	0.001	0.005
	(0.005)	(0.004)	(0.005)	(0.004)
Constant	-40.571***	-39.588***	-22.683***	-17.425***
	(5.513)	(4.989)	(5.295)	(4.945)
Sigma (constant)	47.577***		50.049***	
	(0.775)		(0.723)	
Sigma_u (constant)		41.786***		42.976***
		(0.781)		(0.916)
sigma_e (constant)		29.293***		31.387***
		(0.519)		(0.445)
Log pseudolikelihood	-61553.672	-65175.241	-80944.071	-77011.272
Left-censored observations	13899	13899	10609	10609
Uncensored observations	9674	9674	12134	12134
Right-censored observations	962	962	1792	1792

Notes: Year effects and industrial dummies are included in all models. See table A2 in the appendix for the description of the variables. Robust standard errors clustered at firm level are shown in parentheses. *,**,*** denote the significance at 90%, 95% and 99%, respectively. Number of observations: 24536. Number of firms: 6134.

Table 7
Estimates results: Tobit pooled, persistence in cooperation with universities.

VARIABLES	***The share of sales due product new to the market*** (1)	***The share of sales due product new to the firm*** (2)
Persistence in cooperation with Univ	0.061***	0.036*
	(0.019)	(0.019)
Employees' education	0.067***	-0.009
	(0.018)	(0.019)
Exports share	0.0474	0.0219
	0.04283	0.0424
Part of a group	-0.922	-1.437
	(1.588)	(1.563)
Engagement R&D	0.198***	0.088***
	(0.020)	(0.019)
Innovation intensity	0.152	-0.118
	(0.307)	(0.358)
Incoming knowledge spillovers	0.092***	0.059**
	(0.024)	(0.025)
Appropiability	0.067***	-0.007
	(0.009)	(0.009)
Constant	-39.440***	-15.107**
	(7.906)	(7.384)
Sigma (_cons)	47.115***	49.206***
	(1.143)	(1.047)
Log pseudolikelihood	-14232.164	-18165.965
Left-censored observations	3422	2557
Uncensored observations	2469	3114
Right-censored observations	243	463

Notes: Data for year 2009. Robust standard errors clustered at firm level are shown in parentheses. *,**,*** denote the significance at 90%, 95% and 99%, respectively. Number of observations: 6134. Industrial dummies are included in all models.

Table 8
Heckman selection innovative firms and effects of University-Industry interactions

	Model 1		Model 2	
	Selec. equation	Outcome	Selec. equation	Outcome
VARIABLES	(1)	(2)	(3)	(4)
University as a source of info		0.035***		0.004
		(0.009)		(0.011)
Cooperation with universities		0.466		-0.262
		(0.817)		(0.908)
Employees' education		0.022**		-0.009
		(0.009)		(0.009)
Buying R&D services to Univ		0.037*		0.018
		(0.019)		(0.018)
Exports share	0.004***	0.036	0.004***	0.008
	(0.002)	(0.023)	(0.002)	(0.029)
Part of a group		-0.020***		-0.013
		(0.007)		(0.009)
Engagement R&D	0.013***	0.106***	0.013***	0.027
	(0.000)	(0.022)	(0.000)	(0.026)
Innovation intensity	-0.001	0.045	-0.001	0.004
	(0.015)	(0.218)	(0.014)	(0.145)
Incoming knowledge spillovers		1.564		1.542
		(1.177)		(1.425)
Firm size	0.079***		0.079***	
	(0.010)		(0.010)	
Cost_obsta	0.141***		0.141***	
	(0.018)		(0.016)	
Info_obsta	0.001		0.001	
	(0.022)		(0.022)	
Mills lambda		8.722**		1.200
		(3.581)		(4.298)
Constant	-0.493***	0.579	-0.493***	12.153***
	(0.141)	(3.752)	(0.170)	(4.339)
Rho	0.34		0.04	
Wald Chi2		454.08		98.59
Observations	8,551	6134	8,551	6134

Notes: The dependent selection variable is one if the firm has introduced an innovation (in products or processes) and zero otherwise (columns 1 and 3). The dependent outcome variable in column 2 is the share of sales due to products new to the market. The dependent outcome variable in column 4 is the share of sales with significantly improved products or products new to the firm. See table A2 in the appendix for the description of the variables. Industrial dummies are included in all models. Robust standard errors clustered at firm level are shown in parentheses. *,**,*** denote the significance at 90%, 95% and 99%, respectively.

Table 9
Estimates results: Tobit pooled model, regressors related with university role in innovation are referred to t-4

VARIABLES	*The share of sales due product new to the market* (1)	*The share of sales due product new to the firm* (2)
University as a source of info $_{t-4}$	0.033*	0.028
	(0.018)	(0.018)
Cooperation with universities $_{t-4}$	0.036**	0.033*
	(0.018)	(0.018)
Employees' education $_{t-4}$	0.067***	-0.004
	(0.019)	(0.019)
Buying R&D services to Univ $_{t-4}$	0.011	0.010
	(0.033)	(0.032)
Exports share	0.061	-0.004
	(0.047)	(0.048)
Part of a group	-0.989	-0.517
	(1.610)	(1.592)
Engagement R&D	0.183***	0.076***
	(0.020)	(0.020)
Innovation intensity	0.108	-0.144
	(0.292)	(0.351)
Incoming knowledge spillovers	0.081***	0.036
	(0.025)	(0.026)
Appropiability	0.068***	-0.013
	(0.009)	(0.009)
Constant	-38.615***	-15.690**
	(8.114)	(7.770)
Sigma	45.955***	47.940***
	(1.131)	(1.043)
Left-censored observations	3304	2434
Uncensored observations	2587	3225
Right-censored observations	243	466
Log pseudolikelihood	-12917.16	-15932.236

Notes: Data for year 2009. Robust standard errors clustered at firm level are shown in parentheses. *,**,*** denote the significance at 90%, 95% and 99%, respectively. Number of observations: 6134. Industrial dummies are included in all models.

Table 10
Estimation results: Probit models. Dependent variable is patent application

	Pooled (1)	Panel RE (2)	Selection Equation (3)	outcome (4)
University as a source of info	0.4951***	0.3798***		0.1485**
	(0.0618)	(0.064)		(0.0488)
Cooperation with universities	0.5029***	0.4736***		0.2704***
	(0.0592)	(0.0669)		(0.0521)
Employees' education	0.2634***	0.2513***		0.1821***
	(0.0646)	(0.0702)		(0.0513)
Buying R&D services to Univ	0.0023*	0.002		0.0019*
	(0.001)	(0.0012)		(0.0009)
Exports share	0.0002	0.0002	0.0012	0.0042**
	(0.0002)	(0.0002)	(0.0022)	(0.0013)
Part of a group	0.177**	0.2209**	0.0366	0.0734
	(0.0597)	(0.0722)	(0.0618)	(0.0458)
Engagement R&D	1.2067***	1.0568***	0.3507***	0.6039***
	(0.0846)	(0.0902)	(0.0648)	(0.0606)
Innovation intensity	0.0017	0.0023	0.0003	0.0034
	(0.0029)	(0.0037)	(0.0099)	(0.0055)
Incoming knowledge spillovers	0.4744***	0.4192***	0.5904***	0.1306
	(0.0832)	(0.0812)	(0.1031)	(0.086)
Firm size			0.0892***	
			(0.0165)	
Info_obsta			0.0105	
			(0.0262)	
Constant	-4.231	-5.0379	1.2123***	-1.9617***
	(0.3013)	(0.3992)	(0.1068)	(0.128)
Athrho _cons			-0.9858***	
			(0.259)	
Sigma U		2.1777		
		(0.0642)		
Rho		0.8259		
		(0.0085)		
Contant lnsig2u		1.5566***		
		(0.059)		
Time dummies	Yes	Yes	No	No
Observations	26693	26693	8860	6134
Number of groups	8551	8551	8860	6134
Wald chi2	1218.13		820.98	
Log pseudolikelihood	-9396.1276	-7053.9432	-3530.385	

Notes: In column 3, the dependent selection variable is one if the firm has introduced an innovation (in products or processes) and zero otherwise. In column 4, the outcome dependent variable is patent application. Robust standard errors clustered at firm level are shown in parentheses. *,**,*** denote the significance at 90%, 95% and 99%, respectively. Industrial dummies are included in all models. Selection model is done with data for 2009. Athrho _cons stands for the correlation coefficient between the errors of the sample selection and pobit equations.

Appendix

Table A1
Summarize empirical studies

Authors	Dependent variable	Model and data	Significant effect of cooperation with universities?
Miotti and Sachwald (2003)	Patenting and the share of innovative products in turnover	Logit	Yes
Monjon and Waelbroeck (2003)	Binary variable: 1 if firm does formal collaboration with university, 0 otherwise.	Probit. French CIS.	Yes
Belderbos, R et al (2004)	1) Sales with market novelties per employee 2) Labour productivity	Ordinary Least Squares. Dutch CIS	1) Yes 2) Yes
Cassiman and Veugelers (2006)	Percentage of total sales derived from new or substantially improved products	Multinomial Logit	Yes
Aschhoff, B. and Schmidt, T. (2008)	Share of turnover from market novelties 1) the reduction of the average costs for a company due to new or significantly improved processes introduced , 2) the share of sales with significantly improved products or products new to the firm (but not new to the market) 3) the share of sales due to market novelties.	Tobit. Mannheim Innovation Panel	Yes
Lööf, H., and Broström, A. (2008)	1) Share of sales of new products per employee 2) Probability of firms applying for a patent	Several estimators	Yes
Arvanitis and Woerter (2009)	1) Firm files patent applications (yes/no) 2) Logarithm of the share of new products on total sales	Cluster-analysis Probit regression	1) Yes 2) Yes
Spithoven et al. (2010)	Innovative revenue	OLS, 2SLS, ML.	Yes
(Bishop et al., 2011)	A set of dummies which assess the effects in terms of: 1. 'Improve understanding of foundations of particular phenomena'; 2. 'Source of information suggesting new projects'; 3. 'Generation of patents (in products or processes)'; 4. 'Assistance in problem solving'; 5. 'Recruitment of university postgraduates'; 6. 'Training of company personnel by university researchers'; 7. 'Contribution to the successful market introduction of new products/processes'; 8. 'Cost reduction in product or process development' and 9. 'Reducing the time required for completion of company's R&D projects'.	Probit and multivariate probit regressions	

Table A2
Variables' description

Variable	Type	Construction
Dependent variables		
Newfirm_share		The share of sales with significantly improved products or products new to the firm (but not new to the market).
Newmarket_share		The share of sales with products new both for the firm and the market).
Patent	Binary	One if the firm stated it had applied for at least one patent to protect inventions; otherwise its value is 0.
Explanatory variables		
Uni_source	Binary	One if firm stated that information from universities had high or medium importance in the innovation activities, and 0 otherwise.
Uni_coop	Binary	1 if the business unit has reported engagement in innovation in cooperation strategy with universities.
Employees' education	Binary	One, if the firm has a share of employees with higher education above the average of the sample (0.27).
R&D services from universities		The amount of R&D services bought to universities.
Persistence in cooperation with Univ		One, if firm has cooperated with universities in t-2 and t-4, and 0 otherwise.
Controls		
Firm size	Log	Logarithm of the number of employees.
Exports share	Share	Total exports as a percentage of total turnover
Part of a group	Binary	One, if the firm belongs to a domestic group of firms.
Engagement R&D	Binary	One, if the firm had any R&D activities between 1998 and 2000.
Innovation intensity	Share	Total expenditure on innovation activities as a percentage of total turnover.
Incoming knowledge spillovers	Categorical	Sum of importance (number between 0 (not used) and 3 (high)) of professional conferences, meetings and journals and of exhibitions and trade fairs as sources of innovation; rescaled between 0 (no spillovers) and 1 (maximum spillovers).
Appropriability	Categorical	Sum of the number of strategic and formal protection methods for innovations (secrecy, complexity of design, lead-time advantage, patents, copyrights, trademarks, registered designs); rescaled between 0 and 1.
Obstacle: costs Cost_obsta	Categorical	Sum of the scores for the following obstacles to innovation: lack of internal funds; lack of external funds; very high innovation costs; and demand uncertainty. Rescaled between 0 (not relevant) and 1 (highly relevant).
Obstacle: information Info_obsta	Categorical	Sum of the scores for the following obstacles to innovation: lack of qualified personnel; lack of information on technology; lack of information on markets; problems to find partners. Rescaled between 0 (not relevant) and 1 (highly relevant).

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Chapter 5

Concluding remarks and future research

This dissertation consists of three essays related to the relationship between higher education institutions and economic development. Chapter 2 focuses on the effects that the founding of a university has on the location decision of firms in a region. Chapter 3 examines the contribution of the universities to the creation of human capital by analyzing the determinants of graduation rates, while Chapter 4 investigates the effects of university-industry interactions. Finally, this chapter provides a general overview of the results of this dissertation. Some policy implications are derived and a future research agenda is drawn.

Chapter 2 carries out an analysis on the effects that the presence of a university has on creating new firms in a region. Based on a study of the impact of Spain's 1983 University Reform Act (LRU), which opened the door to the founding of new universities and faculties expanding the regional network of HEIs, this chapter examines whether university (or faculty) location affects the creation of new firms within a given province. In order to disentangle the specific effect, variables usually taken into account in studies of firm location such as market potential, population size, and specialization index are also introduced. A difference-in-differences approach is adopted, which enables us to avoid the endogeneity problems.

The first finding is that founding a university has an important effect on firms' location decision. In order to analyse the effect across industries by level of technology, the sample is split into three industrial groups; high (HT), medium (MT), and low tech (LT).

The founding of a university does not have any effect on the creation of new firms in the HT and MT sectors. However, it does have a statistically significant effect on creating new firms in the LT sector. This is consistent with industrial specialization of the Spanish economy during the period of analysis, markedly influenced by the democratic transition and the country joining the European integration process. Somehow, our results indicate a moderate presence of universities-industry links, as a mechanism for reinforcing competitive advantages of the Spanish economy and its regions.

In addition, the kind of faculty founded matters when analysing the effect of universities on the creation of firms. Three types of academic fields are taken into account: science, health, and social sciences. The results suggest that founding science and social science faculties has had a marked impact on the creation of firms. However, creating a faculty of health does not have any effect on the firms' location decision. Moreover, when the sample is split according to technological level of industries, the results indicate that firstly, founding a social science faculty has a statistically significant effect on the creation of new firms in MT and LT sectors. Secondly, founding a science faculty has a similar effect on LT sectors.

Combining these results tell the following story. Firstly, although it is expected that the main contribution from universities takes place on HT or MT sectors, the findings for the Spanish case in the 80's do not confirm this expectation. The reason is in that decade, new universities were established in regions that had an economic structure based on traditional sectors. The presence of HT firms was very scarce in those regions, and, therefore, it is not possible to capture any effect that founding a university may have had on the creation of HT firms. Secondly, the fact that founding a university has a statistically significant effect on creating firms in LT sectors tells us that universities fit very well with the productive structure of the regions and offer firms good support in terms of knowledge and capabilities that they demand.

There is empirical evidence to suggest that creating human capital is the main channel through which universities influence economic development. Chapter 3 investigates the contribution of universities by examining the determinants of one of the most frequently applied measures of institutional performance: graduation rates. In addition, educational attainment is one of the areas through which universities can see productivity increases. Chapter 3 helps further our understanding of the ways in which institutional features can affect university outcomes. A dataset is assembled for the entire public university system in Spain over the last decade. A panel model is adopted in order to better control for unobserved university characteristics. By observing the same university over time, we can determine the factors that make a university permanently more productive in terms of the number of graduates.

The main findings that can be drawn from the results of Chapter 3 are that university features such as expenditure, student-teacher ratio and financial-aid to students are important in accounting for graduation rates. Furthermore, the analysis also shows that the performance of university research is important. Indeed, there would seem to be a complementarity effect between university activities of teaching and research. On the contrary, factors such as tuition fees and student ability do not have any effect on graduation rates in Spain.

In addition, achieving a higher level of education in fewer years and/or enhancing graduation rates have financial implications for universities. The results from Chapter 3 reveal some key aspects that helped shape a university policy to enhance graduation rates. Hence, three policy implications can be derived. Firstly, it is shown that pupil-teacher ratio is the most important factor in achieving better levels of graduation rates. Secondly, universities with low graduation rates –specifically, those universities belonging to the 20^{th} and 40^{th} quantiles of the distribution – can enhance them through increases on expenditure per student. However, there is a threshold from which any increase in graduation rates cannot be achieved through higher expenditures. Finally, graduation rates can also be enhanced through a policy that deepens financial support to students. Indeed, it is shown that universities with a higher share of students with financial support from Ministry of Education have higher graduation rates.

Chapter 4 analyses the effects of university–industry links on the firms' innovative performance. In most countries, government policy promotes both research excellence in the university sector and its translation into economic benefits through university–business engagement. This is supported by the argument that university–industry links facilitate the transmission of knowledge between academics and industry scientists, thus contributing to improved national innovation performance. Hence, the relevance of universities is expressed when they connect and engage with partners without any constraints, i.e. institutional, sector, disciplinary, or geographical. In the case of government financial cuts, this link becomes an invaluable innovation strategy because universities are forced to generate new revenues from whatever other sources they can.

Much public sector investment in university research has taken place on the basis that there is long-term potential for knowledge spillovers from universities to business and that it may positively impact on innovation, productivity and economic growth. Indeed, much of the public investment in university research is designed to have a strong public good element. By its very nature, it should disseminate into the private sector at low or zero marginal cost and be used for economically significant innovations and/or productivity gains (Hewitt-Dundas, 2011) .

Chapter 4 assesses the different ways through which universities positively affect the innovative output of firms i.e. creators of human capital, providers of research findings, partners in R&D projects, and suppliers of R&D services. The effects of University-Industry Interactions were subsequently estimated to capture innovation dimensions and distinct levels of complexity. The three measures used were 1) the share of sales with significantly improved products or products new to the firm but not new to the market, 2) the share of sales due to products new both for the firm and the market, and 3) patent applications.

Four mechanisms are analysed through which universities can influence industrial innovation: universities as a: 1) source of information and knowledge, 2) partner of cooperation, 3) supplier of highly skilled workers, and 4) supplier of R&D services. The results from Chapter 4 strongly support the view that universities enhance firms' innovative performance through those mechanisms.

These results further suggest that the contribution of universities is very helpful in terms of getting new products to market and for generating patents, while it is less important for conducting innovations new to the firm. Thus, the University-Industry relationship tends to focus on the type of interactions that potentially have the highest value in terms of incoming knowledge, and tends to be related directly to the introduction of higher-level innovations, as in the results for patent applications.

An implication of the findings of Chapter 4 is that there are opportunities to enhance innovation by strengthening the links among funding sources and universities as performers. In particular, one of the most evident disconnections is that only 8% of university research that is funded by industry, a very small fraction. This marked imbalance suggests that there is much room for growth and a necessary next step in enhancing innovation.

A future research agenda in this field should answer the following questions. Firstly, what structural changes are required in a large traditional university to build the capability for industry-focused multidisciplinary research? Secondly, once that capability has been established what institutional structures are required to transform academic behaviour, incentive structures, resource allocation and recruitment?

Also, a better understanding on the way in which technical change itself is transforming the 'production of knowledge' should be obtained. New organisational forms for interacting and developing knowledge and innovations are developing due to the presence of new information technologies. These new forms of interacting influence the ways in which education may be organised and how research will be done in the future. Indeed, digitisation not only facilitates global communication and the provision of teaching services, it also makes it possible to run business and comparative international research experiments much more cheaply, share observations, and, from a business perspective, to scale up innovations faster and with more accuracy (Brynjolfsson and McAfee, 2011).

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