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Article

A resource-based view of university spin-off activity: New evidence from the Spanish case

David Rodeiro Pazos*, Sara Fernández López, Luís Otero González, Alfonso Rodríguez Sandiás

Departamento de Economía Financiera y Contabilidad, Facultad de Ciencias Económicas y Empresariales, Universidade de Santiago de Compostela, 15782-Santiago de Compostela, Spain

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ABSTRACT

Universities now play a major role in regional economic and social development. This new mission is transforming the traditional university into an entrepreneurial university. This entrepreneurial activity has mainly been carried out by transferring technology to industry; in particular by creating spin-off firms. Drawing on a resource-based view, the objective of this paper is to understand why some Spanish universities are more successful than others at generating spin-offs. In order to determine the factors that influence the spin-off activity, we used a balanced panel comprising all 47 Spanish Public Universities using information that is biannually available between 2002 and 2006. The results showed that university spin-offs are significantly positively associated with industry-funded research, the tradition of the university spin-off activity, the research orientation, and the existence of incubation services in the university. Furthermore, we also found some unexpected results which highlight some peculiarities of Spain and other countries with little tradition in university entrepreneurial activity, such as the absence of the effect of a Technology Transfer Office (TTO) on spin-off production.

This study contributes to the literature on university spin-off activity. First, there are no similar empirical studies about Spanish universities. Second, we set out several policies to improve the dissemination of scientific knowledge and technology transfer activities.

Una aplicación de la teoría de los recursos a la creación de spin-offs universitarias: nuevas evidencias desde el caso español

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RESUMEN

Actualmente las universidades son uno de los agentes responsables del desarrollo económico y social de las regiones. Esta nueva misión ha transformado la universidad tradicional en una universidad emprendedora. Esta actividad emprendedora se ha llevado a cabo principalmente mediante la transferencia de tecnología a la industria, en particular mediante la creación de spin-offs. Partiendo del enfoque de la teoría de los recursos, el objetivo de este trabajo es entender por qué algunas universidades españolas tienen más éxito que otras en la creación de spin-offs. Con el fin de determinar los factores que influyen en la generación de estas empresas, se utilizó un panel que comprende 47 Universidades Públicas Españolas con información bianual de cada una entre el año 2002 y el 2006. Los resultados muestran que la creación de spin-offs mantiene una relación positiva con la investigación financiada por el sector privado, la antigüedad de la universidad en este tipo de actividades, la orientación de la investigación y la existencia de servicios de incubación en la universidad. Adicionalmente, han surgido algunos resultados inesperados y que ponen de manifiesto algunas particularidades de España y de otros países con menos tradición en emprendimiento universitario, tales como la ausencia de un efecto de las OTRIs en la generación de spin-offs.

Este trabajo contribuye a la literatura sobre creación de spin-offs universitarias ya que no existen estudios similares de carácter empírico sobre las universidades españolas, y en el mismo se proponen una serie de políticas para mejorar la difusión del conocimiento científico y la transferencia de tecnología.

* Corresponding author.
E-mail address: david.rodeiro@usc.es (D. Rodeiro Pazos).

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Introduction

The external environment in which universities carry out their activities has changed substantially in the last century. A historical milestone was the publishing of Bush's report in 1945. *Science. The Endless Frontier* has shaped science policy of the U.S. and most of the OECD countries for more than six decades. The fundamental principle of Bush's report was simple: basic research discoveries will be converted via technology transfer to become powerful drivers of economic development and social welfare.

More recently, as a consequence of a set of reforms targeted to improve the transfer of research results to industry, a reconceptualization of the universities' role started during the 1980s. In the U.S., Bayh-Dole Act allowed universities to own patents resulting from federal research money. Starting from early 1990s, structural changes in the external environment of European universities pushed them for a more proactive role in technology transfer, too (Baldini, Grimaldi, & Sobrero, 2006; Rasmussen, Moen, & Gulbrandsen, 2006; Siegel, Veugelers, & Wright, 2007). As a result, universities currently have to meet the social and economic needs of society. Therefore, the mission of universities is no longer limited to research and training (Etzkowitz, Webster, Gebhardt, & Terra, 2000); in addition, they are also expected to contribute to local economic development (the "third" mission). This objective is not entirely altruistic; the university's financial situation improves as it contributes to the economic development. The new University emerged from the "second revolution" has been labelled "the entrepreneurial University" (Etzkowitz et al., 2000).

There are a very wide range of university–industry interactions which may contribute to carry out this entrepreneurial activity (Agrawal & Henderson, 2002; Cosh, Hughes, & Lester, 2006; Hughes, 2007; Lester, 2005): informal contacts, recruitment of graduates, use of publications, collaborative research, faculty consulting, attending conferences, patenting and licensing, and new business formation around university science and technology (spin-offs).

Although founding a new company is only one of a number of mechanisms for the transfer of knowledge from universities to industry, this choice as an instrument for transferring university knowledge and fostering local economic growth has been growing in importance. In fact, recent decades have seen a increasing number of companies stemming from university-developed technology. This phenomenon is more evident in the U.S. (Carayannis, Rogers, Kurihara, & Allbritton, 1998; Degroof & Roberts, 2004) and in some European countries such as the U.K. (Lockett, Wright, & Franklin, 2003; Shane, 2004) or Sweden (Stankiewicz, 1994).

However, several recent studies have suggested that spin-offs are not the most useful of the available pathways for the transfer of knowledge from universities to industry, even in the countries where this phenomenon is more extended. In general, academic spin-off firms tend to remain relatively small and fail to grow. Some studies show that academic spin-offs tend to stay small (Zhang, 2009) and to grow less than other high-technology start-ups (Ensley & Hmieleski, 2005). In the European Union (EU) most of the spin-offs are not larger than 10 employees after 6 years of existence (Van Geenhuizen & Soetanto, 2009). Thus, according to Lester (2005), spin-offs is a very small fraction (2–3%) of the total rate of new business starts in the U.S. In addition, Hughes (2007) suggests that there is an overemphasis on spin-offs, which may lead decision makers to misunderstand the nature of the technology transfer model.

Therefore, the number of studies focused on university spin-off activity has rapidly expanded as a result of the growing number of spin-offs rather of their economic impact or sustainability. Until the late 1990s, this literature was rather fragmented (Rothaermel, Agung, & Jiang, 2006) and primarily atheoretical and based on case studies (Djokovic & Souitaris, 2004). However, in the 2000s this approach has radically changed with the publication of several quantitative studies which attempt to explain the influence of the university's characteristics on the number of new firms created (see Table 1).

In Spain, the university system has traditionally been an example of a fully and highly centralized governance structure. After the restoration of democracy, the major change was introduced by the University Reform Act (1983). This increased the universities' administrative autonomy and transferred the responsibility for universities to the seventeen regional governments, which have had to take care of them in financial and organizational matters.

Despite these legal changes, Spanish universities have been characterized by a short tradition of ties with industry. In 1986, the *Law of Promotion & General Coordination of Scientific & Technical Research* (*Law of Science*) designed a new scientific and technological policy in order to face certain deficiencies of the national research system. Later, in 1988, the Government established the universities' Technology Transfer Offices (TTOs) to support and promote the dissemination of scientific knowledge and technology transfer activities.

Twenty years later, Spanish universities have substantially improved their contribution to the national research system by increasing the activities related to the commercial exploitation of knowledge. For instance, they created about 143 spin-offs in 2006. The research contracts have increased considerably in recent years, growing from 100 million Euros in 1996 to 428 million Euros in 2006. The requests of patents made in the Spanish University System have growth from the 282 requests in 2000 to 572 in 2006. The TTOs have also played an important role in this process by managing about the 98% of the knowledge protection in the Spanish universities (Office of Technology Transfer, 2007). Despite the efforts being made, this performance reflects the fact that the Spanish universities are not acting in a sufficiently proactive manner.

The objective of this paper is to understand why some Spanish universities are more successful than others at creating spin-offs. This analysis offers interesting opportunities for a better understanding of the universities' spin-off activity in countries such as Spain, where universities have been characterized by a short tradition of ties with industry and the technology transfer model presents important institutional differences with the Anglo-Saxon model. First, cooperation between industry and universities is still not sufficiently developed. Second, fundraising to bring new inventions to market is more difficult in Spain than it is in the U.S. Third, the high level of bureaucracy in the universities and their aversion to risk partially explain the low level of involvement of several universities in the process of the creation of companies (Fundación CYD, 2009).

This paper is organized as follows. The 'Theoretical development' section describes the theoretical background of the models and the hypotheses. In the 'Methodology' section the methodology is explained. In the 'Empirical results' section the empirical results are presented. In the 'Conclusions and implications' section, we conclude by summarizing the most important findings, discussing several implications for policy-makers, introducing the potential limitations of the research and discussing areas for further research.

Theoretical development

The literature on university spin-off activity has rapidly expanded in recent years. The creation of academic spin-offs is a multidimensional phenomenon, being conditioned by a wide range of institutional factors, social and legal (Gómez, Mira, Verdú, & Sancho, 2007). O'Shea, Chugh, and Allen (2008) suggest that the existing literature on this topic can be categorized into six separate

Table 1
Summary of empirical research.

Authors	No.	Country (period)	Econometric models	Main results	Type
Resource-based theory					
Lockett et al. (2003)	57	United Kingdom (1994–1998)	Mann–Whitney test	TTO (+)	Com.
				Networks (+)	Hum.
				When the company was formed the university had not equity stake (−)	Fin.
				When the company was formed the academic-inventor had up to a 20% equity stake (+)	Fin.
Lockett et al. (2004)	48	United Kingdom (2001–2002)	Poisson	Research expenditure (+)	Inst.
			Negative binomial	Expenditure on external intellectual property advice (+)	Inst.
				TTO experience (+)	Com.
				Business development capabilities of TTO members (+)	Com.
Lockett and Wright (2005)	48	United Kingdom (2001–2002)	Poisson	Expenditure on external intellectual property advice (+)	Inst.
			Negative binomial	Business development capabilities of TTO members (+)	Com.
				Royalties (−)	Inst.
O'Shea et al. (2005)	141	United States (1980–2001)	Negative binomial	Previous spin-off counts (+)	Inst.
				Faculty quality index (+)	Hum.
				Percentage of total R&D revenues that derive from industry (+)	Inst.
				Total amount of the science and engineering budget (+)	Inst.
				Number of TTO members (+)	Com.
Powers and McDougall (2005)	120	United States (1991–2000)	Negative binomial	Industry R&D funding (+)	Inst.
				Availability of venture capital in each university's geographical area (+)	Fin.
				TTO experience (+)	Com.
				Faculty quality (+)	Hum.
Vinig and Van Rijsbergen (2010)	124	United States, Europe and Australian (2006–2007)	Pearson's bivariate correlation	Faculty quality index (+)	Inst.
				Number of TTO members (+)	Com.
				Business incubator (+)	Com.
				Science park (+)	Com.

Source: own.
Note: (+) Positive/negative relationship.
Types of resources: Inst: institutional; Hum: human capital; Fin: financial; Com: commercial resources.

streams: four of them study the determinants of spin-off activity within a university context and the two remaining research groups focus on the consequences of spin-off activity. As the aim of this paper is to investigate the determinants of the creation of spin-off companies by the Spanish universities, we revise the papers which analyze the effect of the university's resources on spin-off activity. Most of these empirical studies adopt a resource-based view perspective (Table 1).

This theory describes companies as bundle of resources (Penrose, 1959) and provides a key role to inter-organizational differences with respect to resources and capabilities as well as their impact on firm behavior and performance (Lockett & Wright, 2005). In this framework, organizations such as universities differ from one another because of the resources and capabilities possessed at a particular time (Penrose, 1959; Wernerfelt, 1995), affecting their future performance. Such a perspective suggests that the likelihood of spin-offs production will increase when either the resources or their mobilization will be appropriate or sufficient (Landry, Rherrad, & Amara, 2005).

In this paper, we mainly draw on the resource-based theory of the firm and categorize four types of resources: institutional, human capital, financial and commercial resources (O'Shea, Allen, Chevalier, & Roche, 2005; Wernerfelt, 1995). A model based on analysis of resources and capabilities can provide a useful result for the generation of a series of recommendations for those agents involved in the creation of spin-offs. Moreover, the results can be used as a framework to develop programs dedicated to supporting the creation of technology-based companies and therefore innovation (Merino & Villar, 2007). Besides the papers listed in Table 1, there are other empirical research with a different approach and methodology which may indirectly contribute to detecting university factors in the spin-offs creation (Caldera & Debande, 2010; Clarysse, Wright, Lockett, Van de Elde, & Vohora, 2005; Degroof & Roberts, 2004; Siegel, Waldman, Atwater, & Link, 2003; Vohora, Wright, & Lockett, 2004). Thus, their findings have also been considered when developing our hypotheses.

Institutional resources

Blundell, Griffith, and Van Reenen (1995) suggest that a key explanation for the source of unobserved heterogeneity of innovation activity amongst firms lies in the different past knowledge stocks that reside within them. In the case of the universities, several studies showed that experience in the commercialization of technology and spin-off creation has a positive influence on the number of spin-offs generated by a university (Lockett, Wright, & Vohora, 2004; O'Shea, Allen, Chevalier, & Roche, 2005; Powers & McDougall, 2005), making spin-off activity a path-dependent process. According to this perspective, knowledge accumulation from the past generates benefits in the university's future ability to produce spin-offs.

H1. There is a positive relationship between the tradition and history of the university spin-off activity and the creation of university spin-offs.

Shane (2001) demonstrated that the tendency for an invention to be exploited through firm creation depends on the attributes of technology regime in which it is found. For instance, the age of the technical field, the tendency of the market toward segmentation, the effectiveness of patents, and the importance of complementary assets in marketing and distribution are favorable market preconditions for technology transfer to occur successfully. As a result, some scientific disciplines may show a greater trend to generate spin-off companies.

Although this aspect has not been addressed in the majority of the previous empirical papers reported in Table 1, some studies indicate that the nature of university research plays a key role in spin-off activity. For example, Golub (2003) reports that half of all spin-off companies that emerged from Columbia University derived from biomedical research while the remainder came from the electronics and software field. Similarly, Shane (2004) showed that the majority of MIT spin-off firms operated in the biomedical industry. In addition, Landry et al. (2005) found that the size of research funding in engineering was significantly related to the likelihood of ending up in a transfer of technology. O'Shea et al. (2005) also found that the universities that receive a greater proportion of their research funding within the life sciences, chemistry and computer science disciplines have a greater propensity to generate spin-off companies. These results support the idea that some scientific disciplines are more effective than others at generating spin-offs. Particularly, the stronger patent protection in life sciences as well as the relatively newness of the biomedical research lead us to consider that life sciences may show a greater trend to generate spin-off companies. Similarly, engineering is closer to applied research questions and industry, which leads it naturally to the commercial exploitation of research findings.

H2. There is a positive relationship between disciplines with a greater market orientation, namely life sciences and engineering, and the creation of university spin-offs.

Human capital

Leading researchers tend to have a greater academic and research activity as well as a greater propensity to create companies to capture the rents generated by their intellectual capital (Di Gregorio & Shane, 2003; O'Shea et al., 2005; Powers & McDougall, 2005; Zucker, Darby, & Brewer, 1998). In addition, researchers' prestige can also be helpful in obtaining funds to exploit untested technologies by increasing the entrepreneur's credibility (Di Gregorio & Shane, 2003) and reducing information asymmetry problems (Heirman & Clarysse, 2004). The results of (Vinig & Van Rijsbergen, 2010) and (Grandi & Grimaldi, 2003) suggest that more spin-offs are formed when there is scientific excellence. Grass, Galiana, Mira, Verdú, and Sancho (2008) used a construct based on data on the number of professors and the number of university SCI-covered publications in order to measure the excellence of academic staff, and concluded that exist a strong association between this variable and the start-up activity of universities.

H3. There is a positive relationship between the research quality of the academic staff and the creation of university spin-offs.

Financial resources

The traditional view claims that research is a prior step to technology transfer (Declercq, 1981); the higher the university's research activity, the higher the stock of technology for commercialization. Such stock of technology is directly related to the university's research funding. Thus, several studies showed that the volume of research funding has a positive effect on the university spin-off activity (Lockett et al., 2004; Lockett & Wright, 2005; Link & Scott, 2005; Van Looy, Landoni, Callaert, van Pottelsberghe, Sapsalis, & Debackere, 2011).

H4. There is a positive relationship between the amount of the university's total research funding and the creation of university spin-offs.

University–industry ties and closer partnerships with industry result in greater levels of commercialization (O'Shea et al., 2005), because the universities which have a long tradition of ties with industry tend to obtain a larger amount of industry-funded research. Such research tends to focus on solving problems or discovering technologies that have sufficient commercial value for inventors to create companies. In addition, industry-funded research tends to suffer from lesser information asymmetry problems than does government-funded research, making it more likely that entrepreneurs will be able to finance firms to commercialize industry-funded research than government-funded research (Di Gregorio & Shane, 2003). Blumenthal, Campbell, Causino, and Louis (1996) surveyed 2052 academics at 50 universities in the life sciences and found that industry funded academics are more commercially productive than those who are not industry funded. Di Gregorio and Shane (2003), O'Shea et al. (2005) and Powers and McDougall (2005) also found a positive and statistically significant relationship between the amount of industry-funded research and spin-off activity.

H5. There is a positive relationship between the amount of industry-funded research and the creation of university spin-offs.

In addition, financial resources play a crucial role in the early stages of a spin-off company, when funds are required to develop business plans, prototypes or market research (Carayannis et al., 1998; Vohora et al., 2004). Some parent universities offer funding to the spin-off firms in these stages. Such financing may have a positive signalling effect to the private sector because the ventures would have had access to initial money, which could be additionally interpreted as a signal of the firm's growth potential by external investors, mitigating the problems of information asymmetry (Alemany, 2004). Moreover, in the European universities, Grass et al. (2008) suggest that university financial support may be critical for the development of new spin-offs, due to the lack of investment sources such as external venture capital and business angels. In the Spanish case universities that facilitate researchers' access to risk capital have a higher rate of creation of spin-offs (Caldera & Debande, 2010).

H6. There is a positive relationship between the financial support of the university and the creation of university spin-offs.

Commercial resources

The TTO's mission is to promote relations between academic community and industry. This role is important especially in countries such as Spain, where universities have been characterized by a short tradition of ties with industry. In particular, TTO staff may be a key resource in promoting spin-off activity. Firstly, TTO personnel are often the best placed individuals for detecting commercialization opportunities among the university's lines of research. On many occasions, the inventor is not the best individual for recognizing a business opportunity; the TTO staff tend to have a better knowledge of the state of technology and possible marketability (Lockett et al., 2003). In addition, as university

insiders, TTO staff maintain closer ties with academics than outsiders (Lockett & Wright, 2005). Secondly, TTO personnel also provide company formation expertise for academics (evaluating markets, writing business plans, raising funds, etc.) (Chugh, 2004). Thirdly, once the decision has been made, the members of TTO help academics to manage the spin-off process and develop business skills. Thus, empirical literature found that both the number of TTO staff (Caldera & Debande, 2010; Grass et al., 2008; O'Shea et al., 2005; Van Looy et al., 2011; Vinig & Van Rijsbergen, 2010) and their skills (Lockett & Wright, 2005; Lockett et al., 2004), have a positive influence on the number of spin-offs.

H7. There is a positive relationship between the TTO stock of human resources and the creation of university spin-offs.

According to Mian (1996), an alternative measure of commercial resources is the availability of incubation services in the university which provide spin-offs with a series of advantages: (a) faster growth by helping firms to overcome technical, management, and market barriers (Jensen & Thursby, 2001); (b) development of business skills by providing company formation expertise; (c) continuous interaction with industry (Siegel et al., 2003). Moreover, firms located within university incubators reduce set-up costs by sharing general administrative costs. As a consequence, the availability of incubation services in the university facilitates the spin-off activity (Link & Scott, 2005; Montañez, 2006; Tornatzky, Batts, McCrae, Lewis, & Quittman, 1996; Vinig & Van Rijsbergen, 2010). Findings of Caldera and Debande (2010) suggest that the "incubating role" of university science parks increases the rate of creation of new firms through a reduction in start-up costs.

H8. There is a positive relationship between the existence of incubation services in the university and the creation of university spin-offs.

Methodology

The sample

The information for this study has been obtained from several sources. Firstly, *The Spanish University in Numbers*, a report published biannually by the CRUE (Association of Spanish University Presidents) which gathers information on funding and staffing. Secondly, we also obtained information through the database of the Network OTRI of the Universities. The Network OTRI annually surveys the university TTOs to collect information pertaining to patenting, licensing, and spin-off activity, as well as information on funding, staffing and incubation services. Thirdly, to gather information on university research quality, we utilized the information provided by the Institute of Documentary Studies on Science and Technology (Instituto de Estudios Documentales sobre Ciencia y Tecnología—IEDCYT), an agency who belongs to the Spanish National Research Council (Consejo Superior de Investigaciones Científicas—CSIC). The IEDCYT possesses different bibliographic databases covering the Spanish scientific production published from the 70s up to date. They mostly include articles from scientific journals, but also a selection of congress and conference proceedings, reports and monographies. Lastly, we obtained the percentage of regional GNP spent on R&D by consulting the on-line database of the National Statistics Institute.

The sample of the present study is made up of all 47 Spanish Public On-Campus Universities (SPOUs) between 2002 and 2006. As in Spain neither private universities nor open universities tend to have spin-off activity, the study includes practically 100% of the spin-off activity in the Spanish University System. As a result, we have constructed a balanced panel comprising 47 universities for which the information is biannually available between 2002 and 2006.

Definition and measurements of variables

Dependent variable

As a measure of the university spin-off activity, we use the number of university spin-offs created in a given year (SPINOFFS).

Independent variables

As independent variables we have selected a set of factors which may determine university spin-off activity.

Institutional resources. In order to test the dependence on history hypothesis we consider the number of spin-offs generated before the analyzed years as a proxy for past knowledge accumulation activities (PASTUSOS), similarly to Blundell et al. (1995) and O'Shea et al. (2005).

To determine the influence that research in disciplines with a greater market orientation may have on the spin-off activity, we use the percentage of dissertations in the engineering and life sciences (%D_ENG_LIFE).

Human capital. Measuring the research quality of the academic staff is always controversial.[1] In the present study we consider two measures. Similarly to O'Shea et al. (2005), we use the proportion of the academics with a PhD (%PHD_ACAD). According to Landry et al. (2005), Powers and McDougall (2005) and (Vinig & Van Rijsbergen, 2010) we also use the number of publications by PhD academic (NPUB_PHD).

Financial resources. There is lack of consensus on the variable to use for measuring the university's stock of technology. The number of invention disclosures received by a TTO is normally used to analyze the US case, since the Bayh-Dole Act (1980) obliges scientists to communicate any scientific discovery made during research sponsored by government funding to the TTO (Lockett et al., 2004). Nevertheless, in practice, TTO personnel must make considerable efforts to encourage faculty members to disclose inventions (Thursby & Kemp, 2002). Moreover, this variable can be used as a proxy for stock of technology in countries where there is the obligation to communicate discoveries,[2] but this is not the case of Spain. For these reasons, we chose the university's total research expenditure to measure the stock of technology to be commercialized (Degroof & Roberts, 2004; Link & Scott, 2005; Lockett et al., 2004; Lockett & Wright, 2005). In this way we avoid underestimating the research carried out in the institution when communicating research results to TTOs is not compulsory (Lockett et al., 2004). We use a natural log transformation of this variable due to the skewed distribution of the research expenditures of universities (L_TRESEXP).

Similarly to Di Gregorio and Shane (2003), O'Shea et al. (2005) and Powers and McDougall (2005), the strength of university ties with industry is measured by the amount of industry-funded research. We use a natural log transformation of this variable (L_INDRESEXP).

According to Di Gregorio and Shane (2003) and Grass et al. (2008), to measure if the financial support of the university

[1] The studies considering this variable normally use some rankings such as the *Gourman Report* in the case of Di Gregorio and Shane (2003) or the *National Research Council* in the case of O'Shea et al. (2005). However, the Spanish university system tends to be reluctant to apply this type of practice.

[2] Germany, Denmark, Norway and Japan have recently adopted similar legislation (Lundqvist & Williams, 2005).

influences the spin-off activity, we examine whether or not universities had specific funds to make investments in new spin-off companies (FINANCIALSUP).

Commercial resources. According to O'Shea et al. (2005) and Vinig and Van Rijsbergen (2010), the commercial resources in the TTO are measured by the number of full-time equivalents (FTEs) employed in the TTO (N_TTOSTAFF).

To measure if incubation services influence the formation of spin-offs, we examined whether or not universities had an affiliated incubator (INCUB) (Vinig & Van Rijsbergen, 2010).

Control variables

Similarly to Lockett and Wright (2005) and Siegel et al. (2003) the percentage of regional GNP spent on R&D (%R&D) has been used as a control variable reflecting the external environment (National Statistics Institute). This variable followed the model applied by Owen-Smith and Powell (2003) for the university patenting activity. According to these authors, the location of a university in an active region can confer advantages in the development of intellectual property.

Given that the number of spin-off firms created may be related to the number of inventions produced by the university (Di Gregorio & Shane, 2003; O'Shea et al., 2005), we control for the number of inventions disclosed to the TTO (INVENTIONS).

Empirical results

Univariate analysis

Descriptive statistics relating to the selected dependent, independent and control variables are reported in Table 2.

From the 47 SPOUs analysed in our study, an average of 3.47 spin-offs was generated on an annual basis over the time period 2002–2006. As the sample variance of the dependent variable ($7.27^2 = 52.85$) is fifteen times the sample mean of 3.47, a substantial dispersion exists between the different universities in terms of the number of spin-offs they can generate.

To provide more detail on the variation in spin-off firms over time, it is useful to look at transition probabilities, after first aggregating all instances of four or more spin-offs into a single category. Table 3 shows a considerable persistence: over half of the universities with zero spin-offs one year also have zero spin-offs the next analysed year, and over 80% of the universities with four or more spin-offs one year also have four or more spin-offs the next analysed year.

Table 4 shows the correlation matrix of all the continuous variables in the analysis. As expected, the variables relating to the university spin-off activity were positively correlated. Given that the high correlation found between L_TRESEXP and L_INDRESEXP ($r = 0.703$) may significantly affect the estimation of the models, we used these variables as alternative measures of the university's financial resources in the estimation of the models.

To determine the extent to which multicollinearity was a problem, an OLS analysis was performed in order to compute variance inflation factor (VIF) scores. It was found that the VIF scores did not exceed 3, which is not close to the rule of thumb "threshold" value of 10 (Hair, Anderson, Tatham, & Black, 1998). Therefore, multicollinearity was not a major problem in this analysis.

Multivariate analysis

To test the degree to which university spin-off activity is affected by different sets of resources, the following model is estimated:

$$\begin{aligned} SPINOFFS_{it} = f(&\beta_0 + \beta_1 PASTUSOS_{it} + \beta_2 \%D\_ENG\_LIFE_{it} \\ &+ \beta_3 PHD\_ACAD_{it} + \beta_4 NPUB\_PHD_{it} \\ &+ \beta_5 (L\_TRESEXP_{it} / L\_INDRESEXP_{it}) \\ &+ \beta_6 FINANCIALSUP_{it} + \beta_7 N\_TTOSTAFF_{it} \\ &+ \beta_8 INCUB_{it} + \beta_9 \%R\&D_{it} + \beta_{10} INVENTIONS_{it} \\ &+ \delta_t + \eta_i + \psi_{it}) \end{aligned}$$

where i indexes universities and t indexes years. In addition, δ_t is the time effect, η_i denotes the individual effect, and ψ_{it} is the random disturbance.

To test the determinants of the spin-off activity in SPOUs as well as the preceding hypotheses we could use multiple linear regressions. But the preponderance of zeros and the small values, and the clearly discrete nature of the dependent variable suggest that we can improve on least squares and the linear model with a specification that accounts for these characteristics (Greene, 1998). The basic regression model for count data is the Poisson regression model. However, a drawback of the Poisson distribution is that it automatically assumes that the conditional mean and variance of the process are equal. This condition is referred to as equidispersion and illustrates the restrictive nature of the Poisson distribution, because typically the conditional variance exceeds the conditional mean (overdispersion). In fact, when we examined the distribution of the SPINOFFS variable as a Poisson, a goodness of fit test rejected the Poisson distribution assumption because of the overdispersion.

Among the reasons that may lead to the violation of equidispersion are unobserved heterogeneity and a high frequency of zeros in the data (Cameron & Trivedi, 1998). The negative binomial model relaxes the equidispersion restriction by introducing an individual, unobserved effect into the conditional mean of the dependent count variable (Cameron & Trivedi, 1986; Long, 1997) and assuming a gamma distribution for this conditional mean. Thus, the negative binomial model allows the conditional mean and variance to vary.

Therefore, we analysed the three-year panel data utilizing negative binomial models in generalized estimating equations (GEE). Table 5 presents the results of the regression analysis. As we had multiple observations for each university and we wanted to account for the covariance relationship over time, we specified the correlation between the error terms to be exchangeable. Model 1 provides the main model. Models 2–4 provide a series of robustness checks using alternative measures for independent variables. Models 5–7 provide robustness checks by examining alternative estimation techniques. Thus, we could have also justified assuming either an auto-regressive (AR) (Model 6) or an unstructured correlation structure (Model 7). In both cases, assuming an alternative correlation structure had no meaningful impact on the significance or magnitude of the results.

The results of the empirical analysis ratify some of the outlined hypotheses. The tradition of the university spin-off activity positively influences the university's future ability to produce spin-offs (*Hypothesis 1*). In particular, the estimated coefficients indicate that for every additional spin-off company created by a university before a given year (PASTUSOS), the mean number of spin-offs generated in this year increases by 0.8%, holding all other variables constant. These results are consistent with the findings of Lockett et al. (2004; 2005), O'Shea et al. (2005) and Powers and McDougall (2005). These findings support that past knowledge accumulation activities may help university members to develop relevant capabilities to spin-out companies and to perform more efficiently in the process of generating university spin-offs.

The coefficients of the variable %D_ENG_LIFE are statistically significant in the expected directions, providing strong support for the

Table 2
Summary statistics.

Variables	Definition	Data source	*N.*	Min.	Max.	Mean	S.D.
Spinoffs	Spin-offs created by university in a given year.	Network OTRI	141	0.0000	50.0000	3.4752	7.2748
Pastusos	Spin-offs created by university before a given year.	Network OTRI	141	0.0000	220.0000	9.0943	26.9547
%d_eng_life	% of dissertations in the engineering and life sciences	CRUE	141	0.0800	1.0000	0.6227	0.1737
%phd_acad	% of the academics with a PhD	CRUE	141	0.3699	0.8529	0.5909	0.1032
Npub_phd	Number of publications by PhD academic	IEDCYT	141	0.2423	0.9078	0.4544	0.1542
L_tresexp	Natural log of total research expenditure	CRUE	141	12.8645	18.0333	16.2822	0.9364
L_indresexp	Natural log of the amount of industry-funded research	CRUE	141	11.8560	17.3149	14.5570	1.1462
Financialsup	Whether or not university has specific funds to make investments in new spin-off companies (1 or 0)	Network OTRI	141	0.0000	1.0000	0.1844	0.3892
N_TTOstaff	Number of TTO staff (FTEs)	Network OTRI	141	1.0000	46.0000	12.6345	10.4466
Incub	Whether or not university has an incubator (1 or 0)	Network OTRI	141	0.0000	1.0000	0.3972	0.4911
%R&D	% of regional GNP spent on R&D	National Statistics Institute	141	0.0024	0.0198	0.0097	0.0045
Inventions	Number of inventions disclosed to the TTO	Network OTRI	141	0.0000	60.0000	10.8085	1.1614

Source: own.

Table 3
Percentage of university creating each number of spin-offs.

Number of spin-offs created by a university	0	1	2	3	≥4
0	56.25	16.67	10.42	8.33	8.33
1	20	13.33	20	6.67	40
2	33.33	16.67	0	16.67	33.33
3	0	12.5	12.5	25	50
≥4	0	5.88	5.88	5.88	82.35

Source: own.

Table 4
Correlation matrix.

	Spinoffs	Pastusos	%d_eng_life	%phd_acad	Npub_phd	L_tresexp	L_indresexp	N_TTOstaff	Pibid	Inventions
Spinoffs	1									
Pastusos	0.895*	1								
%d_eng_life	0.378*	0.362*	1							
%phd_acad	0.091	0.087	0.240*	1						
Npub_phd	0.130	0.162	0.140	−0.124	1					
L_tresexp	0.431*	0.393*	0.409*	0.343*	0.276*	1				
L_indresexp	0.434*	0.388*	0.442*	0.204	0.209	0.703*	1			
N_TTOstaff	0.489*	0.475*	0.262*	−0.044	0.506*	0.438*	0.519*	1		
Pibid	0.163	0.201	0.047	−0.021	0.295*	0.316*	0.196	0.407*	1	
Inventions	0.615*	0.562*	0.414*	0.343*	0.223*	0.554*	0.485*	0.474*	0.217*	1

Source: own.
* Significance at 10% level.

view that some disciplines are more effective than others at generating spin-offs (*Hypothesis 2*). These results are consistent with the findings of Landry et al. (2005) and O'Shea et al. (2005). Thus, universities with a strong focus on engineering and life sciences tend to create more spin-offs because both the applied nature and the technology regime of their research output make it more easily marketable.

Hypothesis 3 is not supported. Neither the proportion of academics with a PhD (%PHD_ACAD) nor the number of publications per PhD academic (NPUB_PHD) show to be significant for the models tested. These results differ from those found by Di Gregorio and Shane (2003), O'Shea et al. (2005) and Powers and McDougall (2005). These papers use an overall academic rating score to measure the university's research quality. At this moment, Spanish University System lacks a similar rating which could partially explain the different results. Besides, compared to other OECD countries, the administrative procedures for setting up companies in Spain are more complex, more expensive, and much longer.[3] Academics might be reluctant to dedicate time to the spin-off activity because publishing is more important in their career and not easily compatible with the great effort and time necessary to create spin-offs companies.

Hypothesis 4 is not supported. Total research funding (L_TRESEXP) does not play a key role in the spin-off activity of the SPOUs. These results differ from those found by Lockett et al. (2004) and Link and Scott (2005). On the contrary, the commercial nature of the university research measured as the amount of industry-funded research (L_INDRESEXP) is positively related to the

[3] In 2007, Spanish entrepreneurs starting a business faced 10 administrative procedures on average, whose cost amounted around 15% of the GDP per capita and the time needed to complete them was 47 days. On the contrary, if we consider the OCDE high-income countries as a whole, setting up a company took 6 procedures and 15 days, and its cost amounted the 5% of the GDP per capita (World Bank, 2007).

Table 5
Model estimation.

Model	1	2	3	4	5	6	7
Model specification	GEE exchangeable – semi-robust	GEE exchangeable – semi-robust	GEE exchangeable – semi-robust	GEE exchangeable – semi-robust	GEE exchangeable	GEE AR1 – semi-robust	GEE unstructured – semi-robust
Pastusos	0.008** (0.003)	0.008** (0.003)	0.008* (0.003)	0.009*** (0.003)	0.008 (0.005)	0.010** (0.003)	0.009** (0.003)
%D_eng_life	1.964* (0.856)	1.910* (0.795)	2.048* (0.822)	1.941** (0.720)	2.048* (1.030)	1.810* (0.808)	1.975* (0.840)
%phd_acad	0.141 (1.913)	0.346 (1.830)	0.142 (1.878)	−0.008 (1.602)	0.142 (1.443)	0.477 (1.796)	0.083 (1.833)
Npub_phd	0.963 (0.981)		1.027 (0.965)	0.489 (0.897)	1.027 (0.999)	0.823 (1.005)	1.064 (1.010)
L_tresexp				0.328 (0.318)			
L_indresexp	0.359** (0.113)	0.340** (0.118)	0.362** (0.117)		0.362* (0.144)	0.334** (0.118)	0.364** (0.117)
Financialsup	0.244 (0.250)						
N_TTOstaff	−0.013 (0.011)	−0.003 (0.009)	−0.012 (0.011)	0.004 (0.011)	−0.012 (0.016)	−0.008 (0.011)	−0.013 (0.011)
Incub	0.962** (0.318)	0.959** (0.313)	0.963** (0.307)	1.016*** (0.308)	0.963*** (0.278)	1.013** (0.318)	0.996*** (0.299)
Yr04	0.340 (0.200)	0.276 (0.210)	0.320 (0.199)	0.171 (0.219)	0.320 (0.237)	0.288 (0.206)	0.328 (0.202)
Yr06	0.719*** (0.212)	0.699** (0.221)	0.715*** (0.210)	0.639** (0.227)	0.715** (0.235)	0.678** (0.222)	0.705** (0.216)
%R&D	−7.978 (28.957)	2.094 (31.153)	−5.596 (28.560)	−24.975 (29.878)	−5.596 (36.163)	−5.311 (29.027)	−3.255 (28.539)
Inventions	0.022** (0.008)	0.022* (0.009)	0.023** (0.008)	0.019* (0.009)	0.023* (0.011)	0.022* (0.009)	0.023** (0.008)
Cons	−7.412*** (2.043)	−6.937*** (1.897)	−7.519*** (2.023)	−7.137 (4.573)	−7.519** (2.353)	−7.162*** (2.085)	−7.517*** (2.022)
Wald test (χ^2)	233.06*** (12)	273.68*** (10)	224.87*** (11)	227.43*** (11)	87.14*** (11)	347.91*** (11)	269.40*** (11)
Time (χ^2)	12.75*** (2)	11.82*** (2)	13.93*** (2)	10.49** (2)	9.44** (2)	10.51* (2)	11.70*** (2)

Source: own.

Notes: Table 2 describes the explanatory variables. (i) Standard errors in parentheses; (ii) Wald is a test of goodness of fit, asymptotically distributed as χ^2 under the null of no joint significance, degrees of freedom in parentheses; (iii) Time is a Wald test of the joint significance of the time dummy variables, asymptotically distributed as χ^2 under the null of no relationship, degrees of freedom in parentheses.

* Significance at 10% level.

** Significance at 5% level.

*** Significance at 1% level.

production of spin-offs (*Hypothesis 5*). Thus, a university with a long tradition of responding to the needs of industry also generates more spin-off firms. The estimated coefficients imply that the expected number of spin-off firms increases by 0.35%, if the amount of industry-funded research increases by 1%, all other things being equal. These results are consistent with the findings of Di Gregorio and Shane (2003) and O'Shea et al. (2005).

The presence of the university's internal funds to promote the creation of the spin-off companies is not significant (FINANCIALSUP). These results differ from those found by Di Gregorio and Shane (2003) and Lockett et al. (2003). We hypothesize two opposite explanations which could explain this lack of significance. In spite of the *Hypothesis 6* makes sense from a theoretical point of view, practitioners and entrepreneurs agree that both the universities and their TTOs generally have little business understanding and, when they do get involved in funding, they usually underestimate the needs of the ventures (the "underestimation" hypothesis). This situation may be more acute in the case of the Spanish universities due to their relatively inexperience in spin-off activity. On the other hand, similarly to the rest of Europe, a lot of Spanish university spin-offs are indeed small technical consulting "boutiques". Therefore, they may not need (much) seed and growth funding from their university investment fund. In these cases, the founders are often reluctant to open their capital (the "boutiques hypothesis"). They are not really "entrepreneurs" (with a growth orientation), but people creating a substitute to a job. As such, opening their capital would in their mind threaten their job's safety. To test these alternative explanations, in future studies the amount of available funds to invest in spin-offs should be considered instead of a dummy variable as FINANCIALSUP.

Our results fail to find support for *Hypothesis 7* about the importance of the TTO stock of the human resources. These results differ from those found by O'Shea et al. (2005) and Lockett et al. (2004). We advance three possible explanations for the lack of the "TTO effect" in the study. Firstly, the Spanish TTOs are relatively inexperienced compared to the U.S. case. They tend to be staffed with university bureaucrats with little experience in spin-off activity or even political appointees. Thus, Counti and Gaulé (2010) show that the TTO staff in the U.S. had more experience in industry than did the TTO staff in Europe and, in particular, in an "early stage country" as Spain. Secondly, a lot of spin-offs in Spain are technology-consulting "boutiques" weakly endowed with intellectual property. As a result, they might emerge less from disciplines where IP matters and they do not seek help from the TTOs of their university. Finally, Lockett et al. (2004, 2005) follow the dynamic view of the resource-based theory and consider the staff skills, whereas in our study the resource-based theory has been considered from the static conceptualization.

Finally, our findings show that universities who have incubation services have a greater tendency to spin-off companies (*Hypothesis 8*). For instance, the coefficient estimated indicates that a university who has an affiliated incubator (INCUB) generates more than double the number of spin-off firms. These results are consistent with the findings by Link and Scott (2005).

Conclusions and implications

Society claims University must be a force for fostering regional economic and social development. The University's response has been an increase in the dissemination of scientific knowledge and technology transfer activities. Nevertheless, there are differences in the universities' ability to contribute to this "new" mission. In this paper we have developed a theoretical and econometric model to investigate the determinants of the creation of spin-off companies by Spanish universities. Drawing on the resource-based theory of the firm, we categorize four types of resources: institutional, human capital, financial and commercial.

A first finding of our study shows that the tradition of the spin-off activity positively influences university entrepreneurship. This result supports that past knowledge accumulation activities generate benefits in a university's future ability to produce spin-offs. Thus, public policy and university heads should intensify their activities to enable an entrepreneurship culture to emerge within universities. Policies in this area have a general character and usually involve an important change in university mentality. Entrepreneurship might be taught to enable students and staff to develop knowledge, skills and understanding about the world and practice of entrepreneurship. This is achieved through the combination of formal processes (such as courses) plus practical training and experiential learning (such as developing a business plan on a

potentially viable business opportunity or visiting an incubator or business centre for advice about setting up a company).

A second finding suggests that university–industry ties stimulate the spin-off activity, as the disciplines with a greater marketability and the amount of industry-funded research are positively related to the production of spin-offs. Both variables act as proxies of the university–industry ties. With regard to disciplines with a greater market orientation, research in engineering and life sciences tends to focus on solving industry's problems, which leads it to be commercialized through firm creation. Therefore, new rules and laws should be defined to promote collaborative arrangements in legal and customary formats between universities and industry. Collaboration activities range from joint R&D projects with spin-off firms, incorporation of PhDs into companies, technology consulting and contract research to technology purchases (Motohashi, 2005), but some times the inflexibility of the Spanish legal system acts al a barrier for these activities. Regarding the industry-funded research, universities who attract a higher amount have a greater tendency to spin-off companies. This result highlights the critical importance of applied research funding. Thus, policy makers should intensify activities to increase research funding and favour private investments in R&D, particularly taking into account that the funds allocated to R&D in Spain are far from OECD levels. Applying tax incentives for industry's contributions could be an appropriate measure in the short and medium term.

A third finding of our study also provides evidence that the presence of incubation services in a university increases the spin-off activity. Incubators not only make it possible for spin-offs to reduce administrative and rental costs, but also provide them a set of valuable services (technical and management support or searching for external funding, among others). This initial support seems to play a more important role in promoting spin-off activity in Spain than in other countries (the U.S. and the U.K.). This fact probably reflects differences in business environment. University-spawned firms are a relatively recent phenomenon in Spain compared to countries with a greater tradition of university–industry ties. Government provides scarce support and external investors tend to distrust spin-offs stemming from traditionally theory-focused Spanish universities. Moreover, in Spain the network is a critical factor for the surveyed of spin-offs (Pérez & Martínez, 2003), and the incubation services could help the universities to meeting and networking spin-offs and other agents.

This finding holds implications for university heads: if the presence of incubation services is not within a university's objectives, the institution should try to establish collaboration agreements to externally provide spin-offs with them. However, it is worth noting, this alternative may not be as beneficial as a university-affiliated incubator because of the special needs of university spin-offs compared to other new firms. Thus, academic entrepreneurs tend to have less extensive managerial skills and come from a more bureaucratic environment. Moreover, their entrepreneurial projects are usually more embryonic and hence need further development (Ortín & Vendrell, 2010). In Spain, university spin-offs are younger than the average company, and less likely to have venture capital and patents (March-Chorda, Niosi, & Yagüe-Perales, 2010). Ortín, Salas, Trujillo, and Vendrell (2007) in a descriptive study on a sample of 68 academic spin-offs arising from Spanish universities shows that these firms have the typical characteristics of early companies. Thus, half of the spin-off sample generate sales less than 125,000 € with assets below 120,827 € and with less than six employees hired.

As interesting as the previous findings is the lack of significance of some used variables, because this result tells us more about particularities of Spain. Thus, neither the proportion of academics with a PhD nor the number of publications per PhD academic was significant. The current evaluation of research in universities is focused on article counts in high impact international journals. Therefore, publishing is more important in the academics' career than starting up a company. But, in addition, the Spanish academics have to face the inflexibility of a legal system whose administrative procedures for setting up companies are more complex and expensive, and much longer. Thus, policy makers should simplify administrative procedures for company creation (for instance, by publicizing the electronic procedures or using a simple language in the forms) as well as reduce their costs.

Similarly, both the presence of the university's internal funds to promote the creation of spin-offs and the TTO stock of the human resources were not significant. We have suggested two main possible explanations for this lack of significance. Firstly, most of the Spanish university spin-offs are small technical consulting companies with no ambition to the ventures endowed with IP. As a consequence, they may not need much funding from their university investment fund or help from the TTOs and, probably, they will remain small "boutiques" with a minimal economic impact. From a policy point of view, it would be very useful to revise some of the instruments implemented to create spin-off companies, because they involve resource allocation by governments. For instance, our results show than incubation services are more effective than seed funding from the university.

Secondly, Spanish universities and their TTOs are relatively inexperienced compared to the U.S and the U.K. cases. Their lesser business understanding could partially explain why the TTO effect does not apply in this study. Even so, some Spanish universities are more successful than others at generating spin-offs. For this reason, late entrant universities should benefit from exposure to the experience of earlier entrants by making TTOs communicate and exchange experience, information and resources.

This study contributes to the literature in three ways. First, there were no similar empirical studies at the Spanish university-level. Most of the analysed hypotheses had been already tested in countries with longer experience with university spin-off activity. Although the replication of some results is valuable, the most interesting part of the study lies in the hypotheses that do not materialize. They tell us more about some particularities of Spain, which might be extrapolated to other countries at a similar stage of experience with spin-off activity. Second, we have practically included 100% of the spin-off activity in the Spanish University System between 2002 and 2006, since open universities and private universities do not usually participate in this activity. Third, our findings provide quantitative evidence on the determinants of the university spin-off production. With our results in mind, the policy makers and university heads responsible for designing research policies will be able to make better decisions.

However, this paper also presents some limitations that could open the way for further research. Thus, the study has focused on the number of spin-offs, but universities have several alternatives to carry out entrepreneurial activity. Indeed, this variable could be considered a crude indicator of success in the entrepreneurial activities because most of the created spin-offs stay small "boutiques" with minimal impact (Callan, 2001). In addition, when universities, report that they generated x number of spin-offs, it covers a wide variety of cases: from the small technical consulting company with no ambition to the ventures endowed with IP and exhibiting great ambitions. An alternative to carry out entrepreneurial activity is patenting. Since patents precede university commercialization activities in general, one could intuitively propose that patent production would also be correlated with spin-off creation. Thus, future research could analyze the university spin-off creation and compare the results with those obtained for the patenting activity. This comparative analysis allows us to know whether the determinants of patent production coincide with those of spin-off formation. Similarly, the measure of some independent variables

could be improved. For instance, in future studies the amount of the university's available funds to invest in spin-offs should be considered instead of a dummy variable. Besides, resource-based theory has been considered from a static perspective, without directly considering the skills and abilities of the TTO personnel. Future research could use data of the abilities of TTO staff members on an individual basis. Another possibility, as Lockett and Wright (2005) suggest, is to extend the study field by including samples from other European and American countries, allowing us to examine the effects of various institutional environments on spin-off formation.

Our findings open up a debate about the design of national and regional innovation systems where the University, industry and government play a key role. We have already outlined several policies in order to improve the dissemination of knowledge and technology transfer. In our opinion, the implementation of these policies is crucial for the Spanish University System, which has largely ignored the importance of setting-up incentives for universities and academics to pursue commercialization of technology.

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