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Entrepreneurial effectiveness of European universities: An empirical assessment of antecedents and trade-offs

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ABSTRACT

The phenomenon of entrepreneurial universities has received considerable attention over the last decades. An entrepreneurial orientation by academia might put regions and nations in an advantageous position in emerging knowledge-intensive fields of economic activity. At the same time, such entrepreneurial orientation requires reconciliation with the scientific missions of academia. Large-scale empirical research on antecedents of the entrepreneurial effectiveness of universities is scarce. This contribution examines the extent to which scientific productivity affect entrepreneurial effectiveness, taking into account the size of universities and the presence of disciplines, as well as the R&D intensity of the regional business environment (BERD). In addition, we assess the occurrence of trade-offs between different transfer mechanisms (contract research, patenting and spin off activity). The data used pertain to 105 European universities. Our findings reveal that scientific productivity is positively associated with entrepreneurial effectiveness. Trade-offs between transfer mechanisms do not reveal themselves; on the contrary, contract research and spin off activities tend to facilitate each other. Limitations and implications for future research are discussed.

1. Introduction: the role of entrepreneurial universities in regional innovation systems

The interaction between innovation, entrepreneurship and regional economic development has become a central theme in many policy circles. Inspired by examples such as Cambridge U.K. and Cambridge US and – more emphatically – the phenomenon of Silicon Valley, almost every European region is currently attempting to assemble the ingredients necessary for endogenous economic growth, based on the innovative capacity and the entrepreneurial dynamics that can be mobilised in a particular region. The realisation of such endogenous growth does, however, necessitate a deeper insight into the parameters and the dynamics upon which it is based.

Over recent decades, scholars have highlighted the interactions among a variety of actors as the crucial driving force. Besides the presence of entrepreneurs and established companies, much emphasis has been placed on the role of knowledge-generating institutions (such as universities and research laboratories) and of policy makers. This broader focus arises from an increased recognition of the fundamental role of knowledge and innovation in fostering economic growth, technological performance, and international competitiveness (e.g. Freeman, 1987, 1994; Adams, 1990; Lundvall, 1992; Nelson, 1993; Mowery and Nelson, 1999; Baumol, 2002). Consequently, the concept of 'innovation systems' has gained widespread acceptance since the mid-1980s and has been used as a general framework for designing innovation policies and adequate institutional arrangements in support of those policies (OECD, 1999; European Innovation Scorecard, 2002). In these models, knowledge-generating institutions, such as universities and research laboratories, public and private research laboratories (the dominant loci of R&D and innovation in most fields) and, more recently, government agencies are seen as key actors with respect to the innovative potential of society. Complementary contributions can be found in the influential work of Michael Porter (1995) and the work on the 'Triple Helix' concept, which rose to prominence in the second half of the 1990s (Leydesdorff and Etzkowitz, 1998; Etzkowitz and Leydesdorff, 1997).

Closely associated with the Triple Helix model, the notion of 'entrepreneurial universities' (Etzkowitz, 1983; Branscomb et al., 1999; Etzkowitz et al., 1998) has increasingly been used in relation to the developments in academia: greater involvement in eco-

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nomic and social development, more intense commercialization of research results, patent and licensing activities, the institutionalization of spin-off activities, and managerial and attitudinal changes among academics with respect to collaborative projects with industry. At least in the US, these developments can be seen as a logical extension of the successful engagement of university research in fields such as space, defence and energy during the 1940s, 1950s and 1960s. They can even be traced back to efforts and experiences situated in the 19th century (see e.g. Hane, 1999; Kodama and Branscomb, 1999; Rosenberg and Nelson, 1994). Scholars however do agree that recent developments in the institutionalization of university-industry linkages have implied a more direct involvement of universities, and on a larger scale than before (Geuna and Muscio, 2009). As a consequence, some speak of a 'second academic revolution' during the 1990s, adding entrepreneurial objectives as a third component to the mission of the university (Etzkowitz et al., 1998).

A multitude of elements have contributed to this entrepreneurial phenomenon. Shifts in federal funding (US) and changes in the tax treatment of R&D expenditures have been identified as important drivers. In addition – driven by concerns regarding the competitiveness of American industry – policy measures have been crafted for improving the innovative capacity of the economy (Cohen and Noll, 1994) including measures that regulate intellectual property rights, such as the Bayh-Dole Act and the Stevenson-Wydler Act in the U.S.[1] (e.g., Mowery et al., 2001, 2004). The Bayh-Dole Act confers the IP rights arising from research that is funded with public money to the legal entity receiving the grant (either firms or universities/research institutes) with the objective of enabling market exploitation. Several countries, also in Europe, have adopted regulatory frameworks that define the conditions and terms under which universities can engage in such valorisation efforts (OECD, 2003). These regulations gave a significant boost to the adoption and the further development of IPR-related procedures and policies at universities, whereby contract research conducted at universities increasingly became considered an inherent part of the mission of today's universities (Branscomb et al., 1999; Clark, 1998; Van Looy et al., 2003). Moreover, as Kodama and Branscomb (1999) note, these developments are especially outspoken within rapidly growing economic sectors, which are typically close to the 'science base'. Growth areas like microelectronics, software, biotechnology, medicine, and new materials are dependent on highly skilled people and the latest research findings. It should therefore come as no surprise that universities and knowledge-creating institutions find themselves advantageously placed to contribute and to participate in the growth of these very industries (Kodama and Branscomb, 1999; Mowery et al., 2001).

At the same time, the phenomenon of academic entrepreneurship cannot be seen in isolation from transformations that have characterized business R&D over the last two decades. Increased competition in international technology markets and the need to share increasing research risks and costs determine a growing need for companies to access externally generated knowledge, signalling 'the decline of technical self-sufficiency' (Fusfeld, 1995; Chesbrough, 2003). Business R&D has increasingly faced the challenge of securing access to external sources of technology and knowledge and to identify trained human resources, new partners, and markets. This became a major driver of company involvement in partnerships, alliances, co-operative programs, and consortia with universities and government laboratories at the national or international level (Mowery and Nelson, 1999). Science-industry exchanges can hence play an important role in regional development. Since the seminal study of Jaffe (1989), several authors have empirically confirmed such dynamics. Anselin et al. (1997) provided evidence of local spill-overs at the US state and MSA (Metropolitan Statistical Area) level (see also Varga, 2000; Acs et al., 2002). Blind and Grupp (1999) examined eighteen technology zones in Baden-Württemberg and North Rhine-Westphalia and established a clear link between the public institutions of higher learning and the technology-output emerging from a particular geographical region. Niosi and Bas (2001), in analyzing Canadian biotech clusters, found that universities along with government laboratories and large firms, attract entry of new firms. Fischer and Varga (2003) provided evidence on the importance of geographically mediated knowledge spill-overs from university research activities to regional knowledge production in high-technology industries in Austria. Furman et al. (2002) and Furman and Hayes (2004) demonstrated positive effects of investments in science and education on the innovative performance of (national) innovation systems while Guellec and van Pottelsberghe de la Potterie (2004) show that public R&D, and especially the public research performed in the higher education sector, has a higher long term social return than business funded R&D.

Despite a growing awareness and a vast body of empirical evidence that universities can contribute to the development of local economies, the evidence on antecedents of successful engagement in entrepreneurial activities at the level of universities is more fragmented. Large-scale empirical studies on the relationship between university characteristics, the economic texture in which their activities are embedded, and entrepreneurial performance are lacking. In addition, potential drawbacks – on the level of transfer mechanisms, as well as in relation to scientific activities – have received little attention. This is where we seek to situate our contribution. Using data on 105 universities from 14 European countries, we analyze antecedents of entrepreneurial effectiveness and we examine trade-offs on the level of transfer mechanisms as well as with respect to scientific activities.

The remainder of this paper is structured as follows: after outlining the hypotheses, we document constructs, indicators and the data-gathering strategy adopted for the analyses. A subsequent section covers our main findings regarding antecedents and potential trade-offs on the level of contract research, patent activity, and spin-off creation. We conclude by pointing out implications as well as limitations that might inspire future research in this area.

2. Antecedents of entrepreneurial performance of universities: towards hypotheses

Previous research has identified several elements that stimulate entrepreneurial activities at universities (e.g., Henderson et al., 1998; Varga, 1998; Debackere, 2000; Debackere and Veugelers, 2005; Mowery et al., 2004; Colyvas et al., 2002; Agrawal and Henderson, 2001; Di Gregorio and Shane, 2003; Coupé, 2003; Lach and Schankerman, 2003; Shane, 2004; O'Shea et al., 2005). Building on this literature, we advance specific hypotheses that will be examined empirically for European universities. These hypotheses pertain to the impact of universities' scientific productivity, and potential trade-offs between different transfer mechanisms.

2.1. Impact of scientific productivity

The third mission in academia cannot be considered in isolation from the more traditional research mission. The rationale of 'entrepreneurial universities' is closely connected to the presence of market failures in innovation (Arrow, 1962). Basic scientific

[1] The Bayh-Dole Act is applicable for universities, non-profit organisations and small enterprises. The Stevenson-Wydler Technology Innovation Act of 1980 has a similar objective as the Bayh-Dole Act but is aimed at federal laboratories.

research is characterized by uncertain outcomes and long time frames before exploitation on markets becomes feasible. This poses specific investment challenges for profit oriented actors (firms), who will refrain from investing heavily in such activities. As a consequence, a considerable share of basic research activities is performed by publicly funded research institutes and universities. Entrepreneurial activities are a way to valorize research results beyond the traditional, scientific, dissemination mechanisms (e.g. publications). A broader and more solid scientific base of universities implies more valorization opportunities. Therefore, universities with higher levels of research productivity can be expected to be capable of developing entrepreneurial activities on a larger scale.

Much of the available empirical evidence on the relation between scientific productivity and entrepreneurial activities concerns academic patenting. In spite of concerns about a negative influence of the patenting regime on traditional academic research activities (Blumenthal et al., 1997; Campbell and Slaughter, 1999; Cohen et al., 1998; Murray and Stern, 2005; Noble, 1977; Heller and Eisenberg, 1998), current empirical evidence reveals no such tradeoffs and even signals positive effects. This positive relation has been confirmed mostly at the individual professor and scientist level (Azoulay et al., 2007; Calderini and Franzoni, 2004; Czarnitzki et al., 2007; Fabrizio and DiMinin, 2008; Meyer, 2006; Stephan et al., 2007; Van Looy et al., 2006). The presence of this positive relationship can at least partly be explained by the similarity between the nature of both activities. Both activities share the objective of advancing knowledge and the state-of-the-art, in science and technology respectively, and therefore imply similar knowledge creating activities. As such, patents and publications can result from one and the same underlying research effort (Breschi et al., 2005). In addition, the positive relation between scientific and patenting activities can result from cross-fertilization processes whereby understanding leads to application while application also enhances understanding (Sapsalis et al., 2006; Callaert et al., 2008). These dynamics and the resulting positive relation between scientific and patenting productivity can be considered equally valid at more aggregated levels of analysis, as for instance demonstrated by Carayol and Matt (2004) who revealed a positive relation between patenting and publishing at the laboratory level. We propose a similar positive relationship on the level of universities:

H1a. The scientific productivity of universities coincides with higher levels of patent activity.

In terms of contract research, firms that solicit academic partners for collaboration might favor scientifically prominent universities. As such, the presence of strong scientific capabilities likely facilitates the attraction of contract research. In addition, the execution of contract research might again lead to spillovers on the level of scientific productivity as resources made available through contract research can become reinvested in research activities (Van Looy et al., 2004). Also, contract research might offer opportunities to test and refine theories or discoveries in real-world situations: the results of these tests are of genuine interest to the academic world and hence provide inspiration for consecutive research (Crawshaw, 1985). A positive relation between industrial support and the execution of cooperative projects on the one hand and scientific productivity on the other hand, was empirically confirmed in several studies at the level of individual scientists (Blumenthal et al., 1997; Crespo and Dridi, 2007; Gulbrandsen and Smeby, 2005; Van Looy et al., 2004).[2] In their study of French public research laboratories in the plant breeding and biochemical industry, Joly and Mangematin (1996) found basic research to be compatible with industry contracts at the laboratory level. We test this relation at a higher level of analysis by considering the relation between the amount of contract research and scientific performance of European universities. We propose the following hypothesis:

H1b. The scientific productivity of universities coincides with higher levels of contract research.

A larger scientific base at the same time breeds more opportunities for exploitation of commercially useful ideas through spin-offs. In interviews reported by D'Este et al. (2009) academic founders of spin-offs noted that they perceive these spin-offs as a natural way for research findings to achieve a wider impact. At the same time, the respondents highlighted that the spin-off companies exerted very limited influence on the scientific production of the parent academic departments. The complementarities between scientific productivity and spin-offs may indeed be less clear-cut than the relation between scientific productivity and patenting and contract research. The trajectory from scientific research to commercial exploitation by spin-offs presents itself as more complex in terms of contributing success factors (e.g. Autio, 1997; Carayannis et al., 1998; Clarysse et al., 2005) diminishing the importance of scientific knowledge per se. Joint publication efforts between the company and the university are rare, not only due to intellectual property considerations, but mostly because spin-offs move downstream towards market exploitation as they grow larger (D'Este et al., 2009). At the level of the individual researcher, Audretsch et al. (2006) as well as D'Este et al. (2009) found no positive relation between scientific quality – measured in terms of citations– and spin-off involvement for a sample of US and UK researchers respectively. The uncovered relations were negative but significant only in the former study. At the university level, Di Gregorio and Shane (2003) and O'Shea et al. (2005) did observe a positive relation between start-up formation and intellectual eminence at US universities. They suggest that academics from top-tier universities may have easier access to resources for spin off creation, due to reputation effects. Overall, arguments in favor of a direct (positive) relationship[3] between scientific productivity and spin off creation at the level of universities are limited or absent, resulting in the following hypothesis:

H1c. The scientific productivity of universities does not coincide with higher levels of spin off activity.

2.2. Trade-offs between transfer mechanisms?

Previous literature has highlighted that different transfer mechanisms imply different (inter-) organizational arrangements (D'Este and Patel, 2007). At the same time, the relevance of different transfer mechanisms depends on the nature of the knowledge involved. For instance, only a small fraction of the research conducted at universities can be codified in patents. For tacit knowledge (Polanyi, 1976; Von Hippel, 1994), contract research or spin off creation might be more relevant transfer mechanisms (Grossman and Hart, 1986). Such differences among transfer mechanisms have over the last years raised concerns from university managers and TTO officers, policy makers and company managers. The debate, which has until now rarely been explored in the literature, revolves around relationships between transfer mechanisms and especially around potential trade-offs: focusing on one transfer mechanism might yield detrimental effects for other mechanisms.

[2] Blumenthal et al. (1997) suggested curvilinearity in the relation between industrial support and scientific performance.

[3] Notice that an indirect positive influence via patent activity can be assumed, as the presence of IP might enable the formation of a spin off firm.

Regarding the relation between patents and contract research, one could argue that a university's adherence to creating IP (patent applications) might jeopardize the willingness of firms to engage with them in contract research: companies may increasingly perceive universities as interfering in their ambitions to create fully owned intellectual capital. In this respect, Wright et al. (2008) note that "with regard to contract research, issues with IP and royalty sharing affect mid-sized research groups in the average university". Likewise, Bercowitz et al. (2001) signal revenue trade-offs: "leveraging sponsored research revenue against licensing revenue". In line with these arguments, it seems plausible to advance the following hypothesis:

H2a. Higher levels of patent activity coincide with lower levels of contract research and vice versa.

Likewise, concerns can be uttered that the presence of spin-off firms will influence the capacity of a university to attract contract research. First, firms might be less willing to collaborate with universities that have spin-off firms in relevant fields because they anticipate unintended knowledge spill-overs (Oxley, 1997; Faems et al., 2008). Second, involved researchers could start diverting the execution of research contracts, previously performed by the university, towards spin off companies. Together, these arguments lead towards the following hypothesis:

H2b. Higher levels of spin off activity coincide with lower levels of contract research and vice versa.

Regarding the relation between spin off creation and patent activity, arguments are more nuanced. On the one hand, it is clear that the presence of intellectual property can be beneficial – and in certain industries even necessary – for the creation of spin off activities. At the same time, patenting and especially the subsequent licensing activities provide an attractive alternative for spin off creation. The latter would result in a substitutive relation, rather than a complementary one. As license activities imply less risk, fewer investments and shorter investment cycles, one can argue that substitution effects will prevail. This was confirmed in the work of Wright et al. (2008). We therefore propose the following hypothesis:

H2c. Higher levels of spin off activity coincide with lower levels of patent activity and vice versa.

3. Methodology and data

3.1. Variables

Three indicators of entrepreneurial activity have been used for the empirical analysis: the amount of patent activity, the amount of contract research and the number of spin-offs created at the university. These three variables will act as dependent variables in the models. In line with the hypotheses outlined, the independent variables of interest are the university's scientific productivity, as well as the transfer mechanisms that do not act as dependent variable.

When analyzing universities' entrepreneurial performance, several control variables should be taken into account. First of all, the size of the university in terms of number of academic staff is included. More academic staff implies more potential entrepreneurial actors, so a positive relation can be expected with the amount of entrepreneurial activity (Powers and McDougall, 2005; Carayol, 2007). The disciplinary scope of a university likely plays a role as well. The presence of an engineering department has been shown to stimulate entrepreneurial activities (Coupé, 2003; Lach and Schankerman, 2003; O'Shea et al., 2005; Sine et al., 2003). The effect of a (bio)medical department appears more ambiguous. Although most studies show a positive effect (Chapple et al., 2005; Coupé, 2003; Lach and Schankerman, 2003; Powers, 2004; Sine et al., 2003), others find no effect (Chukumba and Jensen, 2005) or even a negative one (Thursby and Kemp, 2002). To take into account their potential effects, control variables are included that cover the presence of disciplines.

Besides university size and scope, the presence of an institutional-level entrepreneurial orientation should be included. Entrepreneurial activities will be observed on a meaningful scale only to the extent that universities adopt an 'entrepreneurial' strategic stance. The latter implies that entrepreneurial objectives are incorporated in the institute's mission (Bozeman, 2000; Etzkowitz, 1983) and that adequate supportive transfer mechanisms are developed that permit and foster entrepreneurial activity (Debackere, 2000; O'Gorman et al., 2008; Geuna and Muscio, 2009). Several studies have indeed indicated that the presence (and nature) of a technology transfer office affects entrepreneurial outcomes (e.g. Chukumba and Jensen, 2005; Chapple et al., 2005; Geuna and Muscio, 2009; Markman et al., 2005; Lockett and Wright, 2005; Leitch and Harrison, 2005; O'Shea et al. (2005). As such, the presence and the size of the TTO are included as control variables. A final control variable concerns the local economic texture, which has been identified as a crucial issue throughout studies on academic entrepreneurship (Tidd and Brocklehurst, 1999; Fogarthy and Sinha, 1999; Keeble and Wilkinson, 2000; Swan et al., 1998; Deeds et al., 1997). Interaction and alignment with the local economic texture seems to be associated with higher levels of entrepreneurial activity at universities, especially if this local business environment is a knowledge-intensive one. We therefore included the R&D intensity of the local business texture as a control variable. Table 1 shows the variables and the data sources that were used to obtain indicators for these variables. The data collection process and the data used are further detailed in the next paragraphs.

3.2. Data collection and variables specification

The collection of data on universities' entrepreneurial activities (patenting, contract research and spin-offs), scientific productivity and the control variables (university size and scope, presence and size of the TTO, regional business R&D intensity) required a combination of survey data and data obtained from secondary sources.

3.2.1. Survey data

To obtain data on universities' entrepreneurial activities we rely on survey data collected in 2003. In order to obtain a relevant sample, universities have been identified by means of the rankings provided in the Second Science and Technology Indicators Report (EC, 1997). These rankings contain the most active European universities in terms of scientific publications (as covered by the ISI Web of Science) per country. Universities, not included in these STI rankings, were still added to the target list if they were known to be active in patenting. This additional criterion was used because the ownership of patents by a university can be considered an indication of entrepreneurial activities being conducted at the institutional level. Consequently, our sample should not be considered as representative of the entire population of European universities, but rather of the more scientifically and/or technologically oriented ones.

After identification of relevant contact persons, an initial contact was established by phone, whereby the survey aims were introduced. If the target person agreed to cooperate, the survey was sent by email. In order to maximize the response rate, a concise one-page questionnaire was designed for collecting facts and figures relevant to the central research constructs. Questions cover the universities' resource characteristics (number of staff, the presence of disciplines, students, the presence of a TTO, and number

Table 1
Overview of constructs, indicators and sources.

Construct	Indicator	Source
Size of the university	Number of academic staff	Survey
Range of disciplines present at university	Presence (0/1) of Arts and Humanities, Engineering, Science, Life Sciences (Medicine/Pharmaceutical)	Survey
Scientific productivity	Number of scientific publications normalized by number of academic staff	Web of Science EC Report on S&T Indicators
Regional R&D intensity	Business expenditures on R&D (BERD), Nuts level 3	Eurostat
TTO size	Total number of staff (FTE) working at the TTO	Survey
Entrepreneurial performance:	Amount of contract research 2002	Survey
	Number of spin-offs Established	Survey
	Number of patent applications 2002	Survey
	Number of EPO patent applications 1999/2000	EPO Database

of employees at TTO) and entrepreneurial performance (patent applications and grants, spin-offs, contract research) (see Annex 1). Follow-up took place at regular intervals by telephone and by email, until completed surveys were received. Data collection efforts were undertaken by colleagues working in the various European countries under study, lowering participation thresholds due to language barriers. Out of the 170 European universities that were contacted, a total of 105 (62.5%) provided us with the required key figures and data. The list of universities that participated in the survey can be found in Annex 2.

The survey responses provided constructs and indicators that could not readily be extracted from available databases or for which inter-institutional comparison based on secondary sources could result in ambiguous results (e.g. deriving the number of academic staff from university websites). We rely on survey responses regarding the following indicators.

3.2.1.1. Size and scope of universities. The number of academic staff is used as an indicator of the size of the university. It includes professors and researchers (including PhD students), but it excludes technical and administrative staff as well as staff employed within university hospitals. University scope is measured by the presence of different disciplines in the universities. Four categories are used to characterize the scope: the presence of Arts & Humanities, Engineering, Sciences (including Chemistry, Physics and Mathematics) and finally Life Sciences (Medicine and Pharmaceutical Sciences).

3.2.1.2. The presence and size of the TTO. The presence of a technology transfer office is a 0/1 variable; while TTO size is measured by the total number of FTE staff working at the university's TTO.

3.2.1.3. Entrepreneurial outputs. The survey covered entrepreneurial performance in terms of outputs: spin offs, contract research and patenting. With respect to spin-offs, we used a rather restrictive definition. In order to qualify as an academic spin-off, knowledge developed at the university and the active involvement of research staff should be present during the foundation stage. For contract research, the revenues for 2002 were inquired. For patent activity, data were collected on the number of applications as well as grants (EPO/USPTO), whereby attention was paid both to patents applied for by the university and patents involving academic staff (as inventors, so without the university acting as assignee).

3.2.2. Secondary sources

As the response rate for patent figures turned out to be low (less than 50% of the respondents were able to provide accurate figures), the survey data collection efforts were complemented with direct queries in the EPO database (patent applications). This yielded consistent and complete figures about patents applied by the responding universities.

Furthermore, in order to assess scientific productivity, the total number of SCI-covered publications was extracted by combining data from the Third European Report on Science and Technology Indicators (EC, 2000) with queries performed on the Web of Science database (ISI, online edition). The amount of publications retrieved covers the Science Citation Index Expanded, the Social Science Citation Index, and the Arts and Humanities Citation Index for the period 1991–2001. Absolute figures were divided by the total number of academic staff, in order to obtain an indicator that controls for university size. Finally, data on business expenditures on R&D (BERD) for NUTS Level 3 regions were obtained from EUROSTAT.

In summary, our hypotheses about antecedents of entrepreneurial activity relate to the scientific productivity of universities, and the relations between the different transfer mechanisms. We additionally control for university size and scope, the presence and size of the TTO and for the R&D intensity of the regional business texture.

3.3. Analytical approach

Three models were used for testing our hypotheses. Each model considers one of the entrepreneurial activities as dependent variable. When contract research and spin offs act as dependent variables, ordinary least square regressions were performed. For modeling patent activity, a negative binomial regression was used. In order to avoid multicollinearity when introducing entrepreneurial activities as independent variables, intermediate regressions were performed with all other variables under study acting as independent variables. Stated more formally, each endogenous variable in the equation of interest is regressed on all of the exogenous variables in the model. These regressions yield residual variables of entrepreneurial activities (spin off activity, contract research and patent activity) which are then included as independent variables. This approach ensures that the correlations between entrepreneurial activities (as independent variables, i.e. their residual value) and all other independent variables equal zero. It can moreover be noted that, for ensuring sample consistency, the sample of universities has de facto been reduced to include only the universities that have data available on all three types of entrepreneurial activities: patents, contract research and spin offs. The final analyses, reported in section 3, hence pertain to 76 universities.[4] Finally, it should be noted that the reported models include only TTO size as an indicator of the entrepreneurial orientation of universities. The binary variable indicating presence of a TTO turned out to be less relevant for the envisaged analysis, since 89% of the universities in our sample have a TTO as a separate entity within their organizational chart.

[4] Robustness checks were performed with larger subsamples (leaving out variables with missing values in respective analysis); these analysis yield similar results as the ones reported here.

Table 2
Descriptive statistics.

	N	Mean	SD
Academic staff	104	1909.23	1307.22
Presence TTO	105	89%	
Size TTO (FTE)	96	9.307	10.29
Scientific productivity	104	5.0290	3.56
Art and humanities (0/1)	105	74%	
Medicine (0/1)	105	72%	
Engineering (0/1)	105	76%	
Science (0/1)	105	84%	
Amount of contract research (Euro)	94	27,300.456	28,821.176
Number of spin-offs	95	26.88	60.98
Patent activity (Number of Patent Applications EPO (2000))	105	4.52	8.48
Valid N (Listwise)	81		

4. Findings

4.1. Occurrence of entrepreneurial activity

Table 2 presents an overview of descriptive statistics for the indicators used. The average university in our sample comprises over 1900 academic staff. 89% of the universities have a technology transfer office. As already noted, this observation prompted us to use only the size of the TTO as an indicator in the analysis.[5] On average, the size of the TTO is considerable (9.3 staff members). At the same time, Table 2 indicates that variation is significant. While several TTOs have less than one full-time staff member, our sample also contains TTOs employing 50 people. In terms of entrepreneurial performance, the average amount of contract research (annual base, reference year 2002/3) equals 27.3 million euro. Note that this figure is slightly higher than figures reported for American universities over a comparable period: the AUTM survey (2002) reported, for 140 American universities, an average income from contract research equal to 18.7 million euro. In terms of patent activity, the European figures obtained in this study (average number of EPO applications = 4.52) are situated below the American average (average number of applications = 35.84 – see AUTM Survey, 2002). Finally, in terms of spin-off creation, the universities in our sample have an average spin-off portfolio of 26.88 companies. These figures lend themselves less for comparison with American data, since our survey investigated the total number of spin-offs arising from the university. The annual figures reported by AUTM indicate an average of 2.83 spin-off companies for American universities (N = 140) the year 2002. If one assumes that the average university would be active over a ten-year period, comparable figures are obtained.

4.2. Entrepreneurial activity and scientific productivity

For the amount of contract research and the cumulated number of spin-offs,[6] OLS regression models were applied. For the analysis in which patent activity acts as a dependent variable, we opted for a negative binomial regression, given the nature of the distribution of this dependent variable.[7] Before presenting the results obtained, Table 3 shows the – mostly modest – correlations between the main variables under study.

Table 4 summarizes the core findings about university antecedents of the amount of contract research, patent and spin off activity, as well as trade-offs between these types of entrepreneurial activities.

Patenting activities (the amount of patent applications extracted from the EPO patent system) are influenced by university size and scope. Higher levels of patent activity are observed at larger universities and there is a significant and positive effect regarding the presence of an engineering department ($p < 0.05$). The size of the TTO and BERD turn out to be insignificant. Controlling for these effects, hypothesis 1a is clearly confirmed: higher levels of scientific productivity coincide with more patent activity. Contrary to H2a and H2c, our findings do not reveal trade-offs between patenting on the one hand and contract research and spin off activity on the other hand.

For contract research, differences in university size (measured by the number of academic staff) matters whereas scope does not: none of the discipline variables displays a positive relationship with the amount of contract research. As with patenting activity, no significant relationship is observed with TTO size or with regional R&D intensity. The scientific productivity of the university is significantly and positively associated with the amount of contract research. As such, hypothesis 1b is confirmed, indicating that more eminent scientific institutes are in a favorable position to attract contract research. Contrary to Hypothesis 2b, the significant positive relationship with spin off activity suggests complementarities – rather than a substitution effect – between contract research and spin off activities.

If we turn to the model with spin off activity acting as the dependent variable, it can be seen that university size matters, whereas disciplinary scope does not. Unlike for patenting and contract research: TTO size and BERD are significantly related to spin off activity. Scientific productivity coincides positively with the number of spin-offs created, albeit less outspoken ($p < 0.10$) than in the analyses modeling patenting and contract research. Concerning trade-offs between entrepreneurial activities, the findings are in line with the previous analyses: we observe a positive relationship between contract research and spin off activity (invalidating hypothesis 2b) and no relation between patenting and spin

[5] Models which include the size of TTO divided by the total number of (academic) staff have been explored as well. For contract research and patent activity similar findings have been obtained as reported in Table 4. For spin off activity only the TTO staff – measured in absolute numbers – is significant, suggesting that scale (in absolute terms) of internal capabilities is important for this type of entrepreneurial activity.

[6] For both variables, the logarithmically transformed value has been used in the analyses to comply with normality assumptions.

[7] In these models, the size of the university (academic staff) acts as an independent variable. One could envisage an analysis with entrepreneurial outcomes divided by academic staff acting as the dependent variables. When applying this model formulation, the obtained findings are similar to the ones reported in Table 4 for contract research and patent activity. This is not the case for spin off activities, where relationships with antecedents become insignificant. This observation should come as no surprise given that we only have figures on the total number of spin offs created. Normalizing by academic staff implies a precisely defined time window (for contract research and patent activity: one year). Given the lack of information on the relevant time window for spin off activity, we consistently apply models with absolute values (as dependent variable) while at the same time controlling for size of the universities.

Table 3
Correlations.

		Academic staff	Size TTO	Arts and humanities	Medicine	Engineering	Science	Scientific productivity	Number of spin offs	Amount of contract research	Patent activity
Academic staff	Correlation	1	.233(*)	.272(**)	.329(**)	.026	.208(*)	.008	.105	.235(*)	.367(**)
	N	104	95	104	104	104	104	104	94	93	104
Size TTO	Correlation	.233(*)	1	.074	−.039	.167	.016	.071	.031	.071	.311(**)
	N	95	96	96	96	96	96	95	91	86	96
Arts and humanities	Correlation	.272(**)	.074	1	.514(**)	−.175	.570(**)	.105	.033	.115	.087
	N	104	96	105	105	105	105	104	95	94	105
Medicine	Correlation	.329(**)	−.039	.514(**)	1	−.145	.422(**)	.302(**)	−.138	.121	.171
	N	104	96	105	105	105	105	104	95	94	105
Engineering	Correlation	.026	.167	−.175	−.145	1	−.124	−.292(**)	.009	−.005	.079
	N	104	96	105	105	105	105	104	95	94	105
Science	Correlation	.208(*)	.016	.570(**)	.422(**)	−.124	1	.152	−.038	.036	.086
	N	104	96	105	105	105	105	104	95	94	105
Scientific productivity	Correlation	.008	.071	.105	.302(**)	−.292(**)	.152	1	.027	.396(**)	.351(**)
	N	104	95	104	104	104	104	104	94	93	104
Number of spin-offs	Correlation	.105	.031	.033	−.138	.009	−.038	.027	1	.118	.016
	N	94	91	95	95	95	95	94	95	86	95
Amount of contract research	Correlation	.235(*)	.071	.115	.121	−.005	.036	.396(**)	.118	1	.333(**)
	N	93	86	94	94	94	94	93	86	94	94
Patent activity	Pearson's correlation	.367(**)	.311(**)	.087	.171	.079	.086	.351(***)	.016	.333(**)	1
	N	104	96	105	105	105	105	104	95	94	105

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

off activity (invalidating hypothesis 2c). Notice that the positive relationship between contract research and spin off activity also implies an indirect impact of scientific productivity on spin off activity (through contract research).

Table 5 provides a summary overview of the observed effects. Overall, our findings confirm the importance of several hypothesized antecedents of entrepreneurial activity. The effects however differ depending on which entrepreneurial outcome is considered: contract research, patenting or spin-off activity. As can be seen in Table 5, the level of scientific productivity is the only variable that is consistently (and positively) related to levels of entrepreneurial activity. Disciplinary scope – and more specifically the presence of an engineering department – matters only for patent activity. Larger universities have more contract research and, to a stronger extent, also more patenting activity; but university size is not related to spin off activity. The latter is affected by TTO size and regional R&D intensity, whereas these variables do not matter for patent activity and contract research. Concerning trade-offs, our hypotheses were not confirmed: the relations between entrepreneurial activities were generally insignificant. A notable exception here is the *positive* relation between contract research and spin offs, suggesting complementarities rather than trade-offs between both transfer mechanisms.

5. Discussion, limitations and directions for further research

Our findings reveal a strong positive relationship between the scientific productivity of universities and their entrepreneurial per-

Table 4
Antecedents of entrepreneurial performance of EU universities.

	Patent activity		Neg. Bin.		Contract research		OLS		Spin off activity		OLS	
	B	SE	Wald Chi-Square	Sig.	*B*	SE	*t*	Sig.	*B*	SE	*t*	Sig.
Intercept	−.766	.4681	2.674	.102	6.568***	.146	45.027	.000	.550***	.143	3.857	.000
Arts and humanities = 0	−.139	.4549	.094	.759	−.036	.144	−.250	.803	−.098	.141	−.694	.490
Medicine = 0	−.031	.4711	.004	.947	.130	.147	.885	.380	−.035	.144	−.243	.809
Engineering = 0	−1.113**	.4670	5.678	.017	−.216	.132	−1.634	.107	−.095	.129	−.733	.466
Science = 0	.017	.5146	.001	.974	.078	.164	.473	.638	−.035	.160	−.216	.829
TTO size	.013	.0192	.484	.487	.005	.006	.826	.412	.018***	.006	2.984	.004
Scientific productivity	.187***	.0559	11.228	.001	.066***	.018	3.578	.001	.033*	.018	1.827	.072
BERD	.039	.2232	.030	.861	.046	.069	.670	.506	.163**	.067	2.421	.018
Academic staff	.000***	.0001	11.126	.001	8.927E−5*	4.802E−5	1.859	.068	9.852E−6	4.693E−5	.210	.834
Spin-offs (residual)	.378	.4451	.722	.395	.388***	.117	3.304	.002	–	–	–	–
Patents (residual)	–	–	–	–	.010	.010	1.072	.288	.014	.009	1.498	.139
Contract Research (residual)	.429	.3988	1.155	.283	–	–	–	–	.371***	.112	3.304	.002
R-square					0.378				0.381			
Adj *R*-square					0.282				0.286			
Likelihood ratio Chi-square	85.437***											
Total obs	76				76				76			

Table 5
Summary of findings.

Antecedent	Contract research	Spin off activity	Patent activity
Size of the university	+	/	+++
Range of disciplines present at university	/	/	Engineering
Scientific productivity	+++	+	+++
Regional R&D intensity	/	++	/
Size of TTO	/	+++	/
Contract research		+++	/
Spin off activity	+++		/
Patent activity	/	/	

formance. Universities with a stronger scientific productivity seem to find themselves in an advantageous position for developing entrepreneurial activities. The findings for contract research suggest that industrial partners do take into account the scientific output of universities as a criterion for selecting academic partners. Moreover, the absence of a significant relationship between contract research and regional R&D intensity fits an interpretation in which such search and selection processes extend beyond regional boundaries. Indeed, previous research has indicated that companies opt for collaborating with academia on research activities of a more basic nature (see also Faems et al., 2008; Belderbos et al., 2004). Our observations seem to support a view on the complementary role of academia and industry in innovation systems, whereby universities' specific role is focusing on the more basic, long term part of the R&D spectrum.

The relation between scientific productivity and spin off activity is significant, but less pronounced. Notice at the same time that, although the direct relationship between scientific productivity and spin off activity is less outspoken, an indirect relationship through contract research becomes apparent. In addition, the R&D intensity of the regional business environment presents itself as a facilitating (external) factor. Comparing the observed relations between contract research and spin-offs suggest that the former is driven more by the distributed efforts of all faculty, while the latter benefits from a more dedicated expert-oriented approach. Notably the positive significant relationship between spin offs and TTO size seems to corroborate such an interpretation.

The strong association between scientific productivity and patent activity is in line with several recent studies addressing this issue on the level of the individual (academic) researcher (see Van Looy et al., 2006). In these studies, the more prolific scientists emerge as the ones who are more likely to patent. A similar relation now seems to hold on the level of universities. Given the variety of legislative framework conditions that still prevail in Europe – with respect to intellectual property rights arising from research funded with public resources – the strength of this observed relationship might even be considered a surprise.

Our findings do not reveal any trade-offs between the different transfer mechanisms. Spin off and patent activities present themselves as unrelated. And while contract research does not directly affect patent activity, contract research and spin off activity turn out to be positively and significantly related. This observation, opposite to what was proposed in hypothesis 2b, seems to suggest that contract research could be instrumental for creating spin off companies. Indeed, engaging in contract research might result in a better understanding of market potential and in the development of adequate business models. As such, contract research might act in a number of cases as an 'incubation' device, leading to spin off creation. At the same time, the presence of spin off companies may yield more contract research opportunities for universities as further development efforts of the newly established firm could become translated into collaborative research and development projects. Clarifying the exact nature of the observed positive relationship between both activities would require panel data covering longer time frames. Collecting such data might also reveal whether and to what extent spin off firms also become involved in patenting activities and create additional (regional) technological and entrepreneurial dynamics.

Future research could focus on additional antecedents on different levels. At the level of the university, a more detailed documentation of the differences in strategic orientation, incentive arrangements and support structures (TTO) would allow for a more quantitative impact assessment of entrepreneurial practices deployed in universities (e.g. Debackere and Veugelers, 2005; Rothaermel et al., 2007). Complementary research efforts could also be geared to documenting and analyzing the impact of (national or regional) innovation system characteristics in which universities are embedded. For the current analyses, we did explore the impact of country dummies in the different models reported in Table 4. Several of these country dummies turned out to be highly significant, suggesting strong differences between European countries on the level of the entrepreneurial performance of universities.[8] To the extent that future research confirms the crucial role of national innovation system characteristics on the entrepreneurial performance of universities, one can envisage considerable opportunities for growth within the European Research Area. If one were to opt for the model that yields the better results – without jeopardizing scientific and educational excellence (see also Nelson, 2004) – higher levels of entrepreneurial activity could be observed. And although the small numbers implied at the level of any individual university would mean that such actions contribute only marginally to the competitiveness of the European knowledge economy, the sheer number of European universities as well as the potential cumulative effect of their efforts might result in a non-trivial contribution. At the same time, it goes without saying that further research is needed to define, document and analyze the consequences of these models. We hope that the research reported here will inspire scholars to further engage in such efforts.

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[8] These findings have not been reported in this paper as the number of universities for certain countries is rather limited; results are available from the authors upon request.

Appendix A. Annex 1: Questionnaire

Name: ____
University + Unit: ______________________________________
Function: ____
Phone: ____________ *Email:* ___________________________

	Arts & Humanities	*Medicine*	*Engineering*	*Sciences*	
Which disciplines are present at your university?	❑	❑	❑	❑	
Can you indicate for each of these disciplines and/or in total:	*Arts & Humanities*	*Medicine*	*Engineering*	*Sciences*	*Total*
Number of Academic Staff (exclude Technical and Administrative staff)					
Number of students					
• Number of Bachelor students					
• Number of Master students					
• Number of PhD students					

Does the university provide post-educational programs / training? Y / N

Does the university have a Technology Transfer Office? Y / N

If so, what is the total number of staff (FTE) working at the TTO? _____________
Which of the following services are being provided by the TTO? *(You can indicate more than one, if applicable)*:

Total staff (FTE):

- ❑ IPR _________
- ❑ Legal Support for Contract Research _________
- ❑ Administrative, Financial and HRM Support for Contract Research _________
- ❑ Spin-Offs _________
- ❑ Other: ____ _________

Is your university actively involved in patenting activities? Y / N

If so, can you give an indication of the number of granted patents with application year between 1991 and 2001 (include both years)? If you cannot distinguish between EPO and USPTO patents, you can provide only the total number of patents.

	EPO	USPTO	Total # patents
Number of patents with university acting as applicant			
Number of patents with university staff member acting as inventor (without university being applicant)			
Total number of university patents			

How many patent applications did your University file in 2002 ? Again, if possible, p between EPO and USPTO applications. If not, please provide the total number.
EPO: _________ USPTO: ___________ Total: _____________

If the University is applicant, is the University itself acting as a legal entity, or are th involved? If so, can you provide the exact and full name of this / these subsidiarie(s *abbreviate.*

____

Can you give an indication of the total amount of contract research at your univers turnover, in Euro) and provide the year for which this amount holds?
Year: _________
Amount: ____________

If precise figures are not available, can you indicate in which of the follow this amount can be situated?

☐ < 1 million euro ☐ 1 - 2.5 million euro ☐ 2.5 - 5 mi
☐ 5 - 10 million euro ☐ 10 - 25 million euro ☐ 25 - 50 m
☐ 50 - 100 million euro ☐ > 100 million euro

What percentage of the total yearly turnover comes from industry? ____

How many spin-offs[1] does the university currently have? ____________________

Do they fit the description given in the footnote? Y / N
If not, how are spin offs defined at your University? ________________
____
____

Does the University act as a shareholder in these spin offs?
☐ In a minority of cases ☐ In the majority of cases ☐ Always

Approximately how many people are employed in these spin-offs? _____
To which industries do these spin-offs belong? And if possible, please st brackets how many of the spin offs belong to this industry.

☐ Food (:________) ☐ Environment (:_
☐ Pharmaceuticals & Biotechnology (:________) ☐ ICT (:_
☐ Machinery and equipment (:________) ☐ Consultan (:________)

[1] An Academic spin-off is a newly established firm based on university-developed knowled the founders is a researcher, assistant or professor of the university, who has participated to the “knowledge”.

Appendix B. Annex 2: Sample of European universities

Germany – Austria	Belgium	France	Scandinavia	Spain
University of Leoben	LUC Diepenbeek	Ezus Lyon 1 - Subsidiary of Univ Claude Bernard Lyon-1	University of Aarhus	Univ. Polytechnica Catalunya
Graz University of technology research	University of Antwerp	University of Nantes	Technical University of Denmark	University Carlos III de Madrid
Agro University Vienna	Vrije Universiteit Brussel	Ecole Polytechnique	University of Southern Denmark	University Politecnica de Valencia
University of Vienna	Gent University	University Pierre et Marie Curie	Upssala University Holding Company	University Politecnica de Madrid
University of Salzburg	Catholic University of Leuven	Télécom de Paris (Ecole nationale supérieure de Télécommunications)	Chalmers University of Technology	University of Salamanca
University of Tuebingen	University of Mons Hainaut	University of Paris 11	Karolinska Institute	Universidad Autonoma de Barcelona
Technische Universität Dresden (TUD)	University of Namur	University of Rouen	Tampere University of Technology	University Santiago de Compostela
University of Karlsruhe	Faculté Polytechnique de Mons	Aix Marseille II	University of Turku	University of Cordoba
Johannes Gutenberg-Universität Mainz	Université Libre de Bruxelles	University of Rennes 1	Lappeeranta University of Technology	University Complutense de Madrid
Ruhr-Universität Bochum	University of Liège	ENSAM	University of Jyväskylä	University of Sevilla
ZFT Universität Freiburg	Université Catholique de Louvain	University of Franche-Comté-Besançon	Helsinki University of Technology	University of Barcelona
University of Stuttgart		University Victor Segalen Bordeaux 2	University of Kuopio	University of Granada
RWTH Aachen		University Avignon	University of Oulu	Universidad Miguel Hernández de Elche
Universität Heidelberg		Inst. Nat. Polytechnique de Toulouse	University of Helsinki	
		Université des Sciences et Technologies de Lille (USTL)		
		University Louis Pasteur (Strasbourg 1)		
		Université de Reims Champagne-Ardenne		
		Paris 7		
		Université de Bretagne Occidentale		

Netherlands	Italy	Greece – Portugal	United Kingdom - Ireland
University of Amsterdam	University of Genoa	National Technical University of Athens	National University of Ireland, Galway
Delft University of Technology	University of Turin	University of Ioannina	University College Dublin
University of Nijmegen	Universita' degli studi di Bologna	Aristotle University of Thessaloniki	University of Nottingham
Technische Universiteit Eindhoven	Università degli studi di Milano	University of Porto	Queen's University Belfast
University of Utrecht	Scuola Superiore Sant'Anna	University of Lisbon	University of Surrey
University of Leiden	Politecnico di Milano	Instituto Superior Técnico, Lisboa	University of Glasgow
Maastricht University	Università di Siena		University of Oxford
Tilburg University	Università di Pavia		University of Warwick
University of Twente	Università degli studi della Calabria		
	Università di Roma "La Sapienza"		
	Politecnico di Torino		

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