The Effectiveness of University Regulations to Foster Science-Based Entrepreneurship

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Abstract

In this study, we analyze the effect of the introduction of university regulations supporting academic entrepreneurship. Using a sample of 611 companies spun-off from the 64 Italian Science, Technology, Engineering, Mathematics and Medicine (STEMM) universities between 2002 and 2012, we show that university regulations in support of academic entrepreneurship have a positive effect on the creation of academic spin-offs. Nevertheless, their effectiveness is conditioned by specific contingencies. First, the characteristics of university departments influence the positive effect of the regulation: in some cases, there is a substitution effect rather than a complementary one. Second, the design of the regulation impacts the decisions of academic staff regarding whether to start a new venture. Finally, the effect of the regulation is maximized four years after its introduction and then becomes less effective. This paper contributes to the debate on the evaluation of policies supporting science-based entrepreneurship.

1. Introduction

A growing body of research examines how universities have become a font of innovation and economic growth by generating entrepreneurial ventures from academic research (Etzkowitz and Klofsten, 2005; Grimaldi et al., 2011). Scholars have largely documented institutional interventions in support of academic entrepreneurship (Clarysse et al., 2005; Rasmussen et al., 2014), focusing on best practices and factors affecting academic knowledge commercialization (Rothaermel et al., 2007; Perkmann et al., 2013), as well as by looking at specific national cases (e.g., Fini et al., 2011) or using cross-country comparative approaches (e.g., Mustar and Wright, 2010). Policy intervention encompasses forms of participation at both the level of the general environment (e.g., governors' laws and actions) and organizational settings (e.g., laws, schemes, regulations, and actions put in place by specific organizations such as universities).

After 40 years of research on forms of policy intervention, however, it is not yet clear if, when, and under what circumstances these interventions are effective in fostering science-based entrepreneurship.

We expand upon prior work on science and public policy by focusing on the effectiveness of university spin-off regulations, which are specific forms of institutional intervention intended to promote the commercial exploitation of research results via the creation of new science-based companies. University spin-off regulations govern the procedures through which spin-off companies are established, thus defining the conditions for and setting boundaries on the formal engagement of academics in these ventures. While university regulations in general have received much attention, only recently have scholars focused on their impact (Sandstörm et al., 2018). Consistent with this stream of research, we add to the understanding of the effectiveness of university intervention in three ways. First, we focus on the impact of the introduction of university regulations that foster entrepreneurship on the number of academic spin-offs established (hereafter academic entrepreneurship), considering how this relation is affected by departmental characteristics. While some university departments' organizational features may reinforce the effect of university regulations in favor of academic entrepreneurship, others may constrain such relationships. Second, the effectiveness of a regulation might depend upon its characteristics. University regulations defining rules and procedures governing the spin-off establishment process vary across universities, and their content and design will be of interest to policymakers seeking to foster better results. Finally, policy effectiveness varies over time. The extent to which the introduction of a regulation is perceived as an incentive – because it defines new conditions and creates organizational legitimacy in support of entrepreneurial practices – varies across universities. Thus, it is important to know how long it takes for a regulation to be effective and come into force.

To address the abovementioned points, we draw on a longitudinal dataset with

information on the 64 Italian STEMM universities (Science Technology, Engineering, Mathematics, and Medicine), their 1,213 departments, and 611 spin-offs between 2002 and 2012. This unique setting allows us to examine the effectiveness of university regulations in fostering the creation of academic spin-offs. We focus on research-producing departments where the potential for commercial exploitation first emerges (Bercovitz and Feldman, 2008). We analyze university spin-offs, which are notable examples of innovative companies (Colombo and Piva, 2012; Hahn et al., 2018). By definition, to the extent that they are tools to commercially exploit research results and are based on knowledge developed within research settings in the forms of academic know-how or IP-based knowledge, they convey state-of-the-art knowledge and frontier research outcomes to the market.

We find that the effect of introducing a university spin-off regulation almost doubles (+80%) the rate of entrepreneurial events per department per year. This effect varies across scientific disciplines and is conditional upon specific department characteristics. First, we observe that the introduction of university regulations is more effective within scientific disciplines that are characterized by better interactions with industry and that display better cognitive proximity to market dynamics; one such discipline is engineering. In addition, the regulation positively affects the creation of spin-offs across departments that are, by nature, less market-oriented, such as social sciences and humanities. Second, a regulation's effectiveness is conditioned by departmental attributes that could generate a complementary rather than a substitution effect. Specifically, the introduction of a university regulation reinforces the positive impact that a wide variety of knowledge (available within single departments) has on academic entrepreneurship. In contrast, it hinders the positive influence that departments' networks of formal and informal relations with industrial partners have on academic spin-off creation.

Analyzing the characteristics and contents of each regulation, we observe that general

rules governing spin-off establishment and the support mechanisms provided by universities positively affect the creation of new companies. On the other hand, the positive effect of the rules regulating the conditions under which academics might engage in entrepreneurship (e.g., addressing conflict of interests) decreases as the rules become more detailed and constrictive on specific issues: for example, setting limits on monetary incentives or on the amount of time spent on the spin-off activity.

Finally, exploiting the longitudinal nature of the data, we find that the effect of the introduction of a regulation is maximized four years after its introduction; after four years, its efficacy decreases. Thus, the introduction of the regulation produces immediate effects in the short-medium run and scant effects over the medium-long term.

This study has implications for several streams of entrepreneurial research. First, we report evidence that university regulations on academic entrepreneurship can facilitate the creation of academic spin-offs, and by examining how the introduction of a regulation interacts with the organizational context, we add to an emerging stream of research that considers the influence of departmental characteristics on entrepreneurial activities (Bercovitz and Feldman, 2008; Kenney and Goe, 2004; Rasmussen et al., 2014). Second, we provide new insights into the effects of academic institutions on entrepreneurship (Fini et al., 2011; Nosella and Grimaldi, 2009). We build on the work of Muscio and colleagues (2016), who provide evidence of the impact of the set of university rules affecting the creation of academic spin-offs. We complement this effort by exploring the effect of regulations' designs at the department level, and we assess how the regulations' variations over time affect academics' engagement in entrepreneurship. Our results not only provide further evidence of the value of studying the characteristics of the regulations but also highlight the need to better understand how regulations should be crafted. Moreover, by assessing the time needed for a regulation to be effective, we provide evidence of the effect of a regulation over time.

2. Institutional intervention and academic entrepreneurship

Institutional intervention takes place at two levels: the general environment and organizational settings. The former describes interventions by governmental and regional administrations/institutions, which occur mainly through laws and support schemes that provide incentives for the establishment of new ventures. The latter refers to the actions implemented by specific research organizations – mainly universities and public research bodies and consortia – to promote the valorization of their own research results through internal support mechanisms, laws, and regulations. In this paper, we focus on the latter.

Institutional interventions in support of academic entrepreneurship have received considerable attention from both economists and policymakers over the last 40 years (Grimaldi et al., 2011; Link et al., 2007). Authors have documented the evolution of policies and institutional support (laws, incentives, governmental programs and schemes) at both the national and regional levels in different countries (Clarysse et al., 2005; Mustar and Wright, 2010; Rasmussen et al., 2014). Nevertheless, the effectiveness of this effort has been, to the best of our knowledge, overlooked. Only recently have scholars started to pay attention to the impact generated by policy interventions in university settings (Sandström et al., 2018).

In this paper, we focus on a specific type of university intervention, namely, the universities' spin-off regulations, conceived to enable knowledge flow from academia to business via the establishment of research-based ventures. University regulations in support of academic entrepreneurship signal a university's entrepreneurial orientation (Phan and Siegel, 2006; Rasmussen and Borch, 2010; Van Looy et al., 2011), define how stakeholders might participate in the commercialization process (Siegel et al., 2003), and establish procedures for the technology transfer process (Muscio et al., 2016). University spin-off regulations create a procedural framework that drives the behavior of scientists and research-based personnel who are willing to commercialize research results by establishing a new company.

Given the limited existing evidence on the effectiveness of university regulations for academic entrepreneurship, we have adopted an exploratory approach: we draw on prior work in the related literature to identify the key factors and potential relationships and to formulate three sets of research questions to guide the subsequent empirical analysis. We first characterize the impact of university spin-off regulations and argue that their effectiveness might vary based on several organizational features of universities at different levels (Section 2.1). We then conjecture how the design of university regulations in support of academic entrepreneurship might affect university entrepreneurial results (Section 2.2). Finally, we focus on and discuss the effectiveness of university spin-off regulations over time (Section 2.3).

2.1. University regulations in support of academic entrepreneurship and their effectiveness

2.1.1. The introduction of university regulations

Following worldwide legislative reforms in the 1980s-1990s favoring the valorization of research results (Fini and Grimaldi, 2017), universities introduced internal mechanisms such as organizational procedures, incentives, and regulations to foster and support academic entrepreneurship in its different forms (Baldini et al., 2006; Geuna and Rossi, 2011). The proliferation of university regulations fostering academic entrepreneurship promoted a shift from a traditional approach that eschewed direct commercial activities to a new approach that focused on knowledge disclosure, patent activities, academic spin-offs, and research collaboration with industry as legitimate and desirable (AUTM, 2006). In the US, the Bayh-Dole Act of 1980 enabled universities to patent inventions funded by federal agencies, challenging the traditional approach that eschewed the direct involvement of universities in the commercialization of research results and encouraging universities to participate in technology transfer activities (Mowery et al., 2001; Mowery and Samp, 2004).

The introduction of university regulations has contributed to the professionalization of activities that encourage the exploitation of research results in various forms (Meyer, 2003; Siegel et al., 2003). University regulations have raised the overall awareness that universities can play an active role in technology transfer, including licensing, patents, university-industry collaborations, the pursuit of research contracts with companies, and academic spin-offs (Mowery and Sampat, 2004; Walter et al., 2016). Thus, in recent decades, universities have reshaped their role, becoming not only generators of new knowledge but also engines of innovation and fonts of new ventures. Not surprisingly, this relevant and new role has attracted the attention of numerous scholars interested in entrepreneurship (O'Shea et al., 2008; Rothaermel et al., 2007; Shane, 2004). In particular, scholars have focused on factors that enable research commercialization (Perkmann et al., 2013) and technology-transfer activities (Djokovic and Souitaris, 2008), with a dominant narrative that accepts the introduction of university regulations aimed at supporting academic entrepreneurship as necessary for the commercialization of research results and as the reason for universities' success in commercializing research through entrepreneurship.

However, these forms of university intervention do not necessarily lead to effective results (Sandstrom et al., 2018), and there are many reasons for this. First, the effectiveness of university interventions is influenced by general environmental characteristics; governmental and regional administrations/institutions (mainly through laws and support schemes providing incentives) affect the success of research results' valorization. Moreover, local contexts in which universities operate offer a more or less hostile/fertile environment for the creation of new companies. The interrelation between the general environment and university-level support mechanisms is not new in the literature (Fini et al., 2011). Second, in addition to the influence of environmental characteristics, the effectiveness of university intervention is correlated with the 'pure' organizational characteristics of universities themselves. Universities

are often articulated organizations with schools, departments, and interdepartmental research units. Each of these organizational units, within a broader organizational setting, can express specific and additional (with regard to the central organization) actions and forms of intervention in support of the valorization of research results. These more 'peripheral' and additional forms of organizational support may generate a more straightforward effect at the department level or within schools and labs or other contexts. Even in this case, organizational contextual characteristics –such as the role of peers, heads of departments, culture and research communities at large in favor of the valorization of research results– are not new in the literature (Bercovitz and Feldman, 2008; Kacperczyk, 2012; Louis et al., 1989; Rasmsussen et al., 2014). Nevertheless, scant attention has been paid to how these parties interrelate with other more general university regulations and, more specifically, with university spin-off regulations.

All this considered, it is no surprise that the evidence is mixed concerning the extent to which the introduction of university spin-off regulations positively affects the creation of research-based companies (Autio and Rannikko, 2016; Cantner and Kösters, 2012; Jourdan and Kivleniece, 2017). This discussion leads to our first research question (RQ1a): *Does the introduction of university regulations (in support of academic entrepreneurship) foster academic entrepreneurship?*

2.1.2. University regulations in the organizational context

Entrepreneurship does not occur in vacuum. The process by which individuals engage in entrepreneurial activities is influenced by the heterogeneous and multilevel nature of the context (Zahra and Wright, 2011). Organizations are arenas for learning because they shape individual-level knowledge and train people for self-employment, offering them a breadth of functional skills that are fundamental to entrepreneurship. New ventures are created around ideas and innovations that individuals may discover inside organizations, and they represent a form of knowledge diffusion from the parent organization to the new venture (Franco and

Filson, 2006). Academics, by being part of an existing research organization, are both exposed to and socialized with a variety of actors—inside and outside the academic context—who may be conducive to entrepreneurship. Thus, universities, like other research organizations (public institutions or private companies), can act as fonts of entrepreneurship (Sørensen and Fasiotto, 2011). Specifically, the organizational features of universities (at different levels) can affect scholars' engagement in entrepreneurship. Among these, at least two should be considered: scientific disciplines and departmental characteristics (Bercovitz and Feldman, 2008; Kenney and Goe, 2004; Perkmann et al., 2013; Rasmussen et al., 2014).

University regulations and scientific disciplines. Variation across scientific disciplines is a relevant factor to consider when attempting to understand the relationships among organizational context dimensions and the existence of university regulations in support of academic entrepreneurship. Scientific disciplines and their communities differ in terms of engagement with industry (Sauermann and Stephan, 2013), the amount of funding received (Link and Scott, 2005, Lockett et al., 2005; Lockett and Wright, 2005), and the nature of the entrepreneurial opportunities (Shane, 2004) that could emerge. These differences affect engagement in entrepreneurial activities and, by extension, the creation of academic spin-offs.

The nature and degree of industry collaborations are generally field-dependent. Applied fields of research, such as engineering-related fields, are more likely to have industry ties and intense collaborations compared to other fields (Bekkers and Bodas Freitas, 2008). Moreover, how knowledge transfer occurs varies across disciplines. For example, in biomedical fields, technology transfer is more patent-based, whereas in the social sciences, knowledge is transferred through personal contacts and labor mobility (Bekkers and Bodas Freitas, 2008). Scientific disciplines also vary in the amount of funding that they attract: disciplines that are better able to attract external funding are more likely to engage in entrepreneurial activities (Di Gregorio and Shane, 2003). Finally, the nature of entrepreneurial opportunities varies across

disciplines. Intense research activity leads to a large stock of research for commercialization, which is directly connected to more entrepreneurial opportunities to exploit (Link and Scott, 2005; Lockett et al., 2005; Lockett and Wright, 2005). In particular, some scientific disciplines, such as engineering and many medical areas, are better suited to generating spin-offs, as they apply their basic research to solve technology-based problems that are translated into industrial solutions and related market applications (Schartinger et al., 2002). A study from Columbia University shows that the majority of spin-off companies come from the software and electronic fields (Golub, 2003). Similarly, Shane (2004) demonstrated that most spin-offs generated by MIT operate in the biomedical industry.

These results support the idea that scientific knowledge across disciplines leads to diverse types of entrepreneurial activities and that some scientific disciplines are more effective than others in generating spin-offs. Thus, we expect that the introduction of a university regulation in support of academic entrepreneurship might have different effects across scientific disciplines. The research question that arises is (RQ1b): *To what extent does the effect of university regulations (in support of academic entrepreneurship) vary across scientific disciplines?*

University regulations and departmental characteristics. Departments represent the work context in which researchers develop their research activities and in which the potential for commercial exploitation emerges. The seminal work of Louis et al. (1989) shows that contextual characteristics, such as local group norms at the department level, have stronger effects on research commercialization than do university regulations and structures. Moreover, more recent studies demonstrate that the level of entrepreneurial activities varies significantly across departments (Bercovitz and Feldman, 2008). Building on the contribution of Sørensen and Fasiotto (2011), we focus on two department characteristics that can explain different levels

of engagement in academic entrepreneurship: a) departments' variety of knowledge and b) departments' closeness to industry (networks of relations with industries).

Departments' variety of knowledge refers to the departments' orientation/ability to act as contexts in which different types of knowledge are created, pulled in, shared, and internally socialized so that knowledge heterogeneity becomes the essence (and a common background) of all department affiliates, regardless of the specific discipline-based expertise that each individual conveys. Thus, departments can shape the skills and knowledge that faculty members leverage and create ideal conditions for entrepreneurial ideas to emerge (e.g., to be voiced, developed, and implemented). To the extent that departments offer different perspectives, they can not only influence the development of an entrepreneurial mindset (i.e., a holistic view of problems and solutions to a given research input) but also offer/bring in the various types of expertise required to implement entrepreneurial ideas (i.e., expertise in a given field matched with an understanding of other perspectives, applications in new fields, market dimensions, etc.). Moreover, departments shape individual tasks and roles (and the extent to which they are broadly versus narrowly defined) in the work context and therefore influence the range of knowledge and skills that individuals acquire. In departments characterized by higher levels of interdisciplinarity, academics could be expected to develop a wider range of skills and knowledge (by being continuously exposed to diversity), and this may have a positive influence on academic entrepreneurship.

The second aspect to consider is the department's closeness to industry, which represents the network of relationships with players external to a given university, including industry, other universities, and/or research centers. These relationships can be institutionalized by departments or through formal agreements or can be the output of more informal approaches involving individual faculty members and their personal networks with the outside. Networks are necessary for entrepreneurship to occur. Viable networks are those that offer individuals

access to information and opportunities for innovation and new venture creation; these networks facilitate entrepreneurs' ability to secure the assets to start a new venture and develop behavioral control of their resources. Such networks are particularly relevant for academics, who mainly generate and cultivate research-based relations over their academic lives and might have few relationships with firms and other outside players who could trigger and support entrepreneurship in terms of favoring the creation, growth, and success of newly established companies. Relations with industrial partners might act not only as fonts of ideas and solutions to problems and challenges that arise but also as sources of support (complementary resources, knowledge, skills, and funding). Individuals with an important network of relations with industrial partners are, in general, more likely to receive external funds to exploit technological knowledge (Perkmann et al., 2013).

There is scant evidence about how university regulations in support of academic entrepreneurship are either reinforced or constrained by local practices. Thus, it is not clear whether and to what extent university regulations and departmental characteristics act as complements or substitutes. The enactment of top-down regulation can be perceived as a tool that regulates and supports entrepreneurial behaviors that spontaneously occur within departments, or it might signal an excess of bureaucracy and institutional commitment that might negatively affect the start-up process. Thus, the research question that guides our empirical analysis is (RQ1c): *Does the introduction of university regulations (in support of academic entrepreneurship) act as a complement to or substitute for the positive effect that a high variety of department knowledge and closeness to industry have on academic entrepreneurship?*

2.2. Design and characteristics of university regulations in support of academic entrepreneurship

The design of university regulations sets the rules and procedures that regulate the university spin-off process, which might affect university performance in relation to spin-off creation (Muscio et al., 2016; Salvador, 2009). In particular, the adoption of specific rules determines the conditions under which academic staff might decide to pursue (or not) the intention to start a new venture.

Muscio et al. (2016) analyzed Italian university regulations along three classes of rules framing spin-off creation. The first class regards *general rules and procedures* that guide the process of founding a new spin-off and the support provided by universities (e.g., the academic commission that is in charge of evaluating spin-off proposals, support with business plan development). The second class encompasses rules regulating *monetary incentives*, which describe the procedures governing the share of revenue and equity ownership, along with some fiscal requirements (e.g., managing conflicts of interest, requirements for full- vs. part-time employees). Finally, the third class refers to those rules affecting *entrepreneurial risk*, which assess how entrepreneurial risk is shared between academic entrepreneurs and their universities. The classification by Muscio and colleagues (2016) is useful to understand which characteristics of the regulation are more effective in fostering academic entrepreneurship and which aspects inhibit academics from engaging in the creation of new companies. In particular, the existence of general rules for the creation of academic spin-offs is positively associated with university performance in generating spin-offs. By contrast, rules regulating conflicts of interest, such as those setting limits on the revenues that the spin-off can obtain from the parent university, might be obstacles to the creation of new spin-offs (Muscio et al., 2016).

These findings suggest that the design of regulations and their actual content might affect academics' engagement in entrepreneurial activities. This discussion leads to the second research question (RQ2): *How do the designs of university regulations (in support of academic entrepreneurship) affect academic entrepreneurship?*

2.3. University regulations in support of academic entrepreneurship over time

As explained above, assessing the effectiveness of institutional intervention by universities is challenging. In addition to the aforementioned reasons, it generally takes time before institutional intervention produces the desired results.

An important example with which to better understand the role that time plays in policy effectiveness is the introduction of the Bayh-Dole Act of 1980 in the US. This policy initiative drastically changed the way in which universities transfer and commercialize knowledge and new technologies created inside their research laboratories (Grimaldi et al., 2011). Forty years after the introduction of the Bayh-Dole Act, the debate regarding the effectiveness of this policy intervention remains vibrant. On the one hand, many scholars and policymakers recognize the Bayh-Dole Act as an engine of universities' innovations and economic contributions and an important factor in the unique economic development of the US in the late 1990s. On the other hand, some suggest negative consequences of the implementation of this policy, for example, the destruction of the open culture of science (Welsh et al., 2008). Overall, there is little evidence as to whether the Bayh-Dole Act had negative consequences for academic research, and the data needed to monitor such effects are limited. Moreover, to observe changes in how universities and researchers act, a long study period is needed, calling for longitudinal approaches.

Additionally, normative approaches may require significant time to take effect when they are designed to change (even if incrementally) organizational practices that are consolidated and harmonized in the routines of the organizations themselves. This is the case for many universities around the world, for which external engagement (and its regulation at different levels) may represent a threat to the extent that it challenges existing and effective organizational practices. This may be particularly relevant for universities, most of which have existed for centuries driven mainly by two primary objectives: education and research.

Depending on the field, these two objectives have been internalized in different ways by schools, departments, and their affiliated individuals. Over the years, they give rise to diverse patterns of behavior. The span of time for normative approaches to be internalized within organizations depends on different factors, including organizational features (culture, identity, path dependency, etc.) and the influence of the general environment and its evolution over time (Hannan and Freeman, 1977). Additionally, the effect of normative approaches might not have one specific, straightforward direction over time. It could produce immediate effects in the short run and scant effects over the medium-long term.

Only a few policy initiatives track results over time, systematically, and for enough time to enable an impact evaluation (Autio and Rannikko, 2016). These challenges lead to several limitations for policy evaluation, and evidence on the effectiveness of regulations in favor of academic entrepreneurship is virtually nonexistent. Thus, our last research question is meant to explore the timing through which university intervention generates impact. We aim to answer the third research question (RQ3): *How many years does it take for university regulations (in support of academic entrepreneurship) to be effective?*

3. Data and methods

3.1 Research design

We focus on the Italian context, targeting the 64 STEMM universities (i.e., universities with at least one department/school that specializes in Science, Technology, Engineering, Mathematics, and/or Medicine) and their 1,213 departments, between 2002 and 2012. The start and end dates coincide with two major policy changes that occurred in Italy: a) the introduction of Law 297 in 1999, which granted universities autonomy to support technology transfer (TT) activities (before 1999, universities had no role in managing TT activities); and b) the establishment of the 'national scientific qualification' in 2012 – that is, a certification of

eligibility for academic professorship granted by the Ministry of University and Research (this changed academics' incentives to engage in TT activities, which are now one of the criteria for the certification).

Regarding the former, the introduction of Law 297/1999, which concerns the 'reorganization of the discipline and streamlining of the procedures for the support of scientific and technological research,' has increased university autonomy in the definition of specific regulations to support TT activities. Law 297 /1999 introduced a new regulatory framework for activities promoting the diffusion of industrial research, such as the creation of spin-offs for the exploitation of research results by academics and university staff. However, this national-level regulatory framework did not provide specific guidelines for its implementation at the university level. Hence, since early 2000, consistent with the framework provided by Law 297, Italian universities started introducing their own set of regulations in support of academic entrepreneurship, such as spin-off regulations and IP university regulations. In particular, the spin-off regulation (i.e., "Regolamento Spin-off") is a text document of approximately 10 pages and regulates the process of spin-off creation. The spin-off regulation rules a) the relationship between the position of a professor and the time spent in a spin-off firm; b) potential conflicts of interest; c) the management of intellectual property rights; d) the nature of the university's participation in the spin-off in terms of equity capital; and e) the level of support that can be expected from universities throughout the entrepreneurial process (Salvador, 2009). Once released, the regulation can be subsequently modified as often as needed. The university spin-off regulations from the 64 STEMM universities have been downloaded from universities' websites (if not available, we inquired with their research offices). Table 1 shows the distribution of the introduction of spin-off regulations over the observation period across the 64 STEMM universities. The first spin-off regulation was introduced in 2002 (at the University of

Florence), and the last was introduced in 2012 (at the University of Insubria). As of 2012, eight universities had no spin-off regulations in place.

Regarding the second policy change, since 2012, as a result of a major change in the Italian university recruitment system, academics, to be eligible for professorships at Italian universities, need the 'national scientific qualification' (i.e., a certification of eligibility granted by the Ministry of University and Research - MIUR). One of the criteria, among others, used by MIUR evaluators to judge STEMM candidates is the extent to which academics have engaged in technology transfer and academic entrepreneurship-related activities (Bagues et al., 2017). Therefore, since 2012, Italian academics may have strong individual incentives to engage in science commercialization activities.

These two major legislative changes make the Italian normative context between early 2000 and early 2010 quite homogenous, exposing universities, their departments, and the academics employed in them to a similar set of individual incentives and institutional influences.

Table 1 About Here

3.2. Sample

To answer our research questions, we need longitudinal data at both the university and department levels. Via the official website of the Italian Ministry of University and Research (MIUR) (http://nuclei.miur.it/sommario/ and http://cercauniversita.cineca.it/), we retrieved time-variant information on universities' and departments' characteristics for the 64 Italian STEMM universities, as well as the first and last names, and university affiliations, of faculty members who were employed between 2002 and 2012.

Data on new firms created by academics (i.e., academic spin-offs) were collected by contacting, since 2006, each university's Technology Transfer Office (TTO) as well as

NETVAL (www.netval.it), the association of Italian universities and research centers' TTOs. The list has been updated annually. Academic spin-offs are companies created to commercially exploit knowledge produced within universities through research activities; they must have at least one academic faculty member among the founders (Wright et al., 2004). Universities can have shares in academic spin-off companies.

Extant research shows that academic spin-offs are highly innovative firms that may achieve better innovative performance vis-à-vis start-up companies not linked to university labs (Colombo and Piva, 2012). As of 2017, approximately 33.4% of Italian innovative start-ups[1] were established by academics (Italian Ministry for Economic Development, 2017).

Via the Italian Companies House database (https://telemaco.infocamere.it/), for any given academic spin-off, we downloaded the year of incorporation and the time-variant ownership structure. Individual owners have been linked to the list of faculty members employed at Italian universities via first and last names. The few cases of homonymy have been manually disambiguated.

As a result of the aforementioned procedures, we identified 611 academic spin-offs that were established from the population of Italian STEMM universities between 2002 and 2012. Because of the inclusion of lagged variables in the econometric specifications and as a result of the merging of some departments over the observation period, the final sample includes 605 spin-offs from 1,213 departments, resulting in an unbalanced panel of 11,787 department–year observations.

[1] In 2012, the Italian Government introduced the Start-up act (Decreto Legge 19/2012) to support the creation and growth of innovative start-ups. To be innovative, a start-up shall develop, produce, and trade innovative goods or services having a high technological value, and such activities should represent its exclusive or prevailing core business. Moreover, to be innovative, a start-up should meet at least one of the following alternate requirements: (1) the costs allocated to research and development must be equal to or higher than 20% of the higher value of either (i) the company's production costs and (ii) the company's production value; (2) at least one-third of its work force shall be represented by individuals having a PhD or carrying out a PhD, or having a degree and having completed a research program of three years at public or private research entities in Italy or abroad; or (3) the start-up shall be the owner or assignee, or have applied for registration with the relevant authorities, of an industrial property right (i.e., a patent) related to its core business.

Dependent variable

Entrepreneurial events. Our dependent variable was operationalized as a count variable that, for any given year between 2003 and 2012, was equal to the number of spin-offs established in a given department. When a spin-off was co-founded by academics from different departments, the spin-off was assigned to all the departments involved. The total number of entrepreneurial events in the period 2003 to 2012 was equal to 635. The variable ranges between 0 and 3: 88% of entrepreneurial events occurred after the introduction of the spin-off regulations.

Explanatory variables

The explanatory variables were measured on a yearly basis from 2002 to 2012. We identified three sets of variables that characterized universities, departments, and regulations.

Presence of university spin-off regulations. To test our first research question (i.e., RQ1a: What is the effect of the introduction of spin-off regulations?), we operationalized the introduction of the spin-off regulation as a dichotomous variable that switches from 0 to 1 in the year in which the regulation was introduced in the university for the first time. The variable was lagged one year and remained equal to 1 until the end of the observation period. We expect that the introduction of a spin-off regulation will positively affect academics' spin-off creation.

Department scientific discipline. Consistent with the European Research Council classification, we classified the department as conducting research in Life Sciences (LS), Physical and Engineering Sciences (PE), or Social Sciences and Humanities (SH). We expect to see between-discipline variation in predicting entrepreneurial events. This variable was used to test RQ1b (i.e., To what extent does the effect of university regulations vary across scientific disciplines?).

***Department variety of knowledge*.** To measure the extent to which the interdisciplinarity of the department may affect spin-off creation, we used one minus the

Herfindahl index, a standard approach that provides a sense of how diversified the department is (Garcia-Vega 2006; Slavova et al., 2016). We built this variable using the classification of 184 research domains provided by the Italian MIUR. Hence, for each department, the variety of knowledge was calculated as follows. With 184 research domains indexed by j=1..,184, if the "i" department had Ni academics, each academic was assigned to a research domain. Nij denoted the number of academics that the "i" department holds in category "j" such that $\sum_{j=1}^{184} Nij = Ni$. The variety of knowledge was calculated for each department and year as: $1 - \sum_{j=1}^{184}(\frac{Nij}{Ni})$ 2. The variable was lagged one year and ranged between 0 and 1, such that larger values corresponded to greater variety. We expect that the greater the variety of knowledge, the greater the number of entrepreneurial events.

Department closeness to industry. To measure the extent to which a department was more proximal to industry, we created a variable that accounted for the Euro amount (in thousands) of funds received by the department from contracts acquired from firms in any given year. The variable ranged between 0 and 1,650 and lagged one year. We hold that the higher the level of funds from industry contracts, the closer the department to industry, and the higher the number of entrepreneurial events.

Department variety of knowledge and department closeness to industry have been used to investigate RQ1c (i.e., Does the introduction of the university act as a complement to or substitute for the effect of department knowledge and closeness to industry on academic entrepreneurship?).

Spin-off regulation characteristics. To test our second research question (i.e., How do the designs of university regulations affect academic entrepreneurship?), consistent with the work by Muscio et al. (2016), we analyzed the text of any given spin-off regulation: the 56 first releases and the 35 modified ones. Hence, we focused on 91 documents, addressing three main conceptual domains. The first domain, which we labeled 'general rules and procedures,'

captured the support provided by the university to academics during the start-up process. Specifically, it addressed the following topics: the presence of a spin-off commission that was tasked with evaluating spin-off proposals, the management of potential conflicts of interest, and support for business-plan development. The second domain, labeled 'monetary incentives,' characterized the procedures regulating the share of revenues and equity ownership, and it also listed some fiscal requirements (e.g., being employed at universities on a part-time basis). Finally, the third domain, which we referred to as 'entrepreneurial risk,' related to university-defined procedures that may increase academics' entrepreneurial risk when creating a spin-off: for example, responsibility for financial losses or limitation of research contracts with the parent university (see Table 2 for the full list of domains and topics addressed and their definitions).

Hence, for each regulation, we coded the comprehensiveness of any given domain, also measuring the extent to which it varied across years. For any given domain, we created a variable resulting from the sum of the topics corresponding to the domain. The three variables were labeled 'General rules and procedures,' 'Monetary incentives,' and 'Entrepreneurial risk,' and their values ranged between 0 (no topics characterizing the domain were included in the regulation) and 3 (all topics characterizing the domain were included in the regulation).

Number of years since the introduction of university spin-off regulation. To test the third research question (i.e., RQ3: How many years does it take for university regulations to be effective?), we created a variable that counted the number of years since the introduction of the spin-off regulation (the value at the time of introduction was set to 0). The variable ranges between -9 and 11 (negative numbers reflect years prior to regulation introduction).

Insert Table 2 About Here

Control variables

We controlled for several factors at both the university and department levels that may predict firm creation. All variables were measured at time *t*, with the only exception being the department's entrepreneurial rate, which was lagged one year.

At the university level, prior work shows that the existence of a university TTO affects the creation of spin-offs (Bercovitz and Feldman, 2008; Lockett and Wright, 2005; Muscio et al., 2016). Accordingly, we specified a dummy variable, *TTO presence*, that switched from 0 to 1 in the year in which the TTO was established. If the TTO was established before 2002, the variable takes the value of 1 throughout the whole observation period.

We controlled for the *university's research eminence*. Numerous studies have argued that academic involvement in science commercialization is affected by the university's research performance (Cohen et al., 2002; Rasmussen et al., 2014; Renault, 2006; Perkmann et al., 2013). In particular, research shows the existence of a link between research productivity and the number of new ventures generated by academics (Di Gregorio and Shane, 2003; Powers and McDougall, 2005). Hence, we collected data concerning university performance from the Italian Universities Rank by Repubblica (www.repubblica.it), focusing on the years 2002 to 2011.

We also controlled for the ability of any given university to attract public research money. Hence, for any given year, we counted the number of grants for basic research that universities received (*Grant acquisition*) from the Italian Ministry of University and Research (PRIN funding scheme).

For the departmental-level controls, we accounted for the number of academics employed in any given department (*Department size*). We also controlled for the *Promotion rate*, dividing the number of academic promotions in the department in year *t* by the number of faculty members employed in the department in the same year. Finally, to proxy the entrepreneurial culture of the department, we created a variable (*Entrepreneurial rate*) that

counted the number of academics in the department who have established a spin-off up to year *t*-1, dividing it by the number of academics employed in the department up to year *t*.

4. Analysis and results

We employed several techniques to test the proposed relationships. For the multivariate analysis, given the count nature of our dependent variable, we used a Poisson regression approach (Green, 2000). We preferred a Poisson specification over a negative binomial specification because we did not observe severe over-dispersion in the data. We used a longitudinal random-effect Poisson specification to model the number of academic spin-offs by department, accounting for year, regional, and university fixed effects.

Table 3 reports the descriptive statistics, and Table 4 reports the pairwise correlations of variables included in the models. The presence of a spin-off regulation at the university level was positively and significantly correlated with the number of entrepreneurial events in the department (0.056). Furthermore, both departmental variety of knowledge and closeness to industry were positively and significantly correlated with academic entrepreneurship (0.086 and 0.089, respectively).

Insert Tables 3 and 4 About Here

4.1. Regression analysis results

Table 5 shows the results of the hierarchical regression analysis used to test RQ1a,b,c. Per the university-control variables, the presence of a TTO and the university's research eminence had a positive and statistically significant effect on entrepreneurial events. These results are in line with prior research that demonstrates the importance of the TTO and the relevance of university standing for new venture creation (e.g., Lockett and Wright, 2005; Bercovitz and Feldman, 2008). Similarly, department size, promotion rate, closeness to industry, and variety of

knowledge positively predicted entrepreneurship. These results were robust throughout the different specifications. The results in Model 2 provided an answer to RQ1a. Specifically, the introduction of spin-off regulations increased the number of entrepreneurial events by 80%. The effect of the introduction of spin-off regulations on entrepreneurial events increased from 0.033 to 0.06 (predicted values estimated by keeping the other covariates at observed values – results not included in the exhibits).

Theory also suggests that the effectiveness of regulation may vary across disciplines and be conditional on some departmental characteristics (RQ1b). Accordingly, we first investigated between-department heterogeneity, contrasting departments that conduct research in medicine, pharmacy, and biology (LS), engineering and physics (PE), and social and economic sciences and humanities (SH). Descriptive evidence suggested that of the 635 entrepreneurial events, approximately 17% occurred in LS (107), 72% in PE (456), and 11% in SH (72). The introduction of spin-off regulations may indeed have had different impacts depending on the departments' scientific natures. Model 3 and Figure 1 suggest that this effect was pronounced in physics and engineering (PE) departments, with an approximately 100% increase (from 0.054 to 0.1 and significant), and in social sciences and humanities (SH), with an approximately 130% increase (from 0.008 to 0.019 and significant); by contrast, there was no effect in life sciences (LS) (from 0.038 to 0.046 but nonsignificant).

Second, Models 4 to 6 suggest that the presence of spin-off regulations substitutes for closeness to industry (RQ1c). Specifically, as shown in Figure 2, in departments distant from industry (Closeness to industry = 0), the effect of the presence of spin-off regulations was 100% higher vis-à-vis departments in which spin-off regulations were absent. This effect tended to diminish as the department's closeness to industry increased (no differences were recorded for departments with a closeness to industry above 200). By contrast, the positive effect of spin-off regulations was magnified in departments characterized by a high variety of knowledge. For

departments with a variety of knowledge equal to 0.6, the effect of the presence of spin-off regulations was 45% higher vis-à-vis departments in which spin-off regulations were absent, and it increased as the variety of knowledge increased (150% higher when variety was at its maximum).

Insert Table 5 and Figures 1, 2, 3 About Here

To test RQ2, we accounted for within-regulation heterogeneity, coding the extent to which each spin-off regulation addressed aspects related to support, risk, and incentives. The rationale for this was that some regulation characteristics, vis-à-vis others, may have greater or lesser impact on spin-off activities. In Table 6, Models 7 to 10, we tested for the effects of the comprehensiveness of regulations on entrepreneurial events.

Specifically, we interacted with the presence of regulations with the extent to which the three regulation domains – namely, 'General rules and procedures,' 'Monetary incentives,' and 'Entrepreneurial risk'– were in place. We measured the comprehensiveness of any given domain on a scale from 0 to 3. Regulation domains could not exist before the introduction of the regulation; hence, in the specifications, we reported the coefficients for the interacted variables only. Model 7 tests the effect of the comprehensiveness of the 'General rules and procedures' domain. The results plotted in Figure 4a show that, conditional upon having a spin-off regulation in place, there was no positive incremental effect of either including or emphasizing that domain in the regulation (i.e., predicted values of regulations in the 'General rules and procedures' domain equal to 1 or above did not differ from the values of regulations with 'General rules and procedures' domain equal to 0). Using a similar approach, we tested the effect of the 'Monetary incentives' domain. The results from Model 8 and Figure 4b suggest that the greater the comprehensiveness of that domain, the lower the number of entrepreneurial events. In particular, if the 'Monetary incentives' domain is introduced, the positive effect of

the presence of spin-off regulations drops from 0.064 to 0.028. Finally, the results of Model 9 show a similar pattern for the comprehensiveness of the 'Entrepreneurial risk' domain, with a drop in the impact on entrepreneurial events from 0.076 (domain not included in the regulation) to 0.047 (two items related to entrepreneurial risk included in the regulation). Model 10 exhibits the fully specified model.

Insert Table 6 and Figure 4a, b, c About Here

Finally, consistent with RQ3, we investigated the number of years needed for the university regulation to be effective. Hence, we tested the linear and quadratic effect of the variable 'number of years since the introduction of the regulation' on the selected dependent variable. Model 11 exhibits a positive but not significant effect, whereas Model 12 suggests a curvilinear effect. Specifically, the predicted values plotted in Figure 5 suggest that the effect was maximized (equal to 0.06) 4 years after the introduction of the regulation. To validate the presence of an inverted U-shape, we followed Lind and Mehlum (2010), testing whether the relationship increased at lower values and decreased at higher values. In our case, the slope at the lower bound (-9) was 0.21 ($p < .01$) and at the upper bound (11) was -0.11 ($p < .05$), resulting in a significant test for the presence of an inverted U-shape (t-value = 1.88; $p < .05$). Furthermore, the estimated turning point (4) was within the 95% Fieller interval for the extreme point [0; 11].

Insert Figure 5 About Here

4.2. Robustness checks

To further corroborate our results, we implemented several robustness checks that confirmed the results presented in the main analysis.

For RQ1, for the two time-variant boundary conditions (i.e., closeness to industry and variety of knowledge), we replicated the analysis in Table 7 using both linear (Models 13-16) and Poisson (Models 17-20) department-fixed effects estimators.

For RQ2, in Table 8, we used different operationalizations for the three variables characterizing the regulation's comprehensiveness: namely, 'General rules and procedures,' 'Monetary incentives,' and 'Entrepreneurial risk.' First, in Model 21, we focused on the first regulation release only (56 documents), and for each of the aforementioned domains, we created three dummy variables that took the value of 1 if the regulation text addressed at least one topic related to the specific domain, 0 otherwise. Second, in Model 22, we used the same operationalization for all releases (91 documents). Hence, the dummy variables were coded in a time-variant fashion. Last, in Model 23, consistent with the operationalization used in the main analysis, we characterized the three domains as continuous variables, the only difference being that in the robustness check analysis, we focused on the first regulation release only. In contrast to the procedures followed in the main analysis, this variable was time-invariant.

For RQ3, to corroborate the main results, in Models 24 and 25, we ran the analysis including the department–year observations for which the regulation was in place (i.e., number of years since the introduction of the regulation equal to or higher than 0). The sample size dropped to 9,162, but the results were confirmed.

Finally, we ran all main models used to test RQs1, 2, and 3, using as dependent variables two operationalizations of entrepreneurial events: a) the number of academics who have established an academic spin-off in each department-year (N = 949) and b) the number of academic spin-offs that were founded and/or joined by academics (i.e., acquiring shares) in each department-year (N = 675). The results are robust and are available upon request from the authors.

Insert Tables 7 and 8 About Here
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5. Discussion

Prior research has produced mixed evidence concerning the extent to which the introduction of university regulations in support of academic entrepreneurship has a positive effect on the creation of academic spin-offs (Autio and Rannikko, 2016; Cantner and Kösters, 2012; Jourdan and Kivleniece, 2017). In this study, we observe that such 'likely' effects are conditioned by specific contingencies.

Using a unique sample of 1,213 departments active in social sciences and humanities, physical and engineering sciences, and life sciences, we provide evidence of the positive effect of the introduction of a regulation in support of academic entrepreneurship. Through a fine-grained analysis of organizational characteristics, we show that the intensity of such a positive effect is conditioned by certain contingencies that influence the direct effect of introducing new university regulations; in some cases, we observe a substitution effect rather than a complementary one. Specifically, our results show that the spin-off regulation's effectiveness varies across scientific disciplines, and it is more effective within scientific disciplines with a greater market orientation and industry ties (e.g., engineering). Moreover, the extent to which a spin-off regulation is more or less effective depends on particular department characteristics. The results indicate that university regulations complement the positive effect that a high variety of knowledge within departments has on academic entrepreneurship, whereas the regulations substitute for the positive influence that departments' networks of formal and informal relations with industrial partners have on spin-off creation. Moreover, examining the characteristics of the regulations, we observe that the design and content deserve specific attention to achieve better results in terms of new spin-off creation. Finally, the regulations

produce effects immediately after their introduction and reach peak effectiveness at 4 years, after which they tend to be less effective.

Our results provide insights into two related streams of literature. First, there is an important stream of research that focuses on university practices and regulations in order to understand the impact that they have on academic entrepreneurship and, in particular, on spin-off creation (Colombelli et al., 2016; Fini et al., 2017; Muscio et al., 2016; Nosella and Grimaldi, 2009; Rasmussen and Borch, 2010). We contribute to this conversation by demonstrating the boundary conditions of the widely theorized positive effect of the introduction of university regulations supporting academic entrepreneurship. In doing so, we add nuance to the conclusions of Rasmussen et al. (2014), which show how the university department context influences the spin-off process. Specifically, we provide evidence that university regulations in favor of academic entrepreneurship are either reinforced (complement) or constrained (substitute) by local practices within departments. Our analysis shows that when institutional factors come into play (e.g., the introduction of regulations at the university level) in departments characterized by intense relations with industry, the positive effects of the regulation decrease. In these contexts, university regulations can introduce bureaucracy and force scientists to conform to specific guidelines and a given set of rules. Bureaucracy may influence the attitudes and mental disposition of employees, lowering the perceived expected value of entrepreneurial opportunities and making individuals less inclined towards entrepreneurial entry (Sørensen,2007).

Our results also inform the literature that focuses on the effects of academic institutions on entrepreneurship (Fini and Toschi, 2016; Muscio et al., 2016; Nosella and Grimaldi, 2009). One key insight is that the design of regulations affects the creation of academic spin-offs. Specifically, as regulations change over time, becoming more comprehensive by setting more limitations and precise conditions for spin-off creation, the positive effect on the number of

spin-offs created decreases. Thus, regulation design is a strategic tool that can influence spin-off creation over time. Regulations should be crafted with awareness of the effects of specific incentives, limitations, and diverse areas and in relation to personal economic benefits as well as the use of university laboratories and infrastructures and, generally speaking, conflicts and interactions with affiliated departments.

5.1. Implications for policy

Our findings offer some practical recommendations for policymakers in charge of designing effective mechanisms in support of spin-off creation.

First, our results show that the organizational settings (departments in our case) might influence the effectiveness of regulations. Entrepreneurship policy strategies should be tailored to and crafted based on specific institutional contexts (Minniti, 2008; Wagner and Sternberg, 2004), and the application of university regulations should follow the same rationale, tailoring entrepreneurial strategies to specific organizational settings. Departments (and/or other organizational settings) can work within their boundaries to create conditions to maximize the likelihood of regulations' efficacy. Central divisions should work in cooperation with peripheral organizational units (departments) to craft strategies and put actions in place that complement existing regulations and thereby address the perception of obstacles that academics affiliated with specific departments may experience, thereby encouraging engagement. A better focus on communication and dissemination could help. To this extent, even the heads of departments can facilitate effective dissemination of information related to regulations and promote complementary actions in support of entrepreneurship.

Second, our results show that university regulations fostering academic entrepreneurship may indeed have different impacts conditional on departments' scientific natures. Scientific disciplines with a greater market orientation and industrial collaborations are more likely to be involved in academic entrepreneurship, and we observe that, for these

disciplines (e.g., engineering), the introduction of the regulation is highly effective. Moreover, our results show a positive but weaker effect for other scientific disciplines, such as social sciences and humanities. We suggest that for these latter cases, universities should introduce new formal processes and additional support schemes by creating comprehensive strategies that focus on the importance of transferring knowledge through the creation of new ventures rather than just implementing isolated regulations.

Third, we account for some within-regulation heterogeneity, coding the extent to which each spin-off regulation addresses aspects related to support, risk, and incentives, which have variable impacts on spin-off activities. Specific norms in terms of risk and conflict-of-interest management reduce the effectiveness of spin-off regulations. It is possible that some of these rules are mandatory for academic institutions insofar as they conform to public organizations' local ordinances or national laws. Others may reflect choices of specific universities (e.g., the university's priorities for taking equity in a new venture; the percentage of equity ownership) and, as such, they can be more easily changed to maximize a regulation's effectiveness. It is also true that a proper analysis should account for the impact of the regulations and their content, not only on the quantity of spin-offs generated but also on the quality (Fini et al., 2017). Specifically, evidence shows that an important number of Italian academics' spin-offs were created to conduct research or consult with fewer limitations than within the university context (Muscio et al., 2016). Thus, we might expect that setting more constraints could inhibit the total number of spin-offs created but have a positive effect on their quality. Moreover, ceteris paribus, the effectiveness of the regulations may also vary based on the type of knowledge to be spun off – IP-based knowledge vs. non-IP-based knowledge, tacit vs. more codifiable – and codified knowledge could generate differences in the process of new venture creation.

Last but not least, the effect of regulations seems to peak around the fourth year, after which there is a decline in terms of effectiveness. Universities should carefully consider new releases

of internal regulations (which they normally do) as well as the 'ideal' timing for introducing changes.

5.2. Limitations and implications for further research

This study is not without limitations. Our research speculation and related research questions address issues that are still debated and generate controversial answers; we believe that our research introduces new elements to the conversation.

Generally, the assessment of university regulations and their performance is an articulated exercise, given that the entry decision (on the academics' side) is affected by other dimensions as well, such as local context factors (supportive ecosystem, availability of other complementary support mechanisms, etc.), and additional forms of support at the university level (proof of concept funding, incubator policies, specific training, and support during business development, etc.). Consequently, a comprehensive analysis should take all of these factors into account (to different degrees).

In addition, this study is based on the Italian context, which presents certain peculiarities compared to the more widely studied US and UK contexts. First, the spin-off phenomenon is relatively young in Italy; second Italian spin-offs are mainly based on services, and most of them may represent a way to continue a certain research project, with only a few spin-offs based on patented inventions (Netval, 2013, 2014); third, Anglo-Saxon countries have more experience with technology transfer activities compared to Italy and most European countries (Gibb and Hannon, 2006). Thus, our findings are particularly relevant for countries such as Spain, France, and Ireland (Western European Countries), where universities are relatively less experienced in terms of academic knowledge transfer and have the same autonomy in assessing regulations to foster knowledge commercialization.

The issue of the quality of companies remains open and relevant. The effectiveness of institutional intervention should also consider the nature of companies created and their

evolution over time or, at least, their different potentials at the time of establishment. Thus, future research should examine how the introduction of university regulations influences spin-off performance. Moreover, we encourage more exploration of the effects of academic engagement in entrepreneurship on the nature and quality of academics' scientific production and department performance (Fini et al., 2019)

6. Conclusion

This study aims to reveal how the introduction of university regulation (in support of academic entrepreneurship) affects spin-off creation, and we believe this study has one of the most robust designs yet implemented for the study of the impact of entrepreneurship regulation initiatives. We show that spin-off regulations are effective, but their effectiveness varies depending on several contingencies, such as characteristics of the organization, specific content in a regulation, and time. These aspects should be taken into account by policymakers seeking to design effective entrepreneurial policy.

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TABLES AND FIGURES

Table 1: Introduction of spin-off regulations over years

Year	Number of Spin-off regulations introduced	Cumulative number of Spin-off regulations introduced
2002	9	9
2003	9	18
2004	6	24
2005	4	28
2006	8	36
2007	7	43
2008	4	47
2009	3	50
2010	2	52
2011	2	54
2012	2	56

Note: N=64 STEMM Universities.

Table 2: Spin-off regulation text analysis

Domains	Topics	Definition
General Rules and Procedures	Business plan	Availability of a predefined format for business plans at the parent university
	Conflict of interest	Spin-offs cannot carry out activities in conflict with their parent university
	Committee	Presence at the parent university of a Committee evaluating spinoff proposals
Monetary Incentives	Equity share	Minimum share of the spin-off equity held by academic participants
	Part-time	Academic spin-off promoters are forced to a part time regime
	Contract Research	Share of revenues from contract research and consultancies withheld by the university
Entrepreneurial Risk	Limit contract	Maximum limit on research contracts from parent university to the spin-off
	Part losses	The university is not liable to fund any losses of the spinoff
	Incubation limit	Time limit on spin-off incubation in university facilities

Note: Source Spin-off regulations of the Italian STEMM universities

Table 3: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
D: Entrepreneurial events	0.05	0.26	0.00	3.00
D: Scientific discipline (LS)	0.25	0.43	0.00	1.00
D: Scientific discipline (PE)	0.40	0.49	0.00	1.00
D: Scientific discipline (SH)	0.36	0.48	0.00	1.00
D: Size	34.50	20.73	1.00	211.00
D: Promotion rate	0.03	0.05	0.00	0.50
U: TTO presence	0.64	0.48	0.00	1.00
U: Grant acquisition	1.44	2.10	0.00	29.00
U: Research eminence	88.39	6.67	71.00	107.00
D: Entrepreneurial rate	0.00	0.01	0.00	0.20
D: Closeness to industry	27.76	90.49	0.00	1,649.00
D: Variety of knowledge	0.70	0.25	0.00	0.98
U: Spin-off regulation	0.70	0.46	0.00	1.00
U: Spin-off regulation - General Rules and Procedures	1.05	1.01	0.00	3.00
U: Spin-off regulation - Monetary Incentives	0.03	0.17	0.00	1.00
U: Spin-off regulation - Entrepreneurial Risk	0.82	0.87	0.00	2.00
U: Years since the introduction of spin-off regulation	3.44	3.96	-9.00	11.00

Note: N=11,787; D=Department-level variable; U=University-level variable

Table 4: Pairwise correlations

		1.	2.	3.	4.	5.	6.	7.	8.	9.
1.	D: Entrepreneurial events	1								
2.	D: Scientific discipline (LS)	-0.0380*	1							
3.	D: Scientific discipline (PE)	0.1380*	-0.4628*	1						
4.	D: Scientific discipline (SH)	-0.1066*	-0.4274*	-0.6036*	1					
5.	D: Size	0.1388*	-0.0299*	0.1067*	-0.0819*	1				
6.	D: Promotion rate	0.0181*	-0.0373*	-0.0228*	0.0568*	-0.0182*	1			
7.	U: TTO presence	0.0503*	-0.0218*	0.0087	0.0107	0.0834*	-0.1324*	1		
8.	U: Grant acquisition	0.0777*	0.0175	0.1160*	-0.1340*	0.3971*	0.1156*	-0.0857*	1	
9.	U: Research eminence	0.0346*	-0.0485*	-0.0204*	0.0644*	0.0717*	0.0165	0.0941*	0.1279*	1
10.	D: Entrepreneurial rate	0.1094*	-0.0161	0.1285*	-0.1165*	0.0235*	0.0314*	0.0225*	0.0205*	-0.0175
11.	D: Closeness to industry	0.0899*	0.1290*	0.0581*	-0.1752*	0.1676*	0.0071	0.0042	0.1830*	0.1363*
12.	D: Variety of knowledge	0.0857*	-0.0995*	-0.0764*	0.1674*	0.2847*	0.1932*	0.0134	0.1311*	0.0516*
13.	U: Spin-off regulation	0.0560*	0.0218*	-0.0019	-0.0176	0.0726*	-0.2029*	0.3306*	-0.1410*	-0.0445*
14.	U: Spin-off regulation - General Rules and Procedures	0.0381*	0.0272*	-0.0059	-0.0185*	0.0630*	-0.1718*	0.2011*	-0.1482*	-0.1137*
15.	U: Spin-off regulation - Monetary Incentives	-0.0107	0.0229*	-0.0099	-0.0105	0.0026	-0.0196*	0.1087*	-0.0492*	0.1239*
16.	U: Spin-off regulation - Entrepreneurial Risk	0.0111	0.0576*	-0.0194*	-0.0320*	-0.0127	-0.1605*	0.0443*	-0.1785*	-0.3596*
17.	U: Years since the introduction of spin-off regulation	0.0478*	0.0309*	-0.0029	-0.0249*	0.0777*	-0.2445*	0.3933*	-0.2224*	-0.0493*

Notes: * = significant at 0.05 or above; D = Department-level variable; U = University-level variable; N = 11,787

Table 4: Correlations
(continued)

		10.	11.	12.	13.	14.	15.	16.	17.
10.	D: Entrepreneurial rate	1							
11.	D: Closeness to industry	0.0592*	1						
12.	D: Variety of knowledge	0.0659*	0.0307*	1					
13.	U: Spin-off regulation	0.0004	-0.0590*	-0.0254*	1				
14.	U: Spin-off regulation - General Rules and Procedures	-0.0064	-0.0189*	-0.0277*	0.6838*	1			
15.	U: Spin-off regulation - Monetary Incentives	0.0165	-0.0152	0.0237*	0.1166*	-0.0155	1		
16.	U: Spin-off regulation - Entrepreneurial Risk	0.007	-0.0698*	-0.0350*	0.6141*	0.5980*	0.1150*	1	
17.	U: Years since the introduction of spin-off regulation	0.0239*	-0.0561*	-0.0359*	0.7844*	0.5813*	0.0608*	0.4966*	1

Notes: * = significant at 0.05 or above; D = Department-level variable; U = University-level variable; N = 11,787

Table 5: Regression Results (RQ1a,b,c)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Year Fixed-Effects	Yes	Yes	Yes	Yes	Yes	Yes
Regional Fixed-Effects	Yes	No	No	No	No	No
University Fixed-Effects	No	Yes	Yes	Yes	Yes	Yes
U: TTO presence (t)	0.357**	0.626***	0.628***	0.606***	0.628***	0.609***
	(0.123)	(0.163)	(0.162)	(0.163)	(0.163)	(0.163)
U: Grant acquisition (t)	0.030	0.030	0.030	0.027	0.030	0.028
	(0.019)	(0.020)	(0.019)	(0.020)	(0.020)	(0.020)
U: Research eminence (t)	0.019+	-0.011	-0.010	-0.010	-0.011	-0.010
	(0.010)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
D: Size (t)	0.011****	0.011****	0.011****	0.011****	0.011****	0.011****
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
D: Promotion rate (t)	2.245**	2.340**	2.363**	2.368**	2.420**	2.444**
	(0.846)	(0.856)	(0.854)	(0.858)	(0.857)	(0.859)
D: Entrepreneurial rate (t-1)	5.265	2.471	2.464	1.907	2.245	1.836
	(4.650)	(4.848)	(4.844)	(4.881)	(4.897)	(4.912)
D: Discipline PE (t)	0.766****	0.701****	0.338	0.712****	0.702****	0.715****
	(0.133)	(0.133)	(0.257)	(0.134)	(0.133)	(0.134)
D: Discipline SH (t)	-0.921****	-0.981****	-1.558****	-0.991****	-0.983****	-0.992****
	(0.175)	(0.175)	(0.394)	(0.177)	(0.176)	(0.177)
D: Closeness to industry (t-1)	0.001****	0.001****	0.001***	0.002****	0.001***	0.002****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D: Variety of knowledge (t-1)	2.361****	1.986****	1.991****	2.020****	1.091+	1.174*
	(0.321)	(0.316)	(0.316)	(0.318)	(0.575)	(0.584)
U: Spin-off Regulation (t-1)	0.783****	0.576****	0.183	0.686****	-0.310	-0.154
	(0.134)	(0.135)	(0.256)	(0.143)	(0.513)	(0.524)
U: Spin-off Regulation * D: Discipline PE			0.454			
			(0.281)			
U: Spin-off Regulation * D: Discipline SH			0.706+			
			(0.423)			
U: Spin-off Regulation * D: Closeness to industry				-0.002**		-0.001*
				(0.001)		(0.001)
U: Spin-off Regulation * D: Variety of knowledge					1.126+	1.062+
					(0.636)	(0.643)
Constant	-8.192****	-5.439****	-5.174****	-5.598****	-4.747***	-4.932***
	(0.943)	(1.279)	(1.289)	(1.287)	(1.334)	(1.345)
lnalpha	-0.330+	-0.720**	-0.733**	-0.673**	-0.715**	-0.684**
	(0.194)	(0.248)	(0.249)	(0.239)	(0.248)	(0.241)
N of observations	11,787	11,787	11,787	11,787	11,787	11,787
N of departments	1,213	1,213	1,213	1,213	1,213	1,213
Log likelihood	-2,134.271	-2,092.21	-2,090.448	-2,088.749	-2,090.754	-2,087.477

Notes: + p<.1; *p<.05; **p<.01; ***p<.001; ****p<.0001; Poisson models with Standard errors clustered on departments; Models 1 and 2 refer to RQ1a; Model 3 refers to RQ1b; Models 4 to 6 refer to RQ1c; DV= Count of entrepreneurial events; D: Discipline LS = Omitted variable

Table 6: Regression Results (RQ2 and RQ3)

	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
Year Fixed-Effects	Yes	Yes	Yes	Yes	Yes	Yes
Regional Fixed-Effects	No	No	No	No	No	No
University Fixed-Effects	Yes	Yes	Yes	Yes	Yes	Yes
D: Discipline PE (t)	0.701****	0.692****	0.701****	0.694****	0.714****	0.714****
	(0.133)	(0.133)	(0.133)	(0.133)	(0.133)	(0.133)
D: Discipline SH (t)	-0.981****	-0.994****	-0.988****	-0.995****	-0.975****	-0.966****
	(0.176)	(0.176)	(0.176)	(0.176)	(0.176)	(0.176)
D: Size (t)	0.011****	0.011****	0.011****	0.011****	0.011****	0.011****
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
D: Promotion rate (t)	2.341**	2.358**	2.261**	2.324**	1.887*	1.864*
	(0.858)	(0.855)	(0.859)	(0.857)	(0.843)	(0.849)
U: TTO presence (t)	0.626***	0.631****	0.629***	0.646****	0.602***	0.595***
	(0.163)	(0.162)	(0.163)	(0.163)	(0.165)	(0.164)
U: Grant acquisition (t)	0.030	0.028	0.028	0.028	0.030	0.030
	(0.020)	(0.020)	(0.020)	(0.020)	(0.019)	(0.019)
U: Research eminence (t)	-0.011	-0.009	-0.022	-0.019	-0.010	-0.008
	(0.014)	(0.014)	(0.015)	(0.015)	(0.014)	(0.014)
D: Entrepreneurial rate (t-1)	2.473	2.257	1.941	1.821	1.097	1.824
	(4.849)	(4.894)	(4.875)	(4.912)	(4.841)	(4.827)
D: Variety of knowledge (t-1)	1.985****	1.991****	1.986****	1.982****	2.021****	2.007****
	(0.316)	(0.317)	(0.316)	(0.317)	(0.316)	(0.315)
D: Closeness to industry (t-1)	0.001****	0.001****	0.001****	0.001****	0.001***	0.001****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
U: Spin-off Regulation (t-1)	0.573**	0.631****	0.830****	0.742***		
	(0.189)	(0.137)	(0.177)	(0.198)		
U: Spin-off regulation * U: Spin-off regulation - General Rules and Procedures	0.002			0.088		
	(0.087)			(0.100)		
U: Spin-off regulation * U: Spin-off regulation - Monetary Incentives		-0.948**		-0.812*		
		(0.343)		(0.353)		
U: Spin-off regulation * U: Spin-off regulation - Entrepreneurial Risk			-0.239*	-0.242*		
			(0.106)	(0.123)		
U: Years since the introduction of spin-off regulation					0.028	0.067+
					(0.030)	(0.034)
U: Years since the introduction of spin-off regulation (squared)						-0.008**
						(0.003)
Constant	-5.443****	-5.627****	-4.391**	-4.734***	-5.324****	-5.437****
	(1.297)	(1.278)	(1.367)	(1.372)	(1.266)	(1.270)
lnalpha	-0.720**	-0.702**	-0.714**	-0.697**	-0.695**	-0.709**
	(0.248)	(0.247)	(0.248)	(0.246)	(0.244)	(0.246)
N of observations	11,787	11,787	11,787	11,787	11,787	11,787
N of departments	1,213	1,213	1,213	1,213	1,213	1,213
Log likelihood	-2,092.2102	-2,088.0271	-2,089.6338	-2,086.0833	-2,095.9285	-2,092.4393

Notes: + p<.1; *p<.05; **p<.01; ***p<.001; ****p<.0001; Poisson models with standard errors clustered on departments; Models 7 to 10 refer to RQ2; Models 11 and 12 refer to RQ3; DV= Count of entrepreneurial events.

Table 7: Robustness Checks (RQ1a,b,c)

	Model 13	Model 14	Model 15	Model 16	Model 17	Model 18	Model 19	Model 20
Year Fixed-Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional Fixed-Effects	No	No	No	No	No	No	No	No
University Fixed-Effects	No	No	No	No	No	No	No	No
Department Fixed-Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
D: Size (t)	0.000	0.000	0.000	0.000	0.004	0.004	0.004	0.004
	(0.000)	(0.000)	(0.000)	(0.000)	(0.007)	(0.007)	(0.007)	(0.007)
D: Promotion rate (t)	-0.035	-0.034	-0.020	-0.019	-0.396	-0.325	-0.315	-0.258
	(0.052)	(0.052)	(0.052)	(0.052)	(0.954)	(0.954)	(0.953)	(0.953)
U: TTO presence (t)	0.012	0.012	0.012	0.012	0.500**	0.497**	0.521**	0.516**
	(0.008)	(0.008)	(0.008)	(0.008)	(0.189)	(0.189)	(0.189)	(0.189)
U: Grant acquisition (t)	-0.001	-0.002	-0.001	-0.001	-0.008	-0.011	-0.008	-0.011
	(0.002)	(0.002)	(0.002)	(0.002)	(0.022)	(0.022)	(0.022)	(0.022)
U: Research eminence (t)	-0.002*	-0.002*	-0.002*	-0.002*	-0.060***	-0.060***	-0.061***	-0.060***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.018)	(0.018)	(0.018)	(0.018)
D: Entrepreneurial rate (t)	-3.858****	-3.842****	-3.858****	-3.842****	-47.536****	-47.295****	-48.069****	-47.868****
	(0.477)	(0.477)	(0.477)	(0.477)	(7.647)	(7.631)	(7.664)	(7.651)
U: Spin-off Regulation (t-1)	0.025***	0.027***	-0.027	-0.025	0.681****	0.793****	-0.598	-0.379
	(0.007)	(0.007)	(0.018)	(0.018)	(0.144)	(0.154)	(0.643)	(0.668)
D: Closeness to industry (t-1)	0.000**	0.000**	0.000**	0.000**	1.643	1.496	0.074	0.097
	(0.000)	(0.000)	(0.000)	(0.000)	(1.283)	(1.277)	(1.489)	(1.491)
D: Variety of knowledge (t-1)	0.026	0.026	-0.038	-0.039	0.001*	0.002**	0.001+	0.002**
	(0.030)	(0.030)	(0.036)	(0.036)	(0.000)	(0.001)	(0.000)	(0.001)
U: Spin-off Regulation * D: Closeness to industry		-0.000+		-0.000+		-0.002*		-0.001+
		(0.000)		(0.000)		(0.001)		(0.001)
U: Spin-off Regulation * D: Variety of knowledge			0.075**	0.075**			1.591*	1.440+
			(0.024)	(0.024)			(0.783)	(0.805)
Constant	0.205*	0.204*	0.245**	0.244**				
	(0.091)	(0.091)	(0.092)	(0.092)				
N of observations	11,787	11,787	11,787	11,787	3,282	3,282	3,282	3,282
N of departments	1,213	1,213	1,213	1,213	335	335	335	335
R-squared (between)	0.04	0.04	0.05	0.05				
Log likelihood					-1,125.1789	-1,122.7373	-1,123.1525	-1,121.1883

Notes: + p<.1; *p<.05; **p<.01; ***p<.001; ****p<.0001; Standard errors are clustered on departments; Models 13 to 16 use a linear department-fixed effects estimator; Models 17 to 20 use a Poisson department-fixed effects estimator; DV= Count of entrepreneurial events.

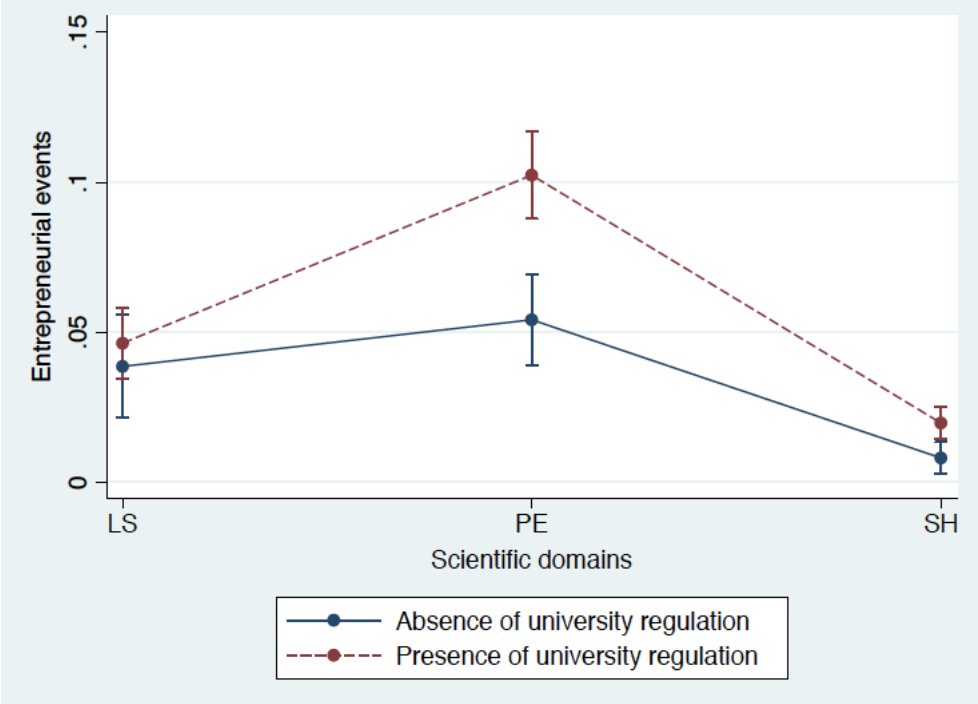
Table 8: Robustness Checks (RQ2 and RQ3)

	Model 21	Model 22	Model 23	Model 24	Model 25
Year Fixed-Effects	Yes	Yes	Yes	Yes	Yes
Regional Fixed-Effects	No	No	No	No	No
University Fixed-Effects	Yes	Yes	Yes	Yes	Yes
D: Discipline PE (t)	0.695****	0.694****	0.695****	0.812****	0.811****
	(0.133)	(0.133)	(0.133)	(0.143)	(0.143)
D: Discipline SH (t)	-0.992****	-0.996****	-0.992****	-0.906****	-0.909****
	(0.176)	(0.176)	(0.176)	(0.187)	(0.187)
D: Size (t)	0.011****	0.011****	0.011****	0.010****	0.010****
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
D: Promotion rate (t)	2.330**	2.325**	2.315**	3.326***	3.417***
	(0.855)	(0.857)	(0.855)	(0.950)	(0.954)
U: TTO presence (t)	0.648****	0.646****	0.646****	0.498*	0.476*
	(0.163)	(0.164)	(0.163)	(0.202)	(0.202)
U: Grant acquisition (t)	0.028	0.027	0.028	0.039+	0.039+
	(0.020)	(0.020)	(0.020)	(0.023)	(0.023)
U: Research eminence (t)	-0.018	-0.019	-0.018	-0.023	-0.019
	(0.015)	(0.015)	(0.015)	(0.016)	(0.016)
D: Entrepreneurial rate (t-1)	1.731	1.810	1.744	-0.545	-1.029
	(4.915)	(4.913)	(4.914)	(5.650)	(5.760)
D: Variety of knowledge (t-1)	1.974****	1.984****	1.974****	2.176****	2.177****
	(0.316)	(0.317)	(0.317)	(0.348)	(0.348)
D: Closeness to industry (t-1)	0.001***	0.001****	0.001***	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
U: Spin-off Regulation (t-1)	0.650*	0.765***	0.652*		
	(0.276)	(0.200)	(0.276)		
U: Spin-off regulation * U: Spin-off regulation - General Rules and Procedures (dummy - time invariant)	0.303				
	(0.318)				
U: Spin-off regulation * U: Spin-off regulation - Monetary Incentives (dummy - time invariant)	-0.807*				
	(0.348)				
U: Spin-off regulation * U: Spin-off regulation - Entrepreneurial Risk (dummy - time invariant)	-0.443*				
	(0.219)				

U: Spin-off regulation * U: Spin-off regulation - General Rules and Procedures (cont. - time invariant)		0.078			
		(0.106)			
U: Spin-off regulation * U: Spin-off regulation - Monetary Incentives (cont. - time invariant)		-0.810*			
		(0.354)			
U: Spin-off regulation * U: Spin-off regulation - Entrepreneurial Risk (cont. - time invariant)		-0.249+			
		(0.129)			
U: Spin-off regulation * U: Spin-off regulation - General Rules and Procedures (dummy - time variant)			0.283		
			(0.316)		
U: Spin-off regulation * U: Spin-off regulation - Monetary Incentives (dummy - time variant)			-0.814*		
			(0.348)		
U: Spin-off regulation * U: Spin-off regulation - Entrepreneurial Risk (dummy - time variant)			-0.421*		
			(0.215)		
U: Years since the introduction of spin-off regulation				0.025	0.197*
				(0.030)	(0.079)
U: Years since the introduction of spin-off regulation (squared)					-0.016*
					(0.007)
Constant	-4.754***	-4.683***	-4.786***	-4.124**	-4.764**
	(1.348)	(1.375)	(1.347)	(1.473)	(1.502)
lnalpha	-0.695**	-0.697**	-0.695**	-0.752**	-0.743**
	(0.246)	(0.246)	(0.246)	(0.275)	(0.275)
N of observations	11,787	11,787	11,787	9,162	9,162
N of departments	1,213	1,213	1,213	1,184	1,184
Log likelihood	-2,085.9455	-2,086.1108	-2,086.0583	-1,786.0101	-1,783.1507

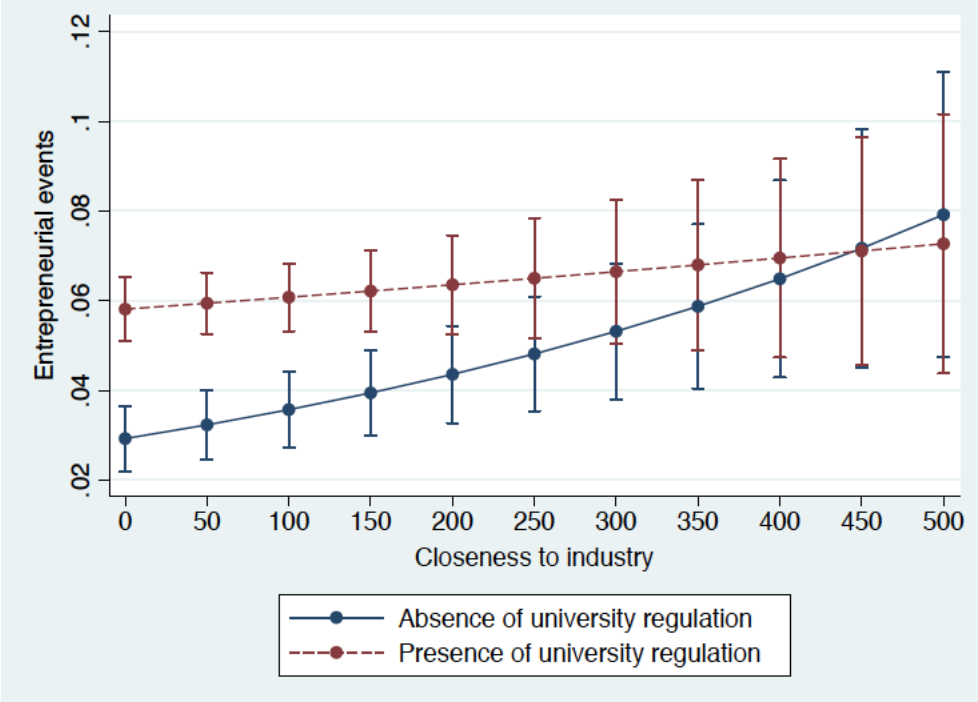
Notes: + p<.1; *p<.05; **p<.01; ***p<.001; ****p<.0001; Poisson models with standard errors clustered on departments; DV= Count of entrepreneurial events.

Figure 1: Predicted values (RQ1b)



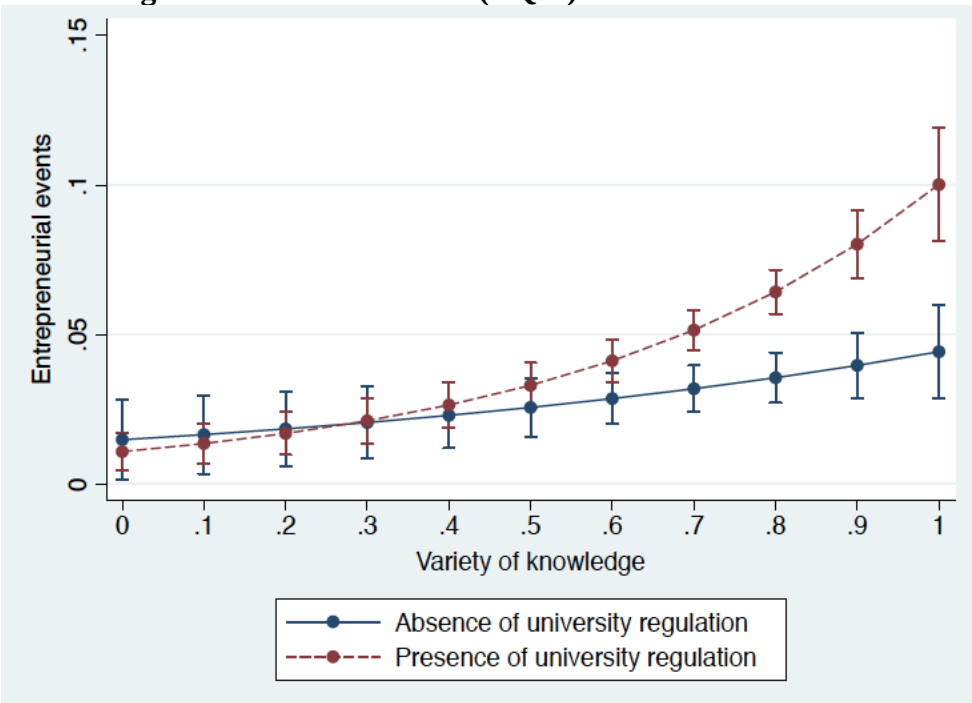
Note: LS=Life Sciences; PE=Physics and Engineering; SH=Social Sciences and Humanities; 95% Confidence intervals reported; Values estimated using Model 3 by keeping the other covariates at observed values.

Figure 2 Predicted values (RQ1c) – First moderator



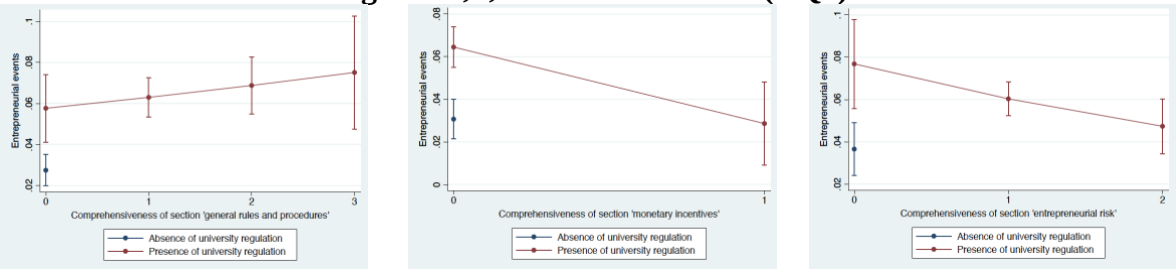
Note: Closeness to industry reported up to 6 standard deviations above the mean. 95% Confidence interval reported; Values estimated using Model 4 by keeping the other covariates at observed values.

Figure 3: Predicted values (RQ1c) – Second moderator



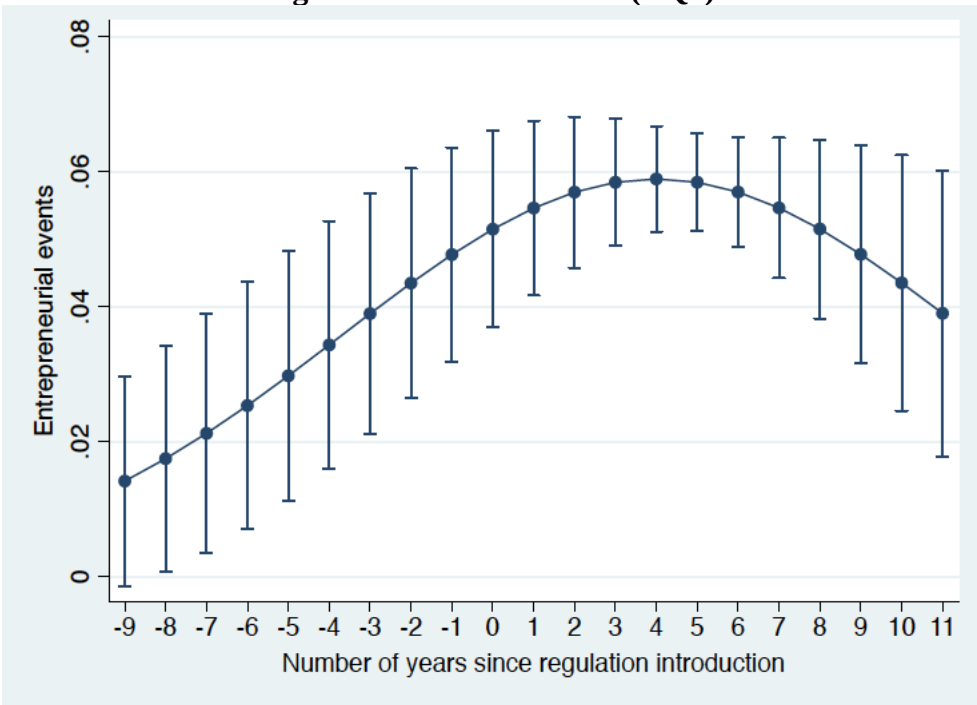
Note: 95% Confidence interval reported; Values estimated using Model 5 by keeping the other covariates at observed values.

Figure 4a,b,c: Predicted values (RQ2)



Note: 95% Confidence interval reported; Values estimated using Model 10 by keeping the other covariates at observed values.

Figure 5: Predicted values (RQ3)



Note: 95% Confidence interval reported; Values estimated using Model 12 by keeping the other covariates at observed values.