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Institutional determinants of university spin-off quantity and quality: a longitudinal, multilevel, cross-country study

Riccardo Fini · Kun Fu · Marius Tuft Mathisen · Einar Rasmussen · Mike Wright

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Abstract The creation of spin-off firms from universities is seen as an important mechanism for the commercialization of research, and hence the overall contribution from universities to technological development and economic growth. Governments and universities are seeking to develop framework conditions that are conductive to spin-off creation. The most prevalent of such initiatives are legislative changes at national level and the establishment of technology transfer offices at university level. The effectiveness of such initiatives is debated, but empirical evidence is limited. In this paper, we analyze the full population of universities in Italy, Norway, and the UK; three countries adopting differing approaches to framework conditions, to test whether national- and university-level initiatives have an influence on the number of spin-offs created and the quality of these spin-offs. Building on institutional theory and using multilevel analysis, we find that changes in the institutional framework conditions at both national and university levels are conductive to the creation of more spin-offs, but that the increase in quantity is at the expense of the quality of these firms. Hence, the effect of such top–down changes in framework conditions on the economic impact from universities seems to be more symbolic than substantive.

Keywords Commercialization of research · Institutional framework · Technology transfer offices · University spin-offs · Venure capital

JEL Classifications C12 · L25 · L26 · O31 · O32 · O38

R. Fini (✉)
Department of Management, University of Bologna, Bologna, Italy
e-mail: riccardo.fini@unibo.it

K. Fu
Glendonbrook Institute for Enterprise Development, Loughborough University, London, UK
e-mail: k.fu@lboro.ac.uk

M. T. Mathisen
Norwegian University of Science and Technology, Trondheim, Norway
e-mail: marius.mathisen@iot.ntnu.no

E. Rasmussen
Nord University Business School, Bodo, Norway
e-mail: Einar.Rasmussen@nord.no

M. Wright
Imperial College London, London, UK
e-mail: mike.wright@imperial.ac.uk

M. Wright
University of Ghent, Ghent, Belgium

1 Introduction

Creating favorable framework conditions for entrepreneurship is perceived as an important tool to foster the creation and subsequent development of new ventures, especially among policy makers (Arshed et al. 2014; Nightingale and Coad 2014). The orientation of such initiatives is debated (Mason and Brown 2013; van Praag and van Stel 2013): while some argue that stimulating more entrepreneurship in general is favorable to the economy, others argue that support should be targeted at high-quality, high-growth firms only (Shane 2009).

The creation of new ventures to commercialize university research is an example of potentially high-growth firms that could have significant economic impact at national and regional levels (Garnsey and Heffernan 2005; Lawton Smith and Ho 2006; Vincett 2010). Governments and universities have introduced many initiatives to promote spin-off creation, such as legislative changes and economic support at national level and the establishment of technology transfer offices (TTOs) at university level. However, the effects of such initiatives on spin-off creation are not yet well understood. In this paper, we consider the effect of university- and national-level framework conditions on the creation and performance of university spin-off firms.

Although there has been an increase in the number of university spin-offs created in both the USA and Europe (Shane 2004; Wright et al. 2007), there are concerns that the majority of these firms have limited growth and impact (Grimaldi et al. 2011; Mowery 2011). Especially in Europe, several studies have noted that most university spin-offs remain small and appear to be lifestyle firms rather than high-growth ventures (Borlaug et al. 2009; Harrison and Leitch 2010). Hence, it could be questioned: (1) Whether the framework conditions put in place at national and university level may have different impacts on the quantity and quality of these firms, and (2) whether the observed growth in the number of university spin-offs results in a more symbolic, rather than substantive, increase in the economic impact from university entrepreneurship.

The commercialization of research, and spin-off creation in particular, is a rather new and unfamiliar activity at many academic institutions across Europe. Creating a successful spin-off firm requires different competencies compared to the traditional core academic missions of teaching and research (Ambos et al. 2008; Rasmussen et al. 2011). The effectiveness of top–down policies and legislative changes to promote commercialization have been debated (Goldfarb and Henrekson 2002; Kenney and Patton 2011; Muscio et al. 2016) individual, social, and cultural factors appear to have a much stronger impact on the propensity of academics to be involved in entrepreneurial activities than institutional arrangements such as TTOs (Clarysse et al. 2011). Clearly, the creation and development of spin-offs in a university context is a highly complex task involving many actors within and outside the university organization (O'Shea et al. 2007; Rasmussen and Borch 2010). Hence, changes in the institutional framework, at both national and university levels, may only have modest effects unless fully embraced at all levels within the academic organization.

Most research investigating university spin-off creation has measured the number of firms and paid limited attention to the quality of these firms (Powers and McDougall 2005; Van Looy et al. 2011). University spin-offs are typically resource constrained and need to overcome liabilities or thresholds to survive and grow (Rasmussen et al. 2011; Vohora et al. 2004). Obtaining venture capital (VC) is often necessary to satisfy the capital requirements of spin-offs (i.e., key to bring a technology from the laboratory to the market), and overcoming this threshold improves the chances for success (Rosenbusch et al. 2013; Shane and Stuart 2002). Moreover, VC investments provide a qualified third-party evaluation of the commercial potential of the university spin-off. Hence, we use the first formal VC investment as a proxy to measure firm quality, and thus university performance in creating quality firms.

Moreover, there is a paucity of research that compares different countries (Clarysse et al. 2007; Fini and Grimaldi 2016), and the evidence about the effect of changes in the institutional framework on spin-off creation and quality is limited. We therefore pose the following research question: How do changes in the institutional framework at national and university levels influence the quantity and the quality of spin-offs from a university?

To explore this question, we build on institutional theory proposing that changes in formal structures may result in symbolic rather than substantial modifications in operation efficiency (Dimaggio and Powell

1983; Tolbert et al. 2011). We rely on a unique panel dataset comprising the 2323 spin-offs created from the full population of universities in Italy, Norway, and the UK, between 2000 and 2012. Our findings reveal that changes in the institutional framework, measured as changes in the intellectual property rights (IPR) legislation at national level and the establishment of a TTO at university level, have a positive effect on the number of spin-off created, while the quality of these ventures decreases.

Our study makes several contributions to the literature on framework conditions for entrepreneurship and university spin-offs. First, while several studies have looked at the link between institutional determinants and the number of spin-offs created from universities, this study, by using a multilevel approach, isolates the effects of national- and university-level initiatives in predicting both the quantity and quality of the firms created. Second, most datasets of university spin-offs comprise a single university or single country and, in the vast majority of the cases, rely on cross-sectional research designs. As this study compares the full population of universities across three different national contexts over a 13-year period, we extend our understanding of the within- and between-country influences on the quantity and quality of university spin-offs. Third, we show that differences in the macro-institutional context regarding university IPR ownership are significantly associated with the extent and nature of university spin-offs.

The paper proceeds as follows. In the next section, we develop hypotheses related to how changes in university and national frameworks may influence the number of spin-offs created and the quality of these firms. The method section outlines our panel study of spin-off creation and quality in the full population of universities in Italy, Norway, and the UK. Then, the findings from our multilevel panel study are presented. Finally, conclusions and implications for research and practice are provided.

2 Theory and development of hypotheses

It is increasingly recognized that the institutional context where entrepreneurs operate both constraints and facilitates the opportunities for starting and growing a business (Urbano and Alvarez 2014; Welter and Smallbone 2011). The institutional context provides the "rules of the game in a society" (North 1990) and include the economic, political, and socio-cultural environment in which the new venture is created (Shane 2003). Emerging evidence shows that favorable institutional conditions at national level increases the probability of entrepreneurship (Levie and Autio 2011; Urbano and Alvarez 2014).

Institutional theory is particularly helpful in understanding entrepreneurship in organizational contexts, which are largely determined by culture, tradition, history, legal environment, and economic incentives (Aldrich and Fiol 1994; Bruton et al. 2010). Entrepreneurs launching university spin-offs are likely to adapt their behavior and strategic model according to the opportunities and limitations of the formal and informal institutional framework they are exposed to (North 1990). Entrepreneurial activity is indeed influenced by the social context and institutional environment in which the scientists are embedded, and a supporting environment will impact scientistś propensity to engage in spin-off activity (Huyghe and Knockaert 2015; Kenney and Goe 2004; Meoli and Vismara 2016). One example is how scientists conform to the behavior of their heads and peers when deciding to engage in the commercialization of research (Bercovitz and Feldman 2008; Tartari et al. 2014).

Moreover, the institutional framework reduces uncertainty by providing human interaction with a stable structure (North 1990), providing a common basis where actors can evaluate the outcome of their behavior. Institutional pressures operate at many levels, from international systems to organizational subsystems (Scott 2008). These levels can be viewed as interacting in a nested structure, where each institutional level will have distinct influence on scientistś participation in entrepreneurship (Kenney and Goe 2004; Rasmussen et al. 2014). Hence, university scientists may consider whether entrepreneurial activity is rewarded, socially and economically, before they choose to engage in spin-off creation. Likewise, universities are likely to consider societal, legislative, and financial pressures when giving priority to entrepreneurial activities. External actors, such as investors or industry partners, make similar judgments about the probability that the new venture is appropriate and will gain acceptance before they are willing to commit resources (Zimmerman and Zeitz 2002). Hence, to increase the chances for a new spin-off venture to be created and succeed, it should be regarded as a legitimate entity across many levels in its institutional environment (Scott 2008). An example of a university that has been remarkably productive in generating spin-offs is MIT. At MIT, spin-off creation is institutionalized through an interrelated set of factors both within and outside the university that has developed over several decades (O'Shea et al. 2007).

This paper emphasizes how institutional changes at national level shape spin-off formation. Governments have implemented legislative frameworks aimed at increasing the commercialization of research, including university spin-off formation. A well-known example is the US Bayh-Dole Act from 1980, which gave universities options to manage IPR and provided licensing preference to small businesses (Grimaldi et al. 2011; Stevens 2004). This legislation has been emulated by most European countries where IPR ownership has been assigned to universities, rather than being held by academics (the so-called professor's privilege). The rationale has been to increase the commercial output from university research in terms of both spin-off firm formation and technology transfer to established firms.

While there is limited evidence on how institutional forces at national level influence university spin-off creation, patenting activity is a proxy of university technology transfer that has been extensively studied. The legislative changes appear highly successful because there has been a dramatic increase in university patenting following the implementation of the US Bayh-Dole Act (Mowery et al. 2001) and also following similar reforms in for instance Italy (Baldini et al. 2006). However, it has been debated whether the increasing number of patents reflects an average lower quality of these patents (Henderson et al. 1998; Sampat et al. 2003) or have other negative effects on the impact of university technology transfer (Czarnitzki et al. 2009).

In parallel with patenting activity, we may expect the number of spin-offs to increase as a result of an augmented attention and institutional pressure upon universities to produce spin-offs. The rationale for this is that scientists, universities, TTOs, and other stakeholders will tend to strategically conform to the presence of such a new framework (Suchman 1995), and increase the number of entrepreneurial ventures. Conversely, changes in the institutional framework increase the level of environmental uncertainty, thus making successful entrepreneurship more difficult to unfold. It takes time for the new institutionalized practices to settle and generate the anticipated benefits. Hence, uncertainties about how the legal framework, the academic community, universities, and other stakeholders will respond to legislative changes may prevent important resource holders from supporting the new venture in the short term (Zimmerman and Zeitz 2002). VCs, for example, will be less willing to invest in spin-off firms, which they already perceive as more difficult than other high-tech ventures (Wright et al. 2006). Further, while institutional pressures may increase the number of spin-offs, the underlying base of viable research-based business opportunities at the university may not increase at the same pace. As such, the increase may comprise lower-quality spin-offs that would not have surfaced in the previous legislative environment. Accordingly, we propose:

Hypothesis 1 Universities in a national context with more changes in national IPR legislation will generate (a) more spin-off companies but of (b) lower quality, than universities in a context with less changes.

Spin-off formation is not only influenced by the institutional framework at the national level but also the organizational environment. This is evident by the uneven and path-dependent numbers of spin-offs created across universities (O'Shea et al. 2005). Moreover, it seems clear that university faculty complies with local group norms when it comes to involvement in spin-off creation (Bercovitz and Feldman 2008; Louis et al. 1989).

The creation of a TTO may be a symbolic reaction to institutional change, signaling that the university acknowledges commercialization and spin-off activity as a part of its mission. As such, the number of spin-offs created may be expected to increase, as scientists become encouraged to engage with TTOs and the officers in TTOs seek to meet activity-based targets. A related example is how patenting activity increases as a result of internal changes in IPR regulation at the university level (Baldini et al. 2006). However, the creation of quality university spin-offs is a highly complex process requiring access to entrepreneurial competencies to help the venture overcome the initial critical junctures (Rasmussen et al. 2011; Vohora et al. 2004). The creation of high-performing spin-offs appears to be more dependent on individual and group-level characteristics, rather than on formal structures and policies (Kenney and Goe 2004;

Rasmussen et al. 2014; Shane and Stuart 2002). TTOs need to have the capabilities to make spin-offs investor ready and the social networks to identify and attract VC investors. Such capabilities take time to develop, and TTOs also need time to engage with the scientific environment at the university to influence the culture toward commercial exploitation of research results. Thus, there may be a mismatch between universities' intention to create quality spin-offs and the resources and capabilities they possess to achieve this goal (Clarysse et al. 2005).

Further, the opportunity recognition capacity and prior entrepreneurial experience of individual academics are the strongest predictors of quality new spin-off creation (Clarysse et al. 2011). To be effective, changes in the framework conditions, such as TTO establishment, need to trigger the development of appropriate competencies and behaviors at lower levels in the organization. For university spin-off creation, this means that scientists and their surrounding environment must be both willing and capable of becoming engaged in pursuing potential high-growth spin-off firms. Without a larger transformation of the university, its capabilities and its surrounding ecosystem (Rasmussen and Borch 2010), the establishment of a TTO may be only a symbolic act with limited short-term effect on bringing new research to the market. A TTO may improve output targets such as creating more spin-offs, but the additional new ventures are not as likely to become high-growth firms. Hence, we propose:

Hypothesis 2 Universities with a TTO will generate (a) more spin-off companies but of (b) lower quality than universities without a TTO.

Finally, government legislations and university-level support mechanisms may also interact in predicting academic entrepreneurship. Given the top–down nature of both the governmental and the university frameworks, we might expect a self-reinforcing effect. The idea is consistent with the evidence provided by (Fini et al. 2011), who show that the introduction of a new national legislative framework to support entrepreneurship and the creation of university TTOs complement each other in predicting academic entrepreneurship. Hence, we propose:

Hypothesis 3 Universities with a TTO and in a context with more changes in national IPR legislation will generate (a) more spin-off companies but of (b) lower quality, than universities in a context with less changes.

3 Research design and data

3.1 The institutional landscape

To test our hypotheses, we used data from three European countries: Italy, Norway, and the UK, in which institutional changes to support the commercialization of university research, at both national and university levels, have been implemented following different pathways.

At national level, as a result of the catalytic effect of the Bayh-Dole Act in the USA (Mowery et al. 2001) and to boost technology transfer activities from public research institutions, several EU countries revoked the so-called professor's privilege, which granted IPR on employees' inventions not to the employer but to the employees themselves (Geuna and Rossi 2011). The UK was the first to abolish it in 1977, followed by France (1982), Spain (1986), the Netherlands (1995), Denmark (2000), Germany (2002), and Norway (2003). Italy, on the contrary, introduced the "professor's privilege" late in 2001, abandoning it in 2005 (Baldini et al. 2014b).

In a similar fashion, UK universities have been proactive in introducing internal policies to foster technology transfer activities by academics, i.e., by year 2000 more than the 80 % of UK universities had a TTO (Lockett et al. 2015; UNICO/NUBS 2002). The Norwegian universities, instead, established their TTOs later, between 2003 and 2005 (Borlaug et al. 2009), whereas the Italian ones have been the least proactive, with more than 40 % of them without a TTO by the end of 2005 (Baldini et al. 2014a).

This evidence suggests that, at both country and university level, the UK has been acting as a leader in establishing formal initiatives to enable technology transfer. Norway, with something of a lag, has put in place similar conditions, while Italy has lagged significantly behind.

3.2 The sample

To account for cross-national differences, we pooled data from different national and EU sources.

As to country-level information, data on gross domestic product and unemployment rates have been retrieved using the World Bank Database (2014b). Data on the number of days required to start a business were obtained from Doing Business project of the World Bank (2014a). Data on investment freedom were from the Index of Economic Freedom provided annually by the Heritage Foundation (2014), whereas data on VC financing were downloaded from the Eurostat Statistics Database (2014). Finally, changes in the national IPR regimes have been coded according to the assessment provided by Baldini et al. (2014a).

University-level data have been collected using a two-pronged strategy. First, through the EUMIDA database, we extracted harmonized, EU-level, time-invariant information on universities' localization, legal status, year of establishment, educational fields, the presence of a university hospital, and whether the university emphasizes Science Technology Engineering and Mathematics (STEM). The EUMIDA database stores information on 2500 higher education institutions from 29 EU countries. Data refer to year 2008 (for details, see European Commission 2010).

Secondly, we relied on national sources, collecting time-variant information on universities' size (i.e., number of faculty members, number of PhD students), operational characteristics (i.e., number and size of research grants awarded from public institutions, number and size of grants and contracts secured from private organizations) and intellectual eminence (i.e., national university quality rankings). For the UK, data on size and operations have been retrieved through the Higher Education Information Database for Institutions (HEIDI) (2014). Data on universities' intellectual eminence have been assessed using the UK University League Tables and Rankings from the Complete University Guide (2014). For Norway, comparable data on size and operations were obtained from the Database for Statistics on Higher Education (2014), Science and Technology Indicators for Norway (The Research Council of Norway 2013) and on national ranking from the CWTS Leiden Ranking (2014), respectively. For Italy, we used the MIUR Web sites (2013), as well as the overall academic rating score of Italian universities published in the "Grande Guida dell'Università" (Repubblica 2013).

Finally, firm-level data have been retrieved through both the universities' TTO and the national Companies' Houses. For the UK, data on firms were mainly retrieved from the Spinouts UK Survey (2014) which includes all spin-off companies from UK universities and institutions since 2000. These data were further complemented and corroborated by data from FAME (2014) and Zephyr (2014). For Norway, firm-level data originate from a database maintained by the Research Council of Norway's FORNY-program, which is designed to support universities in commercializing research results (Borlaug et al. 2009). These data have been complemented with information from the companies' annual reports accessed through the Norwegian Register of Company Accounts (www.brreg.no/english) as well as TTOs' databases, media archives, web pages, and other secondary information. For Italy, the list of firms has been compiled by contacting the universities' TTOs every 2 years since 2003, the last time being 2013. Each firm has been looked up on Infocamere Telemaco (2013), the database of the Italian Companies House, retrieving information on the operational characteristics as well as on the capital structure (for more information please refer to the TASTE project; Bolzani et al. 2014a, b).

The final dataset comprises 185 universities (68 from Italy (IT), 4 from Norway (NO) and 113 from the UK) and their 2323 spin-offs (878 from IT, 120 from NO, and 1325 from UK).[1] The observation period is from 2000 to 2012.

3.3 Dependent variables

University spin-offs Quantity and *Quality* are the two dependent variables. We index quantity as a count of the number of university spin-offs from a given university in a given year. Firm quality denotes the future impact or growth potential of the venture. Following previous work (e.g., Lockett and Wright 2005), we operationalize quality as a count of the number of university spin-offs from a given university in a given year, which have received the first round of VC financing in that year. Firm performance has been measured in many ways, with distinct benefits and concerns (Murphy et al. 1996). University spin-offs typically have long development paths before entering a growth phase (Lawton Smith and Ho 2006), making

[1] The significantly larger number of spin-offs per university in Norway is primarily driven by the countrýs centralized university structure, comprising four relatively large research universities at the start of our observation period.

traditional performance measures less relevant in the short term. Obtaining external financing is a desired goal for the majority of university spin-offs, partly due to poor access to debt financing for this type of ventures (Carpenter and Petersen 2002). Being able to attract VC financing provides an objective measure of external validation of venture quality in terms of expected returns. Although many venture-backed firms ultimately fail, research has shown that the ability to raise VC is significantly related to later success (e.g., Shane and Stuart 2002).

3.4 Predictor variables

IPR institutional changes To account for the effect of institutional changes in IPR-related-matters, we divided the number of changes in a country's IPR legislation by the number of years included in the observation period (i.e., 13). This variable ranges from 0 (UK) to 0.15 (Italy). We also used alternative measures of the changes/turbulence in the institutional environment in a country, as discussed in the robustness checks section.

Establishment of the university TTO To measure the effect of TTO presence on university spin-offs quantity and quality, we specified a dummy variable that switches from 0 to 1 the year in which the TTO is established. If the TTO was established before 2000, the variable takes the value of 1 throughout the whole observation period.

3.5 Control variables

3.5.1 Country-level

Investment freedom Because we expect that spin-off quality would be positively influenced by fewer constraints on the flow of investment capital, we include the Economic Freedom Index by the Heritage Foundation (2014), as a measure of the level of freedom for individuals and firms to move their resources into/out-of-specific activities in a given country in a given year. This index may range from 0 to 100, and in our sample, countries are bounded between 50 and 90.

Ease of doing business Higher levels of bureaucracy may hinder entrepreneurial behaviors, especially the intention and likelihood of entry. To account for this aspect in the spin-off quantity model, we used data from the World Bank (2014a), examining the number of days required to start a business in a given country in a given year. In the sample, this variable ranges from 6 to 23.

Gross domestic product per capita (GDP) The environmental conditions also influence the structure of opportunities to be exploited by individuals. The higher the GDP, the more the resources flowing into innovation and research, the higher the likelihood that entrepreneurship would occur. To account for this, we included in our models the GDP of a given country in a given year, discounted by the yearly consumer price index. The variable was logarithm transformed and its value in the sample ranges from 10.4 to 11.1.

Unemployment rate Similarly, countries with higher unemployment rates may generate less high-tech entrepreneurship compared to those with lower rates. To properly account for this, we examined the unemployment rate of a given country in a given year. The rate in our sample is bounded between 2.5 and 10.8.

VC availability Finally, the number of spin-offs financed by VCs can be influenced by the availably of VC financing. Hence, we control for the amount of early-stage VC investments in a given country in a given year. The variable has been retrieved via the Eurostat Statistics Database (2014), is expressed in million Euros, and ranges between 22 and 4240.

3.5.2 Regional-level

Some regional-level factors may also impact on spin-off foundation and growth. To account for this, via the Eurostat Statistics Database (2014), we have retrieved data at NUTS 2 regional level, between 2000 and 2012, on the *Total intramural R&D expenditure* (GERD), the *Population on 1 January* as well as the *Unemployment rates*.

3.5.3 University-level

Foundation year Under the assumption that the older the university, the higher the prestige of the institution, the higher its impact, we control for the university's year of establishment.

Size University size may also be a predictor of university spin-off activity. The higher the number of faculty members and support staff, the higher the likelihood that some research may be effectively transferred to the market. To account for this, we control for the number of employees of a given university in a given year.

Sponsored research expenditure Because the knowledge exploited by spin-offs is generated by university research, we may expect that that the amount of research money secured from for-profit institutions by a given university in a given year will be likely related to the spin-off quantity and quality. The variable is operationalized in monetary terms and is discounted for the yearly consumer price index.

Prior knowledge in technology transfer activities University TTO expertise in supporting spin-offs may take some time to develop. Some universities have been involved in technology transfer activities before 2000. To account for the accumulated knowledge and experience, we control for the cumulative number of university spin-offs established before 2000 by a given university.

Cumulative spin-off entry The number of firms from a given university receiving VC funding in a given year can be positively correlated with the total number of spin-offs emerging from that university until the year of observation. We therefore control for the cumulative number of spin-off from a university up to the focal year in the quality model.

Average age of spin-offs Firm age can predict the likelihood of receiving VC financing. To account for this, we have calculated the average age of the spin-off portfolio, for any given university in any given year. The variable ranges between 0 and 12.

Intellectual eminence We also assume that the universities' intellectual eminence may be related to their ability to foster entrepreneurial behavior by academics. We relied on national rankings to categorize each university in either the top 25, 25–50, 50–75, or lower 25 %. The variable is country-specific and time-variant.

Educational fields We account for the comprehensiveness of the educational offering by the universities under scrutiny. Relying on the information stored in EUMIDA, we assessed whether each university had education programs in each of the following fields: general programs; education; humanities and arts; social sciences, business and law; sciences; engineering, manufacturing and construction; agriculture; health and welfare; services. The nine variables are time-invariant, non-mutually exclusive, and can take the value of either 1 or 2.

Industrial variance In the quality model, we also controlled for the variance in the industrial sectors of the spin-offs established by each university in a given year. This is because firm quality in terms of access to VC could be influenced by the number of firms that are similar to them emerging from the same university in the same year. This variable is measured by the Herfindahl index. It is measured by the sum of the squares of the shares of spin-offs of a university in a given year within an industrial sector. $\sum_{i=1}^{N} s_i^2$, where s_i is the proportion of total spin-offs of a university in a given year within sector i, and N is the number of industrial sectors. The higher the industrial variance, the lower the critical mass of similar others, the less the competition and more resources a firm would get, which would result in better performance.

High-tech firm rate We finally account for the entry rate of firms established in high-tech sectors (i.e., Bio/Parma and ICT) that spun out from each university every year.

4 Econometric models

As our data feature a hierarchical structure at multiple levels, we applied a multilevel modeling approach to model and test our hypotheses (Bliese et al. 2007). Specifically, our dataset comprises time series cross-sectional data at university level, which is clustered within three countries, over 13 years. Therefore, university-level data are likely to be correlated over time; moreover, universities from the same country may be more similar than those selected randomly. Hence, ignoring the multilevel structure can result in violating the assumption of data independence in traditional multiple regressions, which gives rise to unreliable estimates. Indeed, multilevel modeling enables us to account for interdependence by capturing residuals at different levels, and to specify country-year fixed effects.

Moreover, we are not only interested in the effect of university-level predictors, but we also aim to assess to what extent country-level institutional dimensions impact the quantity and quality of university spinoffs. Multilevel modeling provides ways to evaluate the impact of factors from different levels simultaneously, and makes the test of cross-level interaction effects possible.

Finally, as both dependent variables in the analyses are measured by count data with over-dispersion, we chose multilevel negative binomial regressions over multilevel Poisson modeling, nesting university-level data (level 1) into country-level ones (level 2).

5 Results

5.1 Main models

Table 1 shows descriptive statistics, and Table 2 shows the correlation matrix for all variables in our models. With respect to the main effects, TTO establishment is positively correlated with both quantity and quality, whereas IPR institutional changes are weakly correlated with quantity and negatively correlated with quality. No multicollinearity issues emerge from the data.

We present the estimation results on the *quantity* of university spin-offs in Table 3. Model 1 shows the baseline model that includes university-level and country-level control variables only. The main effects of institutional changes and TTO establishment were estimated in Model 2. The cross-level interaction effect was tested in Model 3 with the introduction of the cross-level interaction term.

Model 2 shows that the level of institutional changes in the IPR regime at country level has a significant positive influence on the number of university spin-offs established (0.521, $p < 0.001$). The establishment of a university TTO has the same significant positive effect (0.178, $p < 0.05$). The interaction effect of university TTO and country-level institutional changes shown in Model 3 is positive and significant (0.336, $p < 0.001$). Therefore, Hypotheses 1a, 2a, and 3a are supported.

To better elaborate the cross-level interaction effect of establishment of university TTO and institutional changes in IPR at country level on the quantity of university spin-offs, we compared the marginal effect of universities with and without TTO across different levels of institutional changes (see Fig. 1). Figure 1 (left part) shows the predictive margins of TTO (at value 0 and 1, respectively) across different values of institutional changes. We can see that more changes in the IPR regime are associated with a higher number of university spin-offs. Universities with a TTO in place almost always produce more spin-offs than those without a TTO. The difference (i.e., the gap between the two lines) is increasing, in a statistically significant way, with the increasing level of changes in IPR regime at country level. This is represented graphically with the conditional marginal effects of TTO shown in Fig. 1 (right part). We also showed the predictive margins and the conditional marginal effects of TTO with a 95 % confidence interval in the appendix (see Fig. 3).

The estimation results on the *quality* of university spin-offs are shown in Table 4. As before, Model 4 shows the baseline model with control variables only. Model 5 shows the main effects of IPR institutional changes and TTO establishment. The cross-level interaction effect is displayed in Model 6. Regression results for Model 5 show that country-level institutional changes in IPR regime have a significant negative influence on the quality of university spin-offs (-0.590, $p < 0.01$). The establishment of a university TTO has a negative effect on the quality of university spin-offs, although the coefficient is only marginally significant (-0.341, $p < 0.1$). The interaction effect of the two variables is also negative and statistically significant (-0.685, $p < 0.01$) as shown in Model 6. The above results provide support for Hypotheses 1b, 2b, and 3b.

We plotted the interaction effect of the two main explanatory variables on the quality of university spin-offs in Fig. 2. As predicted, Fig. 2 shows that the more changes in IPR regime in a country, the lower the quality of university spin-offs measured by the number of spin-offs receiving VC financing. Universities with a TTO in place produce less spin-offs receiving VC financing than those without a TTO. The negative effect is intensified by the increasing level of changes in IPR regime at country level.

5.2 Robustness checks

To check for the stability and replicability of our results, we ran the selected econometric specifications using two alternative operationalizations of the *IPR Institutional Changes* construct. We obtained the first measure by dividing the number of years in which the "professor's privilege" was in place during the observation period, by the total years included in the observation period (13). This index ranges from 0 (UK) to 0.38 (Italy). The second measure was the count of absolute number of changes in the IPR

Table 1 Descriptive statistics

Variable	Observation	Mean	SD	Min	Max
Dependent variables and main predictors					
U: Spinout quantity	2405	0.97	2.11	0	31
U: Spinout quality	2405	0.15	0.59	0	8
U: TTO establishment	2405	0.72	0.45	0	1
C: IPR institutional changes	2405	0.06	0.07	0	0.15
University-level controls					
U: Cumulative entry	2405	6.79	14.44	0	197
U: Prior knowledge in tech transfer activities	2405	5.29	16.47	0	115
U: Average age of spinouts	2405	2.33	2.62	0	12
U: Foundation year	2405	1838	207	1088	2004
U: Sponsored research expenditure	2405	6.60	2.26	0	10.48
U: University size	2405	7.26	1.13	1.39	9.28
U: Intellectual eminence: rank top 25 %	2405	0.25	0.43	0	1
U: Intellectual eminence: rank 50–75 %	2405	0.26	0.44	0	1
U: Intellectual eminence: rank 25–50 %	2405	0.24	0.43	0	1
U: Education field; general	2405	1.01	0.07	1	2
U: Education field; education	2405	1.72	0.45	1	2
U: Education field; humanities and arts	2405	1.90	0.30	1	2
U: Education field; social sci., business and law	2405	1.97	0.16	1	2
U: Education field; sciences	2405	1.91	0.29	1	2
U: education field; engineering, manufacturing, and construction	2405	1.85	0.36	1	2
U: Education field; agriculture	2405	1.48	0.50	1	2
U: Education field; health and welfare	2405	1.89	0.31	1	2
U: Education field; services	2405	1.64	0.48	1	2
U:Industrial variance	2405	2.03	3.14	0	24.5
U: Hi-tech firm rate	2405	0.09	0.25	0	1
Regional-level controls					
R: R&D expenditure	2405	5.89	0.79	3.46	7.87
R: Population	2405	14.65	0.69	12.65	16.09
R: Unemployment rate	2405	7.18	4.05	1.8	27.3
Country-level controls					
C: GDP per capita	2405	10.52	0.10	10.39	11.10
C: Easiness of doing business	2405	13.14	4.10	6	23
C: Unemployment rate	2405	6.80	1.82	2.5	10.8
C: Investment freedom	2405	77.62	10.01	50	90
C: VC availability	2405	617.49	893.6	22	4240.39

U university-level variable, *R* regional-level variable, *C* country-level variable

legislation, which is the number of switches between enforcement of "professor's privilege" and "university's privilege" in a country over the 13 years of observation time. The value of this variable changes from 0 (UK) to 2 (Italy). We adopted the same model specifications for both spin-off quantity and quality in the robustness checks as the ones used in the previous test, respectively. The results remain unchanged. We present the results of the robustness checks in Appendixes 1 and 2.

Furthermore, by using a seemingly unrelated regression approach, we modeled simultaneously quantity and quality, assuming that the two equations are partially related through their error terms. This

Table 2 Correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 U: Spinout quantity	1.00															
2 U: Spinout quality	0.46	1.00														
3 U: TTO establishment	0.14	0.08	1.00													
4 C: IPR institutional changes	0.02	−0.13	−0.36	1.00												
5 U: Cumulative entry	0.65	0.53	0.17	−0.03	1.00											
6 U: Prior knowledge in tech transfer activities	0.17	0.19	0.17	−0.06	0.46	1.00										
7 U: Average age of spinouts	0.64	0.57	0.12	−0.18	0.73	0.23	1.00									
8 U: Foundation year	−0.31	−0.17	−0.05	−0.19	−0.32	−0.14	−0.34	1.00								
9 U: Sponsored research expenditure	0.40	0.27	0.03	0.21	0.44	0.43	0.35	−0.30	1.00							
10 U: University size	0.31	0.29	0.32	−0.53	0.37	0.33	0.36	−0.25	0.41	1.00						
11 U: Intellectual eminence: rank top 25 %	0.30	0.24	−0.07	−0.02	0.34	0.17	0.31	−0.11	0.28	0.15	1.00					
12 U: Intellectual eminence: rank 50–75 %	0.03	0.01	−0.02	0.00	0.03	0.15	0.02	−0.07	0.18	0.13	−0.34	1.00				
13 U: Intellectual eminence: rank 25–50 %	−0.15	−0.13	0.09	0.01	−0.17	−0.14	−0.16	0.05	−0.18	−0.08	−0.33	−0.33	1.00			
14 U: Education field; general	0.00	0.05	−0.02	0.02	0.01	0.05	−0.02	0.05	0.04	0.02	−0.04	−0.04	−0.04	1.00		
15 U: Educ. field; education	−0.02	0.00	0.13	−0.26	−0.03	−0.07	−0.03	−0.06	−0.11	0.27	−0.23	0.06	0.08	0.05	1.00	
16 U: Educ. field; humanities and arts	−0.04	−0.05	0.11	−0.31	−0.05	0.01	−0.01	−0.19	0.02	0.43	−0.08	0.05	0.06	0.02	0.34	1.00
17 U: Educ. field; social sciences, business and law	−0.05	0.03	0.06	−0.22	−0.07	0.00	0.04	−0.08	−0.01	0.16	−0.16	0.05	0.05	0.01	0.27	0.38
18 U: Educ. field; sciences	0.09	0.08	0.24	−0.33	0.10	0.18	0.10	−0.13	0.18	0.52	−0.10	0.09	0.02	0.02	0.18	0.32
19 U: Educ. field; engin., manuf. and construction	0.15	0.09	0.27	−0.09	0.16	0.14	0.12	−0.13	0.25	0.37	−0.07	0.04	0.06	−0.17	0.14	0.01
20 U: Educ. field; agriculture	0.10	0.07	0.13	−0.09	0.11	0.05	0.15	−0.17	0.08	0.23	−0.16	0.04	−0.03	0.08	0.17	0.15
21 U: Educ. field; health and welfare	0.06	0.07	0.14	−0.12	0.06	0.12	0.08	−0.15	0.12	0.31	−0.12	0.03	0.04	0.03	0.29	0.28
22 U: Educ. field; services	−0.16	−0.20	−0.01	0.25	−0.21	−0.16	−0.22	−0.07	−0.13	−0.13	−0.39	−0.01	0.19	0.06	0.20	0.15
23 U: Endustrial variance	0.33	0.12	0.15	0.22	0.31	0.42	0.15	−0.25	0.43	0.16	0.13	0.12	−0.08	0.00	−0.10	−0.01
24 U: Hi-tech firm rate	0.29	0.14	0.06	0.05	0.20	0.15	0.13	−0.06	0.26	0.17	0.12	0.03	−0.05	0.18	0.01	−0.05
25 R: R&D expenditure	0.10	0.20	0.09	−0.40	0.15	0.05	0.17	0.00	−0.02	0.29	0.19	0.07	−0.12	0.03	0.07	0.13
26 R: Population	−0.01	−0.08	−0.19	0.41	−0.02	−0.08	−0.02	−0.05	0.12	−0.21	0.05	0.00	−0.06	−0.17	−0.18	−0.17
27 R: Unemployment rate	−0.09	−0.09	−0.20	0.33	−0.06	0.06	−0.08	0.06	−0.01	−0.22	−0.16	−0.17	0.11	−0.06	−0.12	−0.15

Table 2 continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
28 C: GDP per capita	0.06	0.24	0.28	−0.51	0.14	0.14	0.07	0.13	0.00	0.37	0.01	0.00	−0.01	0.28	0.19	0.12
29 C: Easiness of doing business	−0.08	−0.05	−0.36	0.15	−0.20	−0.33	−0.02	−0.03	−0.12	−0.16	0.00	0.00	0.01	−0.03	−0.05	−0.04
30 C: Unemployment rate	−0.08	−0.16	−0.32	0.63	0.01	0.12	−0.10	−0.14	0.06	−0.38	−0.01	0.00	0.01	−0.13	−0.19	−0.18
31 C: Investment freedom	−0.08	0.04	0.23	−0.55	0.13	0.32	0.11	0.09	−0.15	0.28	0.01	0.00	−0.01	−0.17	0.11	0.19
32 C: VC Availability	−0.01	0.05	0.14	−0.46	−0.04	−0.10	0.08	0.08	−0.11	0.22	0.01	0.00	−0.01	−0.04	0.11	0.15

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
17 U: Educ. field; social sci., business and law	1.00															
18 U: Educ. field; sciences	0.41	1.00														
19 U: Educ. field; engin., manuf. and construction	0.02	0.28	1.00													
20 U: Educ. field; agriculture	0.16	0.23	0.17	1.00												
21 U: Educ. field; health and welfare	0.37	0.49	0.19	0.20	1.00											
22 U: Educ. field; services	0.15	0.11	0.09	0.21	0.28	1.00										
23 U: Industrial variance	−0.04	0.07	0.13	0.04	0.04	−0.01	1.00									
24 U: Hi-tech firm rate	−0.03	0.08	0.08	0.00	0.06	−0.10	0.21	1.00								
25 R: R&D expenditure	0.05	0.14	−0.07	−0.10	0.00	−0.19	−0.08	0.07	1.00							
26 R: Population	−0.20	−0.31	−0.12	−0.19	−0.23	0.12	0.04	−0.10	0.02	1.00						
27 R: Unemployment rate	−0.01	−0.19	−0.03	−0.07	−0.04	0.09	0.00	−0.08	−0.45	0.26	1.00					
28 C: GDP per capita	0.13	0.21	0.02	0.01	0.10	−0.21	−0.03	0.21	0.37	−0.38	−0.34	1.00				
29 C: Easiness of doing business	−0.03	−0.05	−0.01	−0.01	−0.02	0.05	−0.26	−0.07	−0.19	0.07	0.11	−0.27	1.00			
30 C: Unemployment rate	−0.14	−0.23	−0.05	−0.04	−0.09	0.20	0.10	−0.11	−0.36	0.35	0.48	−0.68	0.22	1.00		
31 C: Investment freedom	0.11	0.16	0.06	0.07	0.05	−0.10	−0.06	−0.14	0.16	−0.11	−0.03	0.26	−0.19	0.01	1.00	
32 C: VC availability	0.10	0.15	0.04	0.05	0.05	−0.11	−0.14	−0.04	0.19	−0.17	−0.19	0.37	0.02	−0.38	0.29	1.00

Number of observation: 2405; correlations above |0.04| are significant at 5 %

Table 3 Results of multilevel negative binomial regression: spin-off quantity

	Model 1	Model 2	Model 3
U: TTO establishment		0.178*	0.085
		(0.085)	(0.087)
C: IPR institutional changes		0.521***	0.262**
		(0.067)	(0.094)
UxC: TTO X IPR institutional changes			0.336***
			(0.084)
U: Prior knowledge in technology transfer activities	0.260***	0.283***	0.307***
	(0.024)	(0.024)	(0.024)
U: Foundation year	−0.000	−0.000	0.000
	(0.000)	(0.000)	(0.000)
U: Sponsored research expenditure	0.833***	0.657***	0.596***
	(0.082)	(0.077)	(0.078)
U: Size	0.199*	0.342***	0.343***
	(0.085)	(0.081)	(0.081)
U: Intellectual eminence: rank top 25 %	0.842***	0.910***	0.933***
	(0.129)	(0.129)	(0.130)
U: Intellectual eminence: rank 25–50 %	0.682***	0.746***	0.786***
	(0.121)	(0.121)	(0.122)
U: Intellectual eminence: rank 50–75 %	0.180	0.179	0.202+
	(0.120)	(0.119)	(0.120)
U: Education field; general	0.473	0.389	0.433
	(0.421)	(0.412)	(0.409)
U: Education field; education	−0.039	−0.051	−0.116
	(0.073)	(0.072)	(0.074)
U: Education field; humanities and arts	−0.096	0.011	0.029
	(0.131)	(0.129)	(0.130)
U: Education field; social sciences, business and law	−1.224***	−0.982***	−0.980***
	(0.280)	(0.276)	(0.274)
U: Education field; sciences	0.708**	0.634**	0.525*
	(0.219)	(0.214)	(0.215)
U: Education field; engin, manufacturing, and construction	0.486**	0.470**	0.539***
	(0.162)	(0.162)	(0.162)
U: Education field; agriculture	0.012	0.026	0.022
	(0.067)	(0.067)	(0.066)
U: Education field; health and welfare	0.045	−0.042	0.098
	(0.178)	(0.178)	(0.182)
U: Education field; services	0.164+	0.055	0.081
	(0.091)	(0.090)	(0.090)
U: High-tech firm rate	0.270***	0.250***	0.246***
	(0.027)	(0.026)	(0.026)
R: R&D expenditure	−0.139**	−0.113*	−0.131**
	(0.044)	(0.044)	(0.044)

Table 3 continued

	Model 1	Model 2	Model 3
R: Population	−0.142***	−0.162***	−0.158***
	(0.041)	(0.039)	(0.039)
R: Unemployment rate	0.066	0.082+	0.090+
	(0.048)	(0.048)	(0.048)
C: GDP per capita	−0.083	−0.131**	−0.105*
	(0.067)	(0.049)	(0.050)
C: Easiness of doing business	−0.130*	−0.123**	−0.096*
	(0.061)	(0.040)	(0.042)
C: Unemployment rate	−0.083	−0.289***	−0.274***
	(0.092)	(0.059)	(0.061)
Constant	−1.391+	−2.093*	−2.241**
	(0.830)	(0.832)	(0.826)
Variance of intercept	0.097*	0.013	0.015
	(0.041)	(0.011)	(0.011)
Observations	2405	2405	2405
Number of groups	39	39	39
Log likelihood	−2353	−2329	−2321
Degrees of freedom	23	25	26
Chi2	1415***	1485***	1513***

Standard errors—clustered by country-year—are in parentheses. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; + $p < 0.1$. Observations are grouped per country-year. Continuous variables are standardized. Country-year fixed effects included

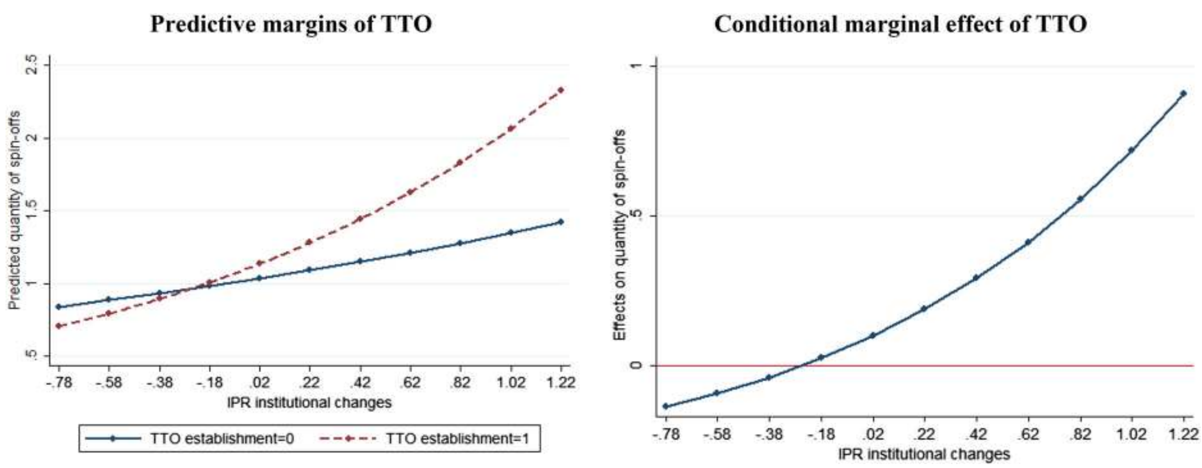

Fig. 1 Interaction effects of TTO and IPR institutional changes on the quantity of university spin-offs

approach gave us the same set of results as we had in our original models (results are available upon request).

As a further robustness check, we also tested for the impact of alternative policies and structural changes introduced in the three countries over the period under scrutiny. Specifically, we focused on the *introduction of a R&D tax-credit scheme*. University spin-offs are R&D-intensive firms that frequently use such instruments. Consistent with the IPR-related measures, the variable was operationalized as the total number of changes in the tax-credit scheme during the observation period, as well as total number of changes over the total number of years included in the observation

Table 4 Results of multilevel negative binomial regression: spin-off quality

	Model 4	Model 5	Model 6
U: TTO establishment		−0.342+	−0.527*
		(0.208)	(0.207)
C: IPR institutional changes		−0.590**	−0.099
		(0.189)	(0.246)
UxC: TTO X IPR institutional changes			−0.685**
			(0.239)
U: Cumulative entry	0.173***	0.177***	0.153***
	(0.045)	(0.042)	(0.040)
U: Average age of spinouts	−0.017	0.066	0.110
	(0.130)	(0.123)	(0.120)
U: Foundation year	0.000	−0.000	−0.000
	(0.000)	(0.000)	(0.000)
U: Size	1.566***	1.165***	1.110***
	(0.228)	(0.269)	(0.260)
U: Sponsored research expenditure	0.339	0.485*	0.608**
	(0.211)	(0.233)	(0.232)
U: Education field; general	3.703***	3.687***	3.423***
	(1.061)	(1.051)	(1.039)
U: Education field; education	−0.037	−0.097	0.020
	(0.161)	(0.168)	(0.169)
U: Education field; humanities and arts	−0.669*	−0.818**	−0.749**
	(0.291)	(0.291)	(0.284)
U: Education field; social sciences; business and law	1.488	0.805	0.606
	(1.047)	(1.081)	(1.082)
U: Education field; sciences	1.016	1.082	1.177
	(1.254)	(1.284)	(1.281)
U: Education field; engin, manufacturing, and construction	1.608*	1.801*	1.605*
	(0.776)	(0.773)	(0.768)
U: Education field; agriculture	−0.051	−0.093	−0.083
	(0.159)	(0.158)	(0.156)
U: Education field; health and welfare	−0.897+	−0.538	−0.706
	(0.480)	(0.484)	(0.485)
U: education field; services	−0.171	0.051	0.037
	(0.200)	(0.206)	(0.203)
U: Intellectual eminence: rank top 25 %	0.852*	0.833+	0.788+
	(0.432)	(0.434)	(0.430)
U: Intellectual eminence: rank 25–50 %	0.791+	0.814+	0.738+
	(0.418)	(0.418)	(0.415)
U: Intellectual eminence: rank 50–75 %	−0.062	0.007	−0.066
	(0.462)	(0.462)	(0.463)
U: Industrial variance	0.382***	0.406***	0.429***
	(0.103)	(0.098)	(0.093)
U: Hi-tech firm rate	−0.033	−0.013	−0.019
	(0.055)	(0.054)	(0.053)

Table 4 continued

	Model 4	Model 5	Model 6
R: R&D expenditure	0.014	−0.055	−0.014
	(0.102)	(0.105)	(0.103)
R: Population	0.021	0.179	0.204+
	(0.110)	(0.121)	(0.120)
R: Unemployment rate	−0.327*	−0.329*	−0.385*
	(0.163)	(0.162)	(0.161)
C: GDP per capita	0.190*	0.287***	0.291***
	(0.079)	(0.081)	(0.078)
C: Investment freedom	−0.005	−0.138	−0.135
	(0.097)	(0.101)	(0.098)
C: VC availability	0.041	0.007	0.004
	(0.078)	(0.064)	(0.063)
Constant	−13.074***	−11.467***	−10.741**
	(3.347)	(3.330)	(3.324)
Variance of intercept	0.023	0.004	0.004
	(0.044)	(0.031)	(0.028)
Observations	2405	2405	2405
Number of groups	39	39	39
Log likelihood	−663.1	−657.6	−653.8
Degrees of freedom	25	27	28
Chi2	499.5***	537.1***	562.8***

Standard errors—clustered by country-year—are in parentheses. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; + $p < 0.1$. Observations are grouped per country-year. Continuous variables are standardized. Country-year fixed effects included

period. Results are very similar to the ones obtained with the IPR scheme (available upon request).

We also adopted an alternative measure for the quality of university spin-offs. Rather than using count data, we measured it as the share of firms receiving VC funding in each university each year. Results are qualitatively the same.

Moreover, we included additional control variables, such as the share of firms receiving VC funding in past (e.g., discrete and cumulative rate in the previous 2 years or since the beginning of the observation period). Similar results were obtained.

Finally, we split the sample according to university rankings. Results based on the top 50 percentile confirmed our results.

5.3 Economic significance

We also evaluated the economic significance of our findings. For spin-offs quantity, the natural log of the expected number of spin-offs in a given year is .178 units higher for universities with a TTO. In other words, keeping other factors constant, the incidence rate of spin-off creation in a given year is about 20 % higher (i.e., exp (.178) − 1 = .195) for a university with a TTO than if the university did not have a TTO. One additional IPR institutional change increases the natural log of the expected number of university spin-offs in a given year by .521 units. Hence, everything else being equal, a change in the IPR legislation at national level increases the expected number of university spin-offs in a given year by nearly 70 % (i.e., exp (.521) − 1 = .683).

The spin-offs quality models show that the natural log of the expected number of spin-offs that receive first-round VC funding in a given year is .342 units lower for universities with a TTO. In other words, everything being equal, universities with a TTO have about 30 % fewer spin-offs that receive first-round VC funding in a given year (i.e., exp (−.342) − 1 = −.29). Moreover, one IPR institutional change reduces the incidence rate of university spin-offs that receive first-round VC funding by a factor of .55 (i.e., exp (−.59) = .55). This means that one IPR institutional

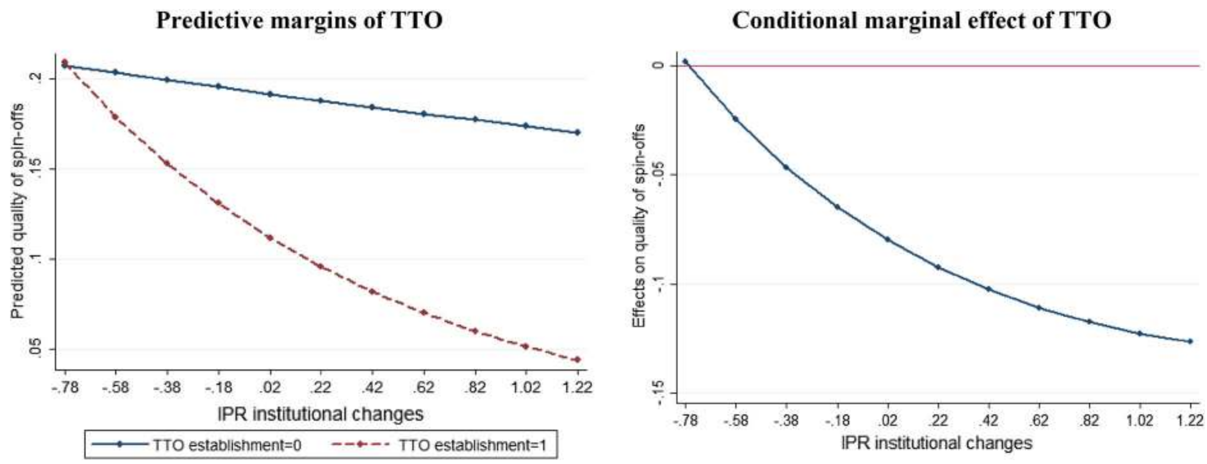

Fig. 2 Interaction effects of TTO and IPR institutional changes on the quality of university spin-offs

change decreases the number of university spin-offs that receive first-round VC funding by 45 % in a given year (i.e., exp $(-.59) - 1 = -.45$).

6 Discussion

6.1 Findings and contribution

Our study, using a unique panel dataset and multilevel analysis comprising the populations of university spin-offs in three European countries, shows that changes in the institutional framework have a positive effect on the number of spin-offs created, but a negative effect on the quality of these ventures, as measured by their ability to attract VC financing. These findings indicate that the implementation of new institutional frameworks to increase spin-off creation has an effect, but this effect appears to be more symbolic than substantive. The response within the university organization is a significant increase in the number of firms created, while the potential economic impact of these firms seems to be more modest.

Universities and TTOs appear to be complying with the new institutional norms of creating more spin-offs. Institutional pressures and expectations provide strong incentives for TTOs to generate visible results and TTO officers consider the number of new commercial ventures created as an important objective (Thursby et al. 2001). There are also examples of explicit incentives embedded in the institutional framework, such as bonus schemes providing additional TTO funding for each new firm established (Gulbrandsen and Rasmussen 2012). However, any substantive impact on spin-off firm quality needs a much longer time to manifest because founding new firms is easier than the long-term involvement contributing to firm success.

We argue that increasing the number of spin-offs may come at the expense of the quality of these firms, because the underlying commercial potential of the scientific research at the university remains unchanged. However, the negative effects on the quality of these firms were stronger than anticipated. Changes in the institutional framework seem to have a detrimental effect on spin-off quality beyond a decrease in average quality resulting from lower quality of the additional spin-offs created. Our findings indicate an absolute decrease in the number of firms able to raise VC funding, suggesting that the presence of a TTO and legislative changes do more harm than good.

Such a conclusion would be speculative because there may be several reasons explaining why university spin-offs attract less VC funding following a TTO establishment or legislative change. Possible explanations may be related to a lower demand for VC financing among university spin-offs, a lower supply of VC financing, or unrelated methodological issues. We will discuss these in turn.

First, changes in the profile or composition of the universitieś spin-off portfolio may reduce the demand for VC funding. In contrast to individual scientists, TTOs have more flexibility in selecting commercialization instruments. Many scientific discoveries, in particular within the life sciences, can be successfully licensed directly to industry (Thursby and Kemp 2002). As shown in a comparative study between Sweden and the USA, the incentive scheme under the "professor's privilege" favors the creation of spin-offs, while TTOs tend to prefer licensing to an established firm, which generates a higher commercialization success (Damsgaard and Thursby 2013). Hence, the lower observed quality of spin-offs may be because a larger share of high-potential inventions are licensed when a TTO infrastructure is in place. While the effect of institutional changes appears negative for spin-off quality, it would be premature to conclude that the total effect on university technology transfer is negative.

Moreover, the establishment of TTOs creates an infrastructure at universities where different resources may be added such as access to facilities and funding arrangements such as proof-of-concept and pre-seed funds (Kochenkova et al. 2016; Munari et al. 2015). Better access to early-stage funding internally may reduce the demand for VC funding among university spin-offs. This is especially true in technological domains with lower capital intensity.

Second, the supply of VC may be reduced as a consequence of institutional changes because university spin-offs become less attractive among potential investors. The establishment of TTOs and to some degree legislative changes at national level is part of an increasing formalization of university technology transfer (Geuna and Muscio 2009). The more formal processes employed by TTOs could have consequences that reduce the attractiveness of USOs as investment targets by VCs. The involvement of TTOs may lead to overvaluation of the spin-off from the offset, which is detrimental to raising VC later due to unrealistic price expectations (Clarysse et al. 2007). Further, it is increasingly common for TTOs to take equity positions in lieu of licensing agreements as compensation for supplying the spin-offś initial IP (Savva and Taneri 2015). VC investors may be more reluctant to invest in firms with a more complicated ownership structure and where the university, rather than the founders, holds a significant ownership stake leaving less equity available to incentivize the entrepreneurs.

Finally, methodological issues may have impacted our results (Perkmann et al. 2015). The introduction of a more formalized technology transfer process may change the universities' reporting practice for spin-offs. Universities with "professor's privilege," without a TTO infrastructure in place, may not record all start-ups by their faculty at an early stage. Hence, some of the early failures may go unnoticed, while the more successful cases are picked up and reported as spin-offs from the institution. Another issue currently debated is the tendency of professors to "bypass" the formal technology transfer infrastructure. Academic entrepreneurs may in some cases avoid disclosure to the TTO in order to circumvent the formal process that follows (Fini et al. 2010; Meoli and Vismara 2016; Siegel et al. 2004). Aldridge and Audretsch (2010) find that "back door" commercialization is more likely in cases with more experienced entrepreneurs and with increased perceived value of the IP. Hence, deliberate avoidance of TTO disclosure and involvement might be a source of underreporting in our data, which potentially could reduce the number of high-potential spin-off formally reported.

Although we control for the supply of VC financing in our analysis, our results could also be impacted by changes in the structure of early-stage VC financing. Research indicates a migration to larger deal sizes due to persistently lower returns in early-stage investing (Mason 2012). It is possible that increased investment concentration has impacted the firmś ability to raise VC, independent of volume of VC funds or underlying firm quality. We encourage future research to explore this possibility.

6.2 Implications

Our findings have a number of implications for practice and policy. It has been debated whether the most efficient policies for commercialization of research are bottom–up or top–down (Goldfarb and Henrekson 2002; Rasmussen 2008). Top–down policies face the risk of being met by strategic responses at the lower levels (Oliver 1991), thus enacting mimetic behaviors (Baldini et al. 2014b; Salvador 2009). Top–down initiatives may lead to symbolic conformance in terms of an increase in the number of spin-offs. However, the creation of quality spin-offs is a complex and resource-demanding process that requires more substantial changes at all levels within the universities. Hence, legislative changes and university-level initiatives, such as the establishment of TTOs, need to be complemented with bottom–up initiatives.

Our results therefore provide a general indication across countries that the effects of policy changes and TTO establishment may not lead to the intended increase in the creation of high-performing spin-offs. Rather, it seems important that universities develop capabilities within their entire organization and surrounding ecosystem that can provide the necessary support to make spin-offs investor ready for VC and other external investment. Earlier qualitative evidence from across European universities (Clarysse et al. 2005) has identified capability deficiencies in TTOs in this respect, and our evidence would seem to suggest that these within- and between-country differences persist. It also seems important that universities and TTOs in different countries develop the social capital to be able to attract VC and other external investment (Rasmussen et al. 2015), especially as VC investors typically view spin-offs as being more challenging propositions than regular high-tech start-ups (Wright et al. 2006). Our analysis also suggests a need for policy toward the commercialization of university research to be connected closely to the development of policies toward entrepreneurship and the funding of entrepreneurial ventures.

6.3 Limitations

Our paper has limitations that open up avenues for further research. First, while we selected countries with differences in their institutional approaches to academic entrepreneurship, further research is needed to explore whether our results hold for other countries or whether there are additional differences.

Second, we measured quality by the ability of spin-offs to attract VC funding. Data limitations restricted our ability to measure access to other external funding notably business angel funding which may be especially important for early-stage spin-off ventures. Further research is needed to explore the role of access to different forms of external investment funds. Additionally, we acknowledge that the performance of the spin-off is a dynamic variable and that TTO actions may impact beyond spin-off birth. However, a large number of spin-offs do not generate revenues for many years, if at all, and accounting data are incomplete for a sizable proportion of our sample not least because small firms have exemptions from reporting financial information. As a result, we do not analyze subsequent accounting, financial and economic performance of spin-offs following VC investment. Further research is needed to explore this aspect, although cross-country data limitations may constrain this approach.

Third, as we have indicated, policies toward the commercialization of university IP have varied over time within and across countries, which have implications for university strategies toward the extent and types of spin-offs (Lockett et al. 2015). While our panel data analysis helps to pick up the quantitative effects of these variations, complementary fine-grained qualitative analysis is required concerning the adaptation of the spin-off processes adopted by universities in different countries. For example, TTOs may have different capabilities and routines (Lockett and Wright 2005). Further, TTOs may be centralized or decentralized which may have implications for the locus of capabilities to support spin-offs and the social capital of technology transfer officers to access external funding (Huyghe et al. 2014). Similarly, different TTOs may have different remits regarding the promotion of different dimensions of academic entrepreneurship which may be reflected in the extent to which they focus on spin-off activity. Further research might attempt to analyze TTO remits, for example by exploring their mission statements. Such mission statements may be time variant as TTOs evolve their approaches to academic entrepreneurship.

Fourth, and relatedly, we have focused on within- and across-country differences in university spin-offs, but TTOs are also involved to a greater or lesser extend or degree of success in other dimensions of commercialization activity. Given the limited qualitative (Wright et al. 2008) and quantitative analyses (e.g., Chapple et al. 2005) of these multiple outputs, additional cross-country examination is warranted.

Fifth, our results indicate the importance of bottom–up initiatives and TTOs programs improving the motivation and ability of scientists to launch successful university spin-offs. However, due to data limitations, we were not able to measure the implementation of such initiatives and how this explains variance in quality of spin-offs. Although challenging to study in large-scale cross-country research, further qualitative studies are required to understand in greater detail how TTOs can successfully influence the quality of their spin-off ventures.

Sixth, although we measured differences in investment freedom across countries, data limitations restricted our ability to account for cross-country and within-country differences in access to external finance. Countries differ in the extent of development of VC markets as well as business angel markets, but the proliferation of new sources of venture funding such as crowdfunding and accelerators (Pauwels et al. 2016) potentially introduces additional within- and between-country variations. Subsequent efforts to encompass these differences will be become more important over time.

Seventh, while our focus was on country-level differences, policy variations that impact university spin-off activity may also differ at regional level (Munari et al. 2015). Additional analysis focused on regional aspects may help extend the insights presented here.

Finally, the private or public legal status of a university may be important. Private universities may be less constrained in investing resources into technology transfer activities compared to public ones. However, we were unable to explore this aspect of the influence on spin-off activity, as in our three countries the number of private universities is too small. Future studies might examine this issue in contexts with a higher incidence of private universities, such as the USA.

7 Conclusion

In sum, the creation of spin-off firms from universities is increasingly seen internationally as an important mechanism for the commercialization of research, and hence forms a central element in the overall contribution of universities to technology development and economic growth. Governments and universities are developing framework conditions that are conductive to spin-offs but as yet there is limited systematic cross-country comparative analysis of the influences on the extent and quality of spin-offs created. Our study adds to the so far limited cross-country analyses of these influences and points the way to further cross-country analyses and policy developments.

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Appendix 1

See Tables 5 and 6 and Fig. 3.

Table 5 Results of multilevel negative binomial regression: spin-off quantity

	Model 1a	Model 2a	Model 3a
U: TTO establishment		0.181*	−0.179
		(0.085)	(0.122)
C: IPR institutional changes		2.742***	1.358**
		(0.358)	(0.500)
UxC: TTO X institutional changes[a]			1.809***
			(0.454)
U: Prior knowledge in technology transfer activities	0.016***	0.017***	0.019***
	(0.001)	(0.001)	(0.001)
U: Foundation year	−0.000	−0.000	0.000
	(0.000)	(0.000)	(0.000)
U: Sponsored research expenditure	0.369***	0.292***	0.265***
	(0.036)	(0.034)	(0.035)
U: Size	0.176*	0.296***	0.298***
	(0.075)	(0.071)	(0.071)
U: Intellectual eminence: rank top 25 %	0.842***	0.912***	0.933***
	(0.129)	(0.129)	(0.130)

Table 5 continued

	Model 1a	Model 2a	Model 3a
U: Intellectual eminence: rank 25–50 %	0.682***	0.747***	0.785***
	(0.121)	(0.121)	(0.122)
U: Intellectual eminence: rank 50–75 %	0.180	0.178	0.200+
	(0.120)	(0.119)	(0.120)
U: Education field; general	0.473	0.360	0.418
	(0.421)	(0.412)	(0.410)
U: Education field; education	−0.039	−0.053	−0.117
	(0.073)	(0.072)	(0.074)
U: Education field; humanities and arts	−0.096	0.018	0.036
	(0.131)	(0.130)	(0.130)
U: Education field; social sciences; business and law	−1.224***	−0.992***	−0.989***
	(0.280)	(0.275)	(0.274)
U: Education field; sciences	0.708**	0.639**	0.530*
	(0.219)	(0.214)	(0.215)
U: Education field; engineering, manufacturing, and construction	0.486**	0.473**	0.541***
	(0.162)	(0.162)	(0.162)
U: Education field; agriculture	0.012	0.028	0.024
	(0.067)	(0.067)	(0.066)
U: Education field; health and welfare	0.045	−0.041	0.099
	(0.178)	(0.178)	(0.182)
U: Education field; services	0.164+	0.058	0.084
	(0.091)	(0.090)	(0.090)
U: High-tech firm rate	1.083***	1.000***	0.987***
	(0.107)	(0.104)	(0.104)
R: R&D expenditure	−0.176**	−0.147**	−0.169**
	(0.056)	(0.056)	(0.056)
R: Population	−0.206***	−0.227***	−0.224***
	(0.059)	(0.057)	(0.057)
R: Unemployment rate	0.016	0.020+	0.022+
	(0.012)	(0.012)	(0.012)
C: GDP per capita	−0.820	−1.439**	−1.214*
	(0.666)	(0.493)	(0.500)
C: Easiness of doing business	−0.032*	−0.031**	−0.024*
	(0.015)	(0.010)	(0.010)
C: Unemployment rate	−0.045	−0.158***	−0.151***
	(0.050)	(0.033)	(0.034)
Constant	8.002	13.933*	11.690*
	(7.435)	(5.472)	(5.539)
Variance of intercept	0.097*	0.013	0.016
	(0.041)	(0.011)	(0.011)
Observations	2405	2405	2405
Number of groups	39	39	39
Log likelihood	−2353	−2329	−2321

Table 5 continued

	Model 1a	Model 2a	Model 3a
Degrees of freedom	23	25	26
Chi2	1415***	1485***	1513***

Standard errors—clustered by country-year—are in parentheses. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; + $p < 0.1$. Observations are grouped per country-year. Country-year fixed effects included

[a] Measured as the number of years in which professor has IPR privilege divided by years of observation time (13 years)

Table 6 Results of multilevel negative binomial regression: spin-off quantity

	Model 1b	Model 2b	Model 3b
U: TTO establishment		0.178*	−0.181
		(0.085)	(0.121)
C: IPR institutional changes		0.543***	0.273**
		(0.070)	(0.098)
UxC: TTO X institutional changes[a]			0.351***
			(0.088)
U: Prior knowledge in technology transfer activities	0.016***	0.017***	0.019***
	(0.001)	(0.001)	(0.001)
U: Foundation year	−0.000	−0.000	0.000
	(0.000)	(0.000)	(0.000)
U: Sponsored research expenditure	0.369***	0.291***	0.264***
	(0.036)	(0.034)	(0.035)
U: Size	0.176*	0.302***	0.303***
	(0.075)	(0.071)	(0.071)
U: Intellectual eminence: rank top 25 %	0.842***	0.910***	0.933***
	(0.129)	(0.129)	(0.130)
U: Intellectual eminence: rank 25–50 %	0.682***	0.746***	0.786***
	(0.121)	(0.121)	(0.122)
U: Intellectual eminence: rank 50–75 %	0.180	0.179	0.202+
	(0.120)	(0.119)	(0.120)
U: Education field; general	0.473	0.389	0.433
	(0.421)	(0.412)	(0.409)
U: Education field; education	−0.039	−0.051	−0.116
	(0.073)	(0.072)	(0.074)
U: Education field; humanities and arts	−0.096	0.011	0.029
	(0.131)	(0.129)	(0.130)
U: Education field; social sciences; business and law	−1.224***	−0.982***	−0.980***
	(0.280)	(0.276)	(0.274)
U: Education field; sciences	0.708**	0.634**	0.525*
	(0.219)	(0.214)	(0.215)

Table 6 continued

	Model 1b	Model 2b	Model 3b
U: Education field; engineering, manufacturing and construction	0.486**	0.470**	0.539***
	(0.162)	(0.162)	(0.162)
U: Education field; agriculture	0.012	0.026	0.022
	(0.067)	(0.067)	(0.066)
U: Education field; health and welfare	0.045	−0.042	0.098
	(0.178)	(0.178)	(0.182)
U: Education field; services	0.164+	0.055	0.081
	(0.091)	(0.090)	(0.090)
U: High-tech firm rate	1.083***	1.005***	0.989***
	(0.107)	(0.104)	(0.103)
R: R&D expenditure	−0.176**	−0.143*	−0.166**
	(0.056)	(0.056)	(0.056)
R: Population	−0.206***	−0.234***	−0.229***
	(0.059)	(0.057)	(0.057)
R: Unemployment rate	0.016	0.020+	0.022+
	(0.012)	(0.012)	(0.012)
C: GDP per capita	−0.820	−1.304**	−1.044*
	(0.666)	(0.486)	(0.494)
C: Easiness of doing business	−0.032*	−0.030**	−0.023*
	(0.015)	(0.010)	(0.010)
C: Unemployment rate	−0.045	−0.158***	−0.150***
	(0.050)	(0.032)	(0.033)
Constant	8.002	12.516*	9.905+
	(7.435)	(5.401)	(5.482)
Variance of intercept	0.097*	0.013	0.015
	(0.041)	(0.011)	(0.011)
Observations	2405	2405	2405
Number of groups	39	39	39
Log likelihood	−2353	−2329	−2321
Degrees of freedom	23	25	26
Chi2	1415***	1485***	1513***

Standard errors—clustered by country-year—are in parentheses. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; + $p < 0.1$. Observations are grouped per country-year. Country-year fixed effects included

[a] Measured by absolute number of changes in IPR institution in a country

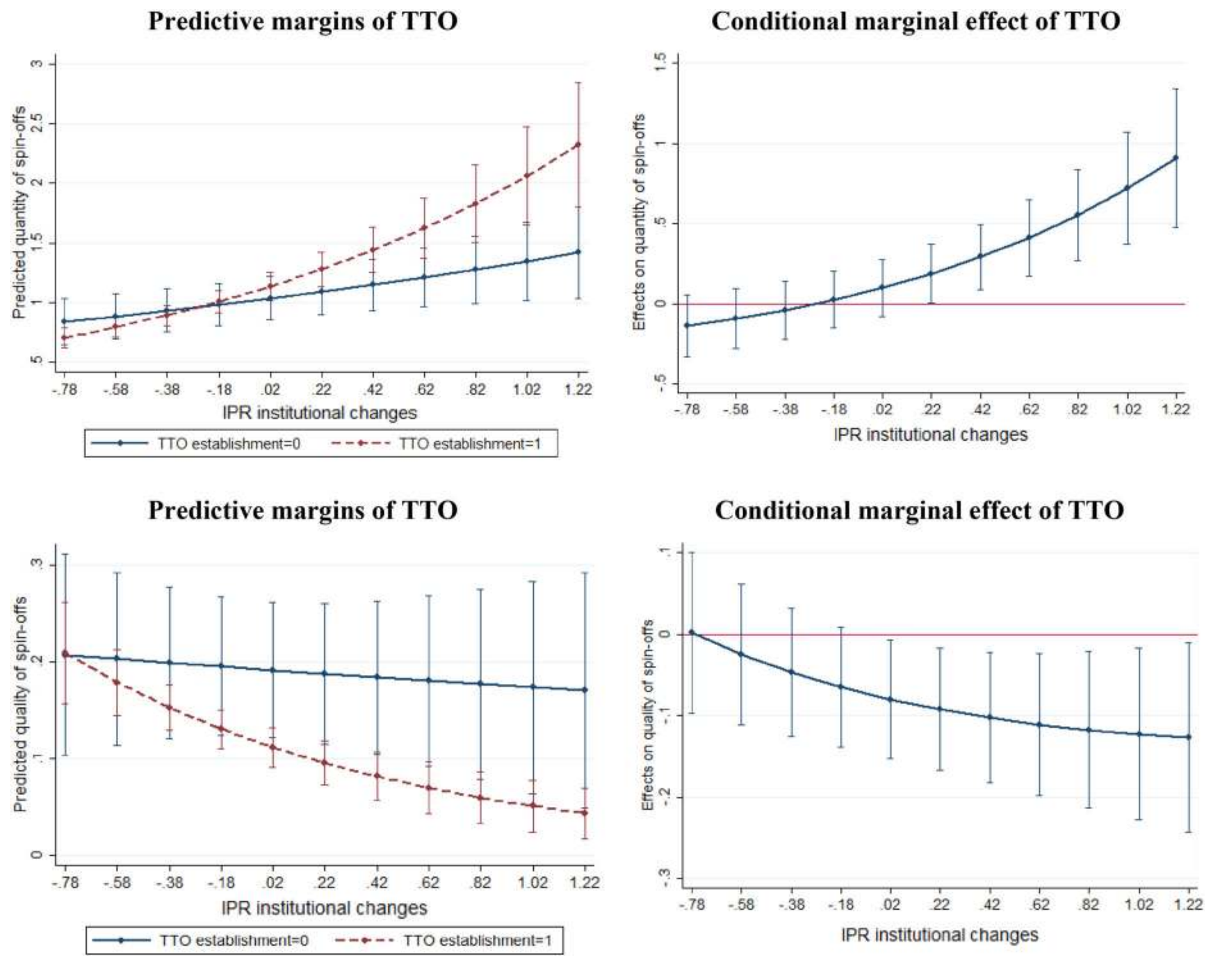

Fig. 3 Interaction effects with confidence intervals (95 %)

Appendix 2

See Tables 7 and 8.

Table 7 Results of multilevel negative binomial regression: spin-off quality

	Model 4a	Model 5a	Model 6a
U: TTO establishment		−0.345+	0.038
		(0.208)	(0.245)
C: IPR institutional changes		−3.078**	−0.402
		(0.997)	(1.295)
UxC: TTO X IPR institutional changes			−3.778**
			(1.263)
U: Cumulative entry	0.012***	0.012***	0.011***
	(0.003)	(0.003)	(0.003)
U: Average age of spinouts	−0.006	0.027	0.045
	(0.050)	(0.047)	(0.046)

Table 7 continued

	Model 4a	Model 5a	Model 6a
U: Foundation year	0.000	−0.000	−0.000
	(0.000)	(0.000)	(0.000)
U: Size	1.382***	1.043***	0.986***
	(0.201)	(0.236)	(0.228)
U: Sponsored research expenditure	0.150	0.210*	0.267**
	(0.093)	(0.103)	(0.102)
U: Education field; general	3.703***	3.707***	3.411**
	(1.061)	(1.052)	(1.039)
U: Education field; education	−0.037	−0.097	0.028
	(0.161)	(0.168)	(0.169)
U: Education field; humanities and arts	−0.669*	−0.823**	−0.748**
	(0.291)	(0.292)	(0.284)
U: Education field; social sciences; business and law	1.488	0.834	0.635
	(1.047)	(1.078)	(1.078)
U: Education field; sciences	1.016	1.068	1.168
	(1.254)	(1.282)	(1.279)
U: Education field; engineering, manufacturing, and construction	1.608*	1.802*	1.594*
	(0.776)	(0.773)	(0.768)
U: Education field; agriculture	−0.051	−0.096	−0.083
	(0.159)	(0.158)	(0.156)
U: Education field; health and welfare	−0.897+	−0.547	−0.723
	(0.480)	(0.484)	(0.484)
U: Education field; services	−0.171	0.046	0.033
	(0.200)	(0.206)	(0.203)
U: Intellectual eminence: rank top 25 %	0.852*	0.831+	0.785+
	(0.432)	(0.434)	(0.429)
U: Intellectual eminence: rank 25–50 %	0.791+	0.813+	0.735+
	(0.418)	(0.418)	(0.415)
U: Intellectual eminence: rank 50–75 %	−0.062	0.010	−0.068
	(0.462)	(0.462)	(0.463)
U: Industrial variance	0.122***	0.129***	0.137***
	(0.033)	(0.031)	(0.030)
U: Hi-tech firm rate	−0.131	−0.048	−0.076
	(0.221)	(0.215)	(0.211)
R: R&D expenditure	0.018	−0.066	−0.009
	(0.129)	(0.132)	(0.130)
R: Population	0.031	0.244	0.289+
	(0.159)	(0.174)	(0.171)
R: Unemployment rate	−0.081*	−0.080*	−0.094*
	(0.040)	(0.040)	(0.040)
C: GDP per capita	1.890*	2.958***	3.074***
	(0.786)	(0.810)	(0.781)
C: Investment freedom	−0.001	−0.015	−0.014
	(0.010)	(0.010)	(0.010)

Table 7 continued

	Model 4a	Model 5a	Model 6a
C: VC availability	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Constant	−44.258***	−53.031***	−54.789***
	(9.595)	(9.578)	(9.269)
Variance of intercept	0.023	0.003	0.003
	(0.044)	(0.031)	(0.027)
Observations	2405	2405	2405
Number of groups	39	39	39
Log likelihood	−663.1	−657.7	−653.5
Degrees of freedom	25	27	28
Chi2	499.5***	536.7***	565.2***

Standard errors—clustered by country-year—are in parentheses. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; + $p < 0.1$. Observations are grouped per country-year. Country-year fixed effects included

[a] Measured as the number of years in which professor has IPR privilege divided by years of observation time (13 years)

Table 8 Results of multilevel negative binomial regression: spin-off quality

	Model 4b	Model 5b	Model 6b
U: TTO establishment		−0.342+	0.014
		(0.208)	(0.243)
C: IPR institutional changes		−0.615**	−0.103
		(0.197)	(0.257)
UxC: TTO X IPR institutional changes			−0.714**
			(0.249)
U: Cumulative entry	0.012***	0.012***	0.011***
	(0.003)	(0.003)	(0.003)
U: Average age of spinouts	−0.006	0.025	0.042
	(0.050)	(0.047)	(0.046)
U: Foundation year	0.000	−0.000	−0.000
	(0.000)	(0.000)	(0.000)
U: Size	1.382***	1.029***	0.980***
	(0.201)	(0.238)	(0.230)
U: Sponsored research expenditure	0.150	0.215*	0.269**
	(0.093)	(0.103)	(0.103)
U: Education field; general	3.703***	3.687***	3.423***
	(1.061)	(1.051)	(1.039)
U: Education field; education	−0.037	−0.097	0.020
	(0.161)	(0.168)	(0.169)
U: Education field; humanities and arts	−0.669*	−0.818**	−0.749**
	(0.291)	(0.291)	(0.284)
U: Education field; social sciences; business and law	1.488	0.805	0.606
	(1.047)	(1.081)	(1.082)
U: Education field; sciences	1.016	1.082	1.177
	(1.254)	(1.284)	(1.281)

Table 8 continued

	Model 4b	Model 5b	Model 6b
U: Education field; engineering, manufacturing, and construction	1.608*	1.801*	1.605*
	(0.776)	(0.773)	(0.768)
U: Education field; agriculture	−0.051	−0.093	−0.083
	(0.159)	(0.158)	(0.156)
U: Education field; health and welfare	−0.897+	−0.538	−0.706
	(0.480)	(0.484)	(0.485)
U: Education field; services	−0.171	0.051	0.037
	(0.200)	(0.206)	(0.203)
U: Intellectual eminence: rank top 25 %	0.852*	0.833+	0.788+
	(0.432)	(0.434)	(0.430)
U: Intellectual eminence: rank 25–50 %	0.791+	0.814+	0.738+
	(0.418)	(0.418)	(0.415)
U: Intellectual eminence: rank 50–75 %	−0.062	0.007	−0.066
	(0.462)	(0.462)	(0.463)
U: Industrial variance	0.122***	0.129***	0.137***
	(0.033)	(0.031)	(0.030)
U: Hi-tech firm rate	−0.131	−0.052	−0.078
	(0.221)	(0.215)	(0.211)
R: R&D expenditure	0.018	−0.070	−0.018
	(0.129)	(0.132)	(0.130)
R: Population	0.031	0.259	0.295+
	(0.159)	(0.175)	(0.173)
R: Unemployment rate	−0.081*	−0.081*	−0.095*
	(0.040)	(0.040)	(0.040)
C: GDP per capita	1.890*	2.852***	2.894***
	(0.786)	(0.803)	(0.776)
C:Iinvestment freedom	−0.001	−0.014	−0.013
	(0.010)	(0.010)	(0.010)
C: VC availability	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Constant	−44.258***	−52.030***	−52.928***
	(9.595)	(9.561)	(9.266)
Variance of intercept	0.023	0.004	0.004
	(0.044)	(0.031)	(0.028)
Observations	2405	2405	2405
Number of groups	39	39	39
Log likelihood	−663.1	−657.6	−653.8
Degrees of freedom	25	27	28
Chi2	499.5***	537.1***	562.8***

Standard errors—clustered by country-year—are in parentheses. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; + $p < 0.1$. Observations are grouped per country-year. Country-year fixed effects included

[a] Measured by absolute number of changes in IPR institution in a country

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