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ORIGINAL PAPER

Heterogeneous effects of spinoff foundations on the means of technology transfer: the role of past academic-industry collaborations

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Abstract
Focusing on the Italian population of academic entrepreneurs, we analyze the effect of establishing a spinoff firm on researchers' attitudes towards carrying out other activities in collaboration with firms, namely, co-publishing and co-patenting. We investigate the heterogeneity in this effect in terms of existing collaborations with firms in the pre-spinoff period. Using a counterfactual analysis on subgroups, we verify that academic entrepreneurs with previous publications with firms diminish their co-publishing and increase their co-patenting after founding a spinoff. Conversely, academic entrepreneurs who had no previous publications with firms increase their co-publishing and decrease their co-patenting. We maintain that such results are related to academics' learning processes connected with their previous technology transfer activities. The policy implications are related to technology transfer aims and contradict the idea that promoting spinoffs is an appropriate "one-size-fits-all" initiative.

Keywords Spin-off · Academic entrepreneurship · Academic publications · University–industry links · Technology transfer · Heterogeneity

JEL Classification O33 · O26 · L26 · O31

1 Introduction

Recent contributions to the literature have extensively studied the effects of knowledge transfer activities on the academic organizations promoting them. Some of the existing studies take academic spinoffs or university incubators, Industrial Liaison Offices (ILO) and Technology Transfer Offices (TTO) as the unit of analysis

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(Lafuente and Berbegal-Mirabent 2017; Baglieri et al. 2018; O'Kane 2018; Rasmussen and Wright 2015; Ruokonen et al. 2008; Maine and Garnsey 2007; Zedtwitz and Grimaldi 2006; Feldman and Klofsten 2010 to cite only some).

Instead, other studies have focused on single researchers. Indeed, academics' background and motivations are crucial for igniting knowledge transfer (Landry et al. 2010; Aldridge and Audretsch 2011; Kalar and Antoncic 2016; Filippetti and Savona 2017) and for determining the choice to activate one specific transfer channel instead of another (Gümüsay and Bohné 2018; Rizzo 2015; Walter et al. 2016, and so on). At the same time, being involved in knowledge transfer activities determines some consequences for researchers. Many scholars have investigated whether and how such involvement affects researchers' publication productivity, quality, and direction. The evidence on such effects is mixed and varies according to the type of transfer activity considered. On the one hand, some studies suggest that being directly involved in entrepreneurial activities brain drains not-for-profit research (Czarnitzki and Toole 2010), even if this finding is not universal (Abramo et al. 2012; see also Larsen 2011, for a review of the contrasting evidence on this topic). On the other hand, some research highlights that knowledge transfer activities such as patenting boost publication rates and quality (Azoulay et al. 2009; Breschi et al. 2008; Van Looy et al. 2006), especially when such transfer activities are not intensive (Crespi et al. 2011), although such an effect might depend upon the field of specialization (Breschi et al. 2008). Similar positive impacts have also been observed for co-publication with firms (Godin and Gingras 2000).

In addition to the diverse impacts on pure research, different knowledge transfer activities might also be substitutive or complementary. Indeed, these activities are heterogeneous in many regards: the effort required, the "readiness-to-use" of the transferred knowledge, and its affinity—and possible economies—with other academic and nonacademic tasks. To the best of our knowledge, the interdependence among academic knowledge transfer activities has been mostly neglected by the existing literature. One exception is Barbieri et al. (2018), who show that establishing spinoffs, in addition to exerting a negative effect on the publishing of purely academic research, also significantly reduces co-publishing with firms, which is an alternative knowledge transfer vehicle.

Despite this gap in the literature, identifying interdependence among knowledge transfer channels might be particularly relevant for policy design. Suppose policy initiatives aim to increase the overall technology transfer to the economy. In that case, they must take into account that the promotion of one specific activity can result in a further incentive to or a brake on the implementation of others. Overall, this might either augment or decrease the general effects of technology transfer to the economic environment, either boosting or jeopardizing the policy effort.

Our analysis deepens the study of the relations among various forms of knowledge transfer. Our focus is on the effects that creating a spinoff has on other scholars' collaborations with firms. More specifically, this paper studies the spinoff effects on researchers' attitudes towards (i) noncommercial knowledge transfer activities such as publishing with firms and (ii) commercial knowledge transfer activities such as patenting with firms. The novelty of the contribution lies in investigating whether such effects are heterogeneous according to the researchers' experience

in collaborating with firms in the pre-spinoff period. In other words, we analyze whether the use of knowledge transfer channels after the spinoff varies according to whether the academic entrepreneur had previously collaborated with firms or not.

This potential heterogeneity is relevant in many regards, particularly for the results of policies aimed at fostering academic entrepreneurship and innovation at large. Policy evaluation studies have noted that the effects of policies can vary profoundly depending on the characteristics of the recipients, being them territories (Barbieri et al. 2020; Cypher and Dietz 2009), social groups (Belaid and Ridde 2015), or individuals (Dubois et al. 2020). In line with this perspective, previous research has highlighted that a single one-size-fits-all policy to encourage university–industry collaborations cannot be effective (Filippetti and Savona 2017) and, more specifically, that the heterogeneity in the effects of academic entrepreneurship policies must be taken into account (Han 2020).

Conversely, in the Italian context, the existing national and university-level regulations on academic entrepreneurship tend to disregard the individual features characterizing the researcher who decides to establish a new spinoff. The regulations of those universities reporting the highest number of spinoffs in the country[1] mainly ground the evaluation of a spinoff's feasibility on the growth and success prospects of the newly established firm. Few universities include an assessment of the compatibility of the spinoff activities with the academic founder's teaching and research tasks and different institutions (e.g., the department, the specializing school, the Ph.D. tutor, and so on) are in charge of the authorization depending on whether the academic has a permanent position or not. Apart from this, there seems to be no pre-established procedure for evaluating the researcher's profile, either in terms of his/her previous experience with the industry or in relation to the effects of the spinoff on the other forms of knowledge transfer that he/she usually carries out.

Instead, we maintain that shedding more light on the extent to which individual pre-spinoff heterogeneity can affect post-spinoff industry–university collaboration can provide useful insights into the need to design differentiated policies and on the direction that these policies should take.

The intuition driving our investigation is as follows. The existing literature on the influence of individual characteristics on engagement in knowledge transfer activities, notably founding a spinoff, has highlighted the importance of prior collaboration with industry (Krabel and Mueller 2009). Such previous contacts would help the academic develop an entrepreneurial attitude and managerial skills (Ortín-Ángel and Vendrell-Herrero 2014), allowing him/her to acquire knowledge, gather information about the market, and accumulate the social capital of linkages with market actors (Landry et al. 2006, 2010). Additionally, some forms of university–industry collaborations critically increase academics' likelihood of exploiting entrepreneurial opportunities, strengthening their capacity to bring new inventions to the market (D'Este et al. 2012). In other words, having previously collaborated with firms

[1] We have analyzed the current regulations of the 11 universities with the greatest number of spinoffs established up to 2020. These universities are responsible for at least 50 spinoffs each, for a total of 729 established spinoffs (50 percent of the total).

makes academics more entrepreneurially "mature" and can affect the spinoff's success (Ortín-Ángel and Vendrell-Herrero 2014).

We claim that this might also impact the technology transfer channels that academic entrepreneurs activate *after* a spinoff is established. For academics who have collaborated with firms in the past, the spinoff acts as an intermediary favoring the transformation of scientific knowledge into productive knowledge (Fontes 2005). From this perspective, a spinoff might incentivize co-patenting activities while crowding out other forms of research collaboration, such as co-publications. Conversely, for those who have never cooperated with firms, a spinoff might be their first opportunity to explore the market and build new networks. Therefore, it might create unique occasions for academics to connect with other firms; such collaborations might involve fewer risks and be more exploratory in form, such as co-publishing. Simultaneously, the lack of information about the market may induce academic entrepreneurs with no previous co-publication experience with firms to compete with other firms in inventions that are more easily marketed, reducing their propensity to co-patent.

To empirically test this intuition, we build upon the unique dataset used by Barbieri et al. (2018). This dataset includes information covering (i) all Italian academic entrepreneurs who founded a spinoff in the time period 2000–2007 and (ii) a control group of similar colleagues who were not involved in any spinoff. To analyze the different behaviors of academic entrepreneurs with respect to their previous experience in co-publishing, we rely on propensity score matching (PSM) and subgroup analysis, which allows us to address (i) the possible biases arising from researchers' self-selection into spinoffs and (ii) the moderating effects of pre-spinoff collaborations with firms (Green and Stuart 2014).

The remainder of this paper is as follows. Section 2 reviews the relevant literature and presents a conceptual and interpretive framework. This framework supports the hypotheses to be tested by the empirical analysis, which are also presented in this section. Section 3 provides a detailed description of the data used in the study and illustrates the methodology used. The results are presented in Sect. 4 and are tested for robustness in Sect. 5. Section 6 offers a discussion and interpretation of the results, while Sect. 7 highlights some policy implications stemming from the study and then concludes.

2 Literature review and hypotheses

Many studies have focused on the individual features and motivations affecting entrepreneurship (Aldridge and Audretsch 2011; Arza 2010; Bekkers and Bodas Freitas 2008; Castillo Holley and Watson 2017; Clarysse et al. 2011; Hayter 2011, 2015; Krabel and Mueller 2009; Lam 2011; Rizzo 2015). Nevertheless, a focus on individual academics rather than on spinoffs and universities in the study of technology transfer has emerged only recently (Perkmann et al. 2013; Rothaermel et al. 2007), grounded in the need to isolate the figure of the academic entrepreneur—in a broad sense—from that of the entrepreneur. Many findings based on empirical evidence from European and extra-European cases acknowledge that academic

entrepreneurs show motivations and behaviors peculiar to their scholarly activity (Castillo Holley and Watson 2017; D'Este and Perkmann 2011; Evans 2010; Rizzo 2015). For example, part of the literature shows that for academics, involvement in entrepreneurship and collaboration with industry is driven by a desire for knowledge creation and dissemination (Castillo Holley and Watson 2017; Haeussler and Colyvas 2011; Hayter 2011, 2015) or by the opportunity for capacity recognition (Clarysse et al. 2011; Rasmussen et al. 2011).

Among the studies investigating the individual aspects of academic entrepreneurship and technology transfer, some streams of literature are particularly relevant for our study. First, there is a growing recognition that the existing means for technology transfer—spinoffs, co-patenting, joint publications, and research—display qualitative differences (Bekkers and Bodas Freitas 2008). In this sense, various studies have distinguished between transfer forms linked more closely to commercialization and others that are mainly oriented towards knowledge creation and dissemination. For instance, Arza (2010) usefully divides knowledge transfer channels into four typologies based on the benefits expected by the public researchers (economic or intellectual) and the attitudes of firms (passive or proactive towards collaborations). Accordingly, the channels of interaction differ depending on the researchers' motivations and the associated benefits. In particular, on the academic side, the various channels are placed along a continuum between two strategies: (1) gaining economic benefits by exploiting the commercial potential of coproduced knowledge and (2) achieving new insights and inspiration for the scientific research agenda. While spinoffs and joint patenting lie closer to the first strategy, co-publications are more closely associated with the second strategy. Following this line, Haeussler and Colyvas (2011) identify a qualitative difference between commercialized forms of technology transfer, such as consulting, patenting and founding new ventures, and more informal knowledge transfer forms such as publications. The latter generally allow open access to knowledge and research results, a feature proper to the public science setting rather than the market setting.

Similarly, Landry et al. (2010) distinguish between knowledge transfer forms that are noncommercial—such as teaching and publishing—and those that are commercial—such as patenting and spinoffs. Such a difference is also highlighted in the review by Perkmann et al. (2013), who discriminate between commercialization (patenting, co-patenting and spinoffs) and academic engagement or informal technology transfer, which is more closely linked to knowledge-related collaboration. In line with other works (e.g., D'Este and Patel 2007 for the UK; Franco and Haase 2015 for Portugal), their review highlights that the latter (and in particular co-publishing) is far more common than patenting and academic entrepreneurship and that such knowledge-related collaborations are usually the first results of joint research efforts between academics and firms.

Our work stresses the role of academic entrepreneurs' previous experience with industry collaborations in influencing subsequent technology transfer. To the best of our knowledge, this aspect has been rarely covered by the literature. Among the few studies on this topic, Krabel and Mueller (2009) underline how German scientists who have already cooperated with firms are more likely to start their own business. Perkmann et al. (2013) note that the literature has identified

that previous experience with commercialization increases collaborations. On the other hand, previous academic engagement can generate subsequent commercialization opportunities. However, their work also underlines that the international debate currently lacks research identifying the possible complementarities and contradictions between knowledge-driven academic engagement and commercialization activities. Finally, Barbieri et al. (2018) note that different types of previous experience in commercializing inventions by Italian academics—such as patenting on their own versus co-patenting with other firms—can have opposite effects on scholars' propensity to found their own ventures.

Very little research has addressed the existence of complementarity and substitution effects among technology transfer mechanisms. In their study, Krabel and Mueller (2009) highlight a complementarity between more intense patenting activities and starting new ventures. Van Looy et al. (2011) studied the trade-offs between scientific productivity and entrepreneurship on the one hand and various forms of technology transfer on the other. Since the different forms of technology transfer correspond to different organizational arrangements, the authors hypothesize and verify whether either complementarities or substitutions exist. In partial contrast with Krabel and Mueller (2009), their findings suggest that patenting is not related to the better performance of the spinoff foundation or of contract research and publications. Nevertheless, the academic entrepreneurs who found their own ventures also engage in larger amounts of contract research. Building on the theoretical framework of Arza (2010), Bhullar et al. (2017) explore the mediating effects of different technology transfer channels and the relation between the existence of past collaborations with firms and various forms of academia-industry relations (including joint publications) in India and find that past collaborative experience influences subsequent collaborative experiences. Landry et al. (2010) find that commercial forms of knowledge transfer, e.g., patents, spinoffs, and consulting, are complementary, while substantial independence exists among commercial and noncommercial forms of transfer, such as publications and teaching.

Based on various national cases, all the previous research has highlighted two distinct but related aspects that concern different forms of technology transfer. First, there is a strong rationale for considering the peculiarities of the various technology transfer activities. Second, since there are interactions and mediation effects among these various forms, it is crucial to study them within a unified analytical framework.

Considering the relationships among various forms of technology transfer more deeply, being involved in a spinoff can affect research with firms in two alternative ways. On the one hand, academic entrepreneurs, becoming focused on their own business, might have less time to cooperate with other firms or might see them as competitors, therefore suspending or slowing down their collaborations with those firms (Colombo and Piva 2012). In this case, spinoffs are expected to adversely affect collaborations with other firms. On the other hand, the impact might be positive if entrepreneurs think that researching with other firms will help them develop their knowledge, stimulate agreements and give them access to missing competencies (Belderbos et al. 2015; Colombo and Piva 2012; Powell et al. 1996; Un and Asakawa 2015). The empirical analysis by Barbieri et al. (2018) suggests that,

concerning co-publications, the first effect prevails, while for co-patenting, the second is observed.

Nevertheless, this analysis neglects the fact that university researchers are highly heterogeneous in collaborations with firms before their spinoff's foundation. Some share a remarkable number of research projects with firms, while others have only limited relationships if any. Our analysis adds to the existing literature by taking this heterogeneity into account.

Based on the previous literature, we argue that the two types of technology transfer channels we analyze after the spinoff—co-publication and co-patenting—are different in nature. Co-publishing implies that the researcher and the company collaborate to generate new knowledge; apart from this, however, such activity does not have any economic value from the perspective of the researcher, who does not need to know the entrepreneurial environment to accomplish this task. Conversely, co-patenting implies that the collaboration between the scholar and the firm has already reached a high-intensity level. The purpose of the collaboration is potential commercialization. Recalling Arza (2010), one can see co-publication and co-patenting on a continuum: co-publication as a first, preliminary step in the relation with economic actors, and co-patenting as a more advanced form of involvement of the scholar with the market.

In light of this and given the existing evidence on the relations between previous collaborations and the propensity to found a spinoff, we hypothesize that becoming an academic entrepreneur has heterogeneous effects on technology transfer channels implemented after the foundation of the spinoff. Furthermore, we hypothesize that such heterogeneity depends on the presence of collaborations before the spinoff.

Specifically, suppose the academic has previously co-published with firms. In that case, it is plausible that he/she will have already acquired some knowledge of managerial and business practices together with the social and knowledge capital that facilitates the relationship with the market (Ortín-Ángel and Vendrell-Herrero 2014; D'Este et al. 2012). Therefore, after the spinoff, he/she might be more likely to engage in joint patenting activity, as the spinoff will act as a booster to enhance his/her entrepreneurial engagement (Fontes 2005).

HP 1.a: Academic entrepreneurs who have previously published with firms will increase their co-patenting activity.

Concerning joint publications, we hypothesize an inverse effect. In fact, after the spinoff, the new academic entrepreneur may think he or she has already acquired the knowledge and competencies needed to develop a product and bring it to the market. Therefore, he or she may consider dropping activities related to joint publications that so far had allowed him/her to come into contact with new contexts and information. Additionally, the opportunity cost of activities with less clear commercial potential, such as joint publication, will rise as the academic increasingly turns his/her attention to entrepreneurial activities (Narula 2004; Colombo and Piva 2012; Czarnitzki and Toole 2010).

HP 1.b: Academic entrepreneurs who have previously published with firms will diminish their co-publishing activity.

Conversely, academics with no previous experience in collaborating on publications with firms might lack knowledge of the economic environment. In such cases, the spinoff would be their first experience with the market, and academic entrepreneurs might consequently be less able to tackle the managerial and economic aspects of their venture, a trait that is typical of spinoffs when compared to other NTBFs (Iazzolino et al. 2019). Such academics might also exhibit a risk-adverse attitude that, in conditions of uncertainty, would work as a deterrent to sharing knowledge and discoveries that could lead to commercialization (Goel and Göktepe-Hultén 2019). In our framework, this would translate into a weaker propensity to share knowledge products that are closer commercialization, such as patents, with other economic actors.

HP 2.a: Academic entrepreneurs who have not previously published with firms will not increase their co-patenting activity.

A possible strategy that these new entrepreneurs might utilize to overcome their insufficient knowledge of the market is to engage in collaborations resulting in knowledge products far from commercialization, such as co-publications. Co-publishing is less risky in economic terms and implies less knowledge of the market. In addition, this activity requires competencies related to scientific research that the academic already has (Jain et al. 2009), which can result in a more immediate acquisition of new knowledge of the market. This leads us to think that it is more likely that co-publications act as exploratory forms of collaboration with the industry. Therefore, we suppose that the trend in such collaborations after the spinoff will be positive.

HP 2.b: Academic entrepreneurs who have not previously published with firms will increase their co-publishing activity.

3 Data and methodology

3.1 Database description

We test the general hypotheses we have formulated using the case of Italian academic entrepreneurs. The empirical analysis is based on the original dataset used by Barbieri et al. (2018). The use of this dataset allows us to compare our results with those of that study.

The dataset covers two comparable groups of tenured researchers in Italian universities who are included in the registry of Italian university research staff held by the Italian Ministry of Education, University, and Research (MIUR).

The first group (*treatment group*) comprises those academic entrepreneurs (n = 221) who founded one of the 115 academic spinoffs created in Italy from 2000–2007[2] that was still active in 2011.[3]

For each researcher, the dataset collects information on intellectual production during the 5 years that precede the foundation of the spinoff and during the 5 years that follow it.[4] The dataset includes information concerning the number of Scopus-indexed publications produced and the number of patents registered in the European Patent Office (EPO) database. We observe both the total number of these publications and patents and the number of publications and patents involving coauthors from firms. For each researcher, we also extracted the following information from the MIUR registry[5]: scientific field (according to the Italian classification of *settore scientifico disciplinare*, or SSD), university of affiliation, and position (assistant professor, associate professor, or full professor).

The second group (*control group*) includes tenured researchers (n = 604) extracted from the MIUR online registry based on an exact match with the treated observations on SSD, university of affiliation, and academic position. To be extracted, those researchers had to be active in the same year that their colleagues founded a spinoff and over the 5 years before and after. For all the researchers in the *control group,* the dataset includes the same information available for the *treatment group*. In detail, the data include the number of publications and patents (total, with and without firms) produced over the same time span considered when examining the *treatment group* counterparts.

Finally, the dataset includes information concerning the number of academic entrepreneurs (per 100 academics) in the researcher's university of affiliation. The data are collected for the year of the spinoff foundation (the same year is used for the corresponding matched controls).

We are aware that innovation is an increasingly collaborative activity and that social networks promote such collaboration (Crescenzi et al. 2016). Previous research has specifically focused on these "relational" aspects and has demonstrated that geographical, institutional, social, and cognitive proximity between potential collaborators play a significant role in shaping university–industry collaborations (Crescenzi et al. 2016, 2017; Filippetti and Savona 2017). Given that we do not have

[2] Data were gathered from the registry provided by the website http://www.spin-offitalia.it and from information collected by the Italian Chamber of Commerce.

[3] By restricting data collection to the entrepreneurs whose spinoffs were still active some years after their foundation, the dataset focuses on cases of successful spinoffs and therefore discards unsuccessful and temporary experiences.

[4] Five years is the period during which most Italian universities allow academic entrepreneurs to keep both their position in academia and their role in the spinoff. Indeed, usually after 4–5 years, academic entrepreneurs are forced to choose whether to maintain their role in the spinoff and leave their academic career or vice versa. With respect to our analysis, considering a smaller time range would result in a loss of information. On the other hand, increasing the number of years under consideration would not guarantee that the academic entrepreneurs still work in academia, generating potential bias in the data concerning their research performance. By symmetry, the 5-year range was also used for the period previous to the foundation of the spinoff.

[5] http://cercauniversita.cineca.it.

Table 1 Variables' labels and definitions

Label	Definition
Covariates (before the spinoff)	
(1) Academic position	Academic position of the researcher at the foundation of the spinoff (same year for the corresponding matched controls). Possible modalities are: (i) Full Professor, (ii) Associate Professor, (iii) Non-confirmed Associate Professor*, (iv) Assistant Professor, (v) Non-confirmed Assistant Professor*
(2) Field of study	Scientific field of study of the researcher according to the MIUR classification. According to the MIUR official classification (Ministerial Decree 4 October 2000 and subsequent modifications) there are 370 recognized fields of study. The dataset used in this paper includes observations from 87 fields of study
(3) University	University the researcher is affiliated to at the foundation of the spinoff same year for the corresponding matched controls)
(4) Year	Year of foundation of the spinoff (same year for the corresponding matched controls)
(5) Patents before the spinoff	Total number of patents in the 5 years preceding the spinoff (same time-span for the corresponding matched controls)
(6) Publications before the spinoff	Total number of publication in the 5 years preceding the spinoff (same time-span for the corresponding matched controls)
(7) Patents with firms before the spinoff	Total number of patents with firms in the 5 years preceding the spinoff (same time-span for the corresponding matched controls)
(8) Citations received before the spinoff	Total number of citations received in the 5 years preceding the spinoff (same time-span for the corresponding matched controls)
(9) Entrepreneurs in the academic environment	Number of academic entrepreneurs every 100 academics in the university of affiliation and in the year of spinoff foundation (same year for the corresponding matched controls)
Outcomes (after the spinoff)	
(1) Publication with firms after spinoff	Number of publications with co-authors from firms in the 5 years following the spinoff (same time-span for the corresponding matched controls)
(2) Publications with firms after spinoff (publications with spinoff excluded	Number of publications with co-authors from firms (spinoff excluded) in the 5 years following the spinoff. For matched controls the total number of publications with firms over the same time-span is considered
(3) Publications only with the spinoff colleagues (after spinoff creation)	Number of publications with co-authors from the spinoff in the 5 years following the spinoff. For matched controls the total number of publications with firms over the same time-span is considered

Table 1 (continued)

Label	Definition
(4) Patents with firms after spinoff	Number of patents with co-authors from firms in the 5 years following the spinoff (same time-span for the corresponding matched controls)
(5) Patents with co-authors from firms after the spinoff foundation (publications with the spinoff excluded)	Number of patents with co-authors from firms (spinoff excluded) in the 5 years following the spinoff. For matched controls the total number of publications with firms over the same time-span is considered
(6) Patents with co-authors from the spinoff after the spinoff foundation	Number of patents with co-authors from firms in the 5 years following the spinoff (same time-span for the corresponding matched controls)

For all the variables the data source is Barbieri et al. (2018) *Three years after the role assignment, Assistant Professors and Associate Professors are assessed by an evaluation committee nominated by MIUR that confirms their adequacy to the role

Table 2 Mean values of the variables considered in the study by treatment (spinoff creation)

Full sample

	Mean treatment group	Mean control group	Mean difference	p-value
Covariates (before the spinoff)				
Patents	0.45	0.18	0.27	0.00
Publications	19.30	15.44	3.87	0.02
Patents with firms	0.22	0.12	0.1	0.10
Citations	638.89	673.71	−34.82	0.75
Entrepreneurs in the academic environment	0.99	0.67	0.32	0.00
Outcomes (after the spinoff)				
Publication with firms	4.09	1.97	2.12	0.00
Publications with firms (with spinoff excluded)	2.71	1.97	0.74	0.07
Publications only with the spinoff	1.37	1.97	−0.6	0.10
Patents with firms	0.62	0.15	0.47	0.00
Patents with firms (with spinoff excluded)	0.35	0.15	0.20	0.00
Patents with only spinoff	0.27	0.15	0.12	0.11

Source: authors' elaboration

such information in our dataset, our study looks only at the revealed direct links between researchers and industry (i.e., joint publications).

Table 1 presents a detailed description of the dataset variables alongside the data sources. Table 2 displays the mean value observed for each of these variables by treatment status and reports the p-value of a t-test of the differences.

To investigate whether there is any heterogeneity in the effect of spinoffs on academic productivity according to pre-existing collaborations with firms, we split our full sample into two subsamples: the first is that of individuals who had no co-publications with firms before the year of spinoff establishment (the same year is used for the corresponding matched controls), which gives a total of 312 individuals, while the second includes those who had at least one co-publication with firms before the year of spinoff establishment (the same year is used for the corresponding matched controls), which gives 513 academics in total.[6] Table 3 shows the incidence of co-publishing with firms before the reference year. While the treated observations are distributed almost evenly between the two groups, the number of academics in the control group who have not previously collaborated with firms is approximately double that of those with previous co-publications. In both cases, the data show substantial heterogeneity in collaboration among the treated and the controls.

Table 4 shows the mean values for the continuous variables considered in the study and highlights the differences between the two groups. We also report the p-value from a *t* test of the differences. The first five variables in the table are a selection of the observed covariates—those for which it is possible to compare means—that we will use to match the group of academic entrepreneurs and their controls (see Sect. 3.2), while the remaining five are the outcomes of interest.

Table 4 presents some preliminary descriptive evidence. First, looking at academic entrepreneurs, those with previous publications with firms show high levels of co-patenting and patenting activity in the pre-spinoff period. In other words, it appears that these two groups of academic entrepreneurs differ in their involvement with firms not only in terms of co-publications but also in the intensity of their other entrepreneurial activities. Such a finding is in line with the previous research, which has found a positive association between publications and patenting (Van Looy et al. 2011; Landry et al. 2010; Gulbrandsen and Smeby 2005, among others). Additionally, this finding highlights that by splitting the sample between academics who had not published with firms before the spinoff and those who had, we are also de facto discriminating between academics who had an entrepreneurial attitude before the foundation of the spinoff, as proxied by co-patenting and patenting, and those who did not.

Second, there seems to be some difference in previous behaviors within the subgroups we consider, between treated and controls. While patenting before the spinoff is higher for academic entrepreneurs than their controls for the whole sample, this difference only holds for academics with previous co-publication experience. These two groups differed before the foundation of the spinoff in terms of research quality,

[6] The choice to use co-publications instead of co-patents as a proxy for the academic's collaboration with firms before the spinoff is related to the size of the two phenomena in the population of academic entrepreneurs and in the matched control sample. Co-publication activities are largely present both among those who have founded a spinoff (52.04 percent of the total) and among their peers (32.62 percent). Co-patenting is a less common phenomenon, with only 12.22 percent of the academic entrepreneurs and 6.95 percent of the controls involved. In addition, the majority of those who co-patent with firms also engage in co-publishing activities (specifically, 88.89 of co-patenting entrepreneurs also co-publish). Co-publishing seems therefore to proxy for collaborations with firms more extensively.

Table 3 Cross-tabulation of *treatment* and *control* groups among academics previously collaborating with firms and academics with no co-publications with firms

	No publications with co-authors from firms before the reference year (spinoff creation)	At least 1 publication with co-authors from firms before the reference year (spinoff creation)	Total
Treatment group (academic entrepreneurs)	106	115	221
Control group (colleagues of the academic entrepreneurs)	407	197	604
Total	513	312	825

Source: authors' elaboration

Table 4 Mean values of the variables considered in the study by treatment (spinoff creation) and by subgroup

Academics with no previous co-publications with firms				
	Mean treatment group	Mean control group	Mean difference	p-value
Selected covariates (before the spinoff)				
Patents	0.15	0.09	0.06	0.21
Publications	8.39	10.96	−2.58	0.09
Patents with firms	0.03	0.06	−0.03	0.20
Citations	231.67	490.11	−258.44	0.00
Entrepreneurs in the academic environment	1.13	0.68	0.45	0.00
Outcomes (after the spinoff)				
Publication with firms	1.58	0.6	0.98	0.00
Publications with firms (with spinoff excluded)	0.92	0.6	0.32	0.09
Publications only with the spinoff	0.66	0.6	0.06	0.80
Patents with firms	0.17	0.14	0.02	0.68
Patents with firms (with spinoff excluded)	0.11	0.14	−0.03	0.54
Patents with only spinoff	0.06	0.14	−0.09	0.07
Academics with some previous co-publications with firms				
	Mean treatment group	Mean control group	Mean difference	p-value
Selected covariates (before the spinoff)				
Patents	0.72	0.35	0.37	0.01
Publications	29.37	24.68	4.69	0.08
Patents with firms	0.4	0.25	0.15	0.22
Citations	1014.23	1053.04	−38.81	0.85
Entrepreneurs in the academic environment	0.87	0.65	0.22	0.03
Outcomes (after the spinoff)				
Publication with firms	6.4	4.79	1.61	0.13
Publications with firms (with spinoff excluded)	4.37	4.79	−0.42	0.66
Publications only with the spinoff	2.03	4.79	−2.76	0.00
Patents with firms	1.03	0.17	0.87	0.00
Patents with firms (with spinoff excluded)	0.57	0.17	0.40	0.00
Patents with only spinoff	0.47	0.17	0.30	0.02

Source: authors' elaboration

proxied by the number of citations. Academic entrepreneurs with no co-publishing history appear to produce academic works of higher quality than their control-group matches. On the other hand, such a difference is not significant for academics with co-publishing experience.

For the outcomes of interest, the results indicate better performance by academic entrepreneurs than by their peers. On the one hand, academic entrepreneurs with no previous experience collaborating with firms tend to report better performance in co-publications after the spinoff. At the same time, no significant effect is observable concerning co-patenting. The results are the opposite for experienced academics: scholars with a spinoff apply for more co-patents than non-entrepreneurs, while they act no differently in terms of co-publications. These results, however, do not take into account the fact that, without proper matching on observables, control groups are likely to include individuals with very different propensities to start a self-owned spinoff. In the next section, we explore the proper methodology to correct for such bias.

3.2 Empirical strategy

In experimental studies, the estimation of the causal effect of treatment on an outcome is carried out by randomized controlled trials, which ensures that the treated population does not systematically diverge from the untreated population except for receiving the treatment. In nonexperimental studies based on observational data, such treatment randomization is not feasible for practical reasons and also frequently for ethical reasons. Consequently, subjects' characteristics are often correlated with their treatment status, which complicates the disentangling of the treatment effect. This is precisely the situation observed in our study.

We are interested in measuring the effect of a treatment (i.e., creating a spinoff) on certain outcomes (publications and patents with firms once the spinoff is established), but we know that academic researchers self-select into treatment, as they autonomously decide whether to start a spinoff. Thus, it seems reasonable to hypothesize that the academic entrepreneurs' profile differs from that of researchers who do not start their own business. The data presented in Table 2 support this hypothesis.

When selection into treatment is based on observable characteristics, propensity score matching (PSM) represents a valuable solution to treatment selection bias. For the i-th individual in the population under study, his/her propensity score (PS) is the probability of receiving treatment (Z) conditional on observed covariates (X):

$$PS_i = \Pr(Z_i|X_i) \tag{1}$$

PS could be calculated by a logit estimation of the following equation:

$$Z_i = \alpha + \beta X_i + \varepsilon. \tag{2}$$

In our case, Z is a dummy variable measuring the creation of a spinoff (taking the value of one in the case of spinoff creation and zero otherwise), and X is a set of covariates fulfilling three essential requirements for PSM (Caliendo and Kopeinig 2008). First, the covariates are both drivers of selection into the treatment and

possible determinants of the outcome variables; second, being measured before the spinoff creation, they are unaffected by the treatment; third, they have been identified as drivers of spinoff creation in the existing literature. Following Barbieri et al. (2018), we have used the covariates presented in Table 1 at points 1–9: the academic position of the individual at the time of the spinoff foundation, her/his scientific sector and university, the year the spinoff was founded, the number of patents filed by the academic in the 5 years before the spinoff, his/her number of publications in the same period, the number of patents filed jointly by an academic and a firm (co-patents) in the previous 5 years, the number of citations received by the academic's publication in the previous 5 years, and the entrepreneurial experience of the university (measured by the percentage of academic entrepreneurs in the year of the spinoff's establishment).[7]

The PS calculated according to Eq. (2) can act as a balancing score (bX), i.e., conditional on that score, the observed covariates are ensured to be independent of the treatment ($X \perp Z|bX$, Rosenbaum and Rubin 1983).

Our analysis uses the radius matching algorithm to match treated and untreated observations displaying a PS within a specified range of values (the caliper). In the following elaboration, this value is set equal to 0.05.[8] In the robustness checks (see the next section), we also test other matching algorithms suggested by the existing literature.

If the conditional independence assumption (CIA) and common support hypotheses are fulfilled (Caliendo and Kopeinig 2008; Imbens 2004), PSM is an unbiased estimator of the average treatment effect on the treated (ATT) defined as follows:

$$ATT = \mathrm{E}\left[Y_{1i}|Z_i = 1,\ \mathrm{b}X_i\right] - \mathrm{E}\left[Y_{0i}|Z_i = 1,\ \ \mathrm{b}X_i\right] = \mathrm{E}[Y_{1i} - Y_{0i}|Z_i = 1,\ \mathrm{b}X_i] \quad (3)$$

where Y (publications and patents with firms after the spinoff's foundation) is the outcome we are interested in.

Our analysis investigates whether the size and direction of Z's effect on Y might depend upon one variable that is not included in vector X. In line with the discussion provided in Sects. 1 and 2, this variable is a dummy that measures collaboration with firms in the form of publications before spinoff activation.

To achieve this objective, we rely on the approach proposed by Green and Stuart (2014) to combine propensity score methods with subgroup analysis. According to these authors, the best way to compare Z's effect among subgroups is to calculate separate propensity score models and matches for these subgroups. This approach, indeed, allows us to achieve covariate balance at the subgroup level and, therefore, to disentangle the causal effect of Z on Y within each subgroup. Ignoring the subgroups in the propensity score process prevents the identification of variables that shape the academic spinoff's impact on collaborations with firms. This strongly limits our understanding of spinoffs'

[7] For the theoretical and empirical foundation in the previous literature for the choice of the covariates, we refer to Barbieri et al. (2018).

[8] It is worth noting that this value is smaller than the one applied by Barbieri et al. (2018), which is 0.08. Nevertheless, using such a caliper produces results in line with those found in that paper.

Table 5 Logit estimates of the probability of creating a spinoff

	(1) Full sample	(2) No previous co-publications with firms	(3) Some previous co-publications with firms
Academic position[a]			
Associate Professor	0.3570 (0.3552)	0.6666 (0.7727)	0.5414 (0.5709)
Non confirmed Associate Professor	1.6213*** (0.5569)	2.4678*** (0.9304)	1.9654** (0.9995)
Assistant Professor	0.3675 (0.3972)	1.0537 (0.8155)	−0.1810 (0.6655)
Non confirmed Assistant Professor	0.9803 (0.6902)	2.9410** (1.2505)	0.8688 (1.2028)
Patents before the spinoff	1.3980*** (0.2698)	3.0611*** (0.8125)	1.2773*** (0.3588)
Publications before the spinoff	0.0143** (0.0070)	−0.0124 (0.0155)	0.0082 (0.0109)
Patents with firms before the spinoff	−1.2757*** (0.3269)	−4.9796*** (1.4318)	−1.1491*** (0.4160)
Entrepreneurs in the academic environment	−1.4453** (0.6531)	−2.9661* (1.6236)	−3.4571** (1.5861)
Citations received before the spinoff	0.0002* (0.0001)	0.0015** (0.0006)	0.0002 (0.0001)
Dummy for university of affiliation, field of study and year	Yes	Yes	Yes
Observations	802[b]	385[c]	276[d]
LR Chi^2	226.17	134.48	92.52
$p > Chi^2$	0.000	0.000	0.009
Pseudo R^2	0.25	0.32	0.27

Coefficients and standard errors in parentheses. Full sample and subsamples built up by looking at collaboration with firms in basic research before the spinoff creation proxied by having publications with co-authors from firms. ***p < 0.01, **p < 0.05, *p < 0.1

[a]Base category: full professor

[b]The estimation perfectly predicts 23 cases

[c]The estimation perfectly predicts 128 cases

[d]The estimation perfectly predicts 36 cases. Source: authors' elaboration

consequences for knowledge transfer. Instead, a more detailed analysis aimed at understanding whether the spinoff's effect is consistent across researchers with different backgrounds can have important policy implications in terms of stimulating academic entrepreneurship that is not detrimental to other forms of university–firm collaborations.

Consistent with this approach, the empirical analyses described in this section have been replicated for the two subsamples presented in Sect. 2. A comparison between the results obtained with the two subgroups can identify any heterogeneity in the effect of Z on Y that depends on the researchers' background.

4 Results

Table 5 shows the logit model results where the dependent variable is a dummy that takes on the value 1 for those researchers who created a spinoff and zero otherwise. The specification uses the covariates presented in the previous section and described in Table 1 (points 1–9).

The table presents three models. The first (column 1) relies on the full sample of researchers. Next, the second (column 2) is based on the subsample containing only academics with no previous publishing activities with firms and their controls. Finally, the third model (3) is based on the subsample that includes only academics with co-publishing experience and their controls.[9]

The results are mostly consistent across the models; however, some differences are observed. The subsamples considered in both models (2) and (3) show the same impact of patents and co-patents found in the full sample. For patents, the commercialization attitude demonstrated by the academic positively affects the foundation of the spinoff. In contrast, for co-patents, the researcher's attitude towards commercialization has already resulted in joint efforts with the private sector, which negatively affects the academic's propensity to become an entrepreneur him- or herself. This finding suggests that spinoffs and previous co-patenting with firms, both of which involve a high degree of commercialization, might be substitutes. The results also confirm the crowding-out effect due to the diffusion of academic entrepreneurship at the local (university) level, as in Barbieri et al. (2018). Finally, it seems that in both subgroups, non-confirmed associate professors tend to be more likely to found a spinoff than other types of academics, suggesting that establishing a venture can act as a means for researchers to acquire scientific prestige and reputation (Franzoni and Lissoni 2006; Rizzo 2015). For some variables, the subgroups exhibit different performance relative to the full sample. First, when the total sample is split, academic productivity's positive effect on the propensity to become an entrepreneur disappears. In our interpretation, this means that both groups show less within-variability in terms of the number of publications produced,[10] which might offer a further argument for deepening the analysis by subgroups. Second, when considering academics with no history of co-publishing with firms, the reputational motivation that is documented for associate professors seems to also hold for younger non-confirmed positions such as assistant professors. Finally, the impact of research quality on the propensity to found a spinoff considerably differs between subgroups. Only in the case of scholars without a co-publishing history did this impact turn out to be statistically significant. This finding is in line with the wider involvement of the first

[9] It is worth noting that in models (2) and (3) some of the cases are perfectly predicted by the estimation. While their frequency is not particularly remarkable in model 3 (36 observations), it is much more impressive in model (2), where 128 cases are perfectly predicted. Nevertheless, as the next section shows, the exclusion of such cases does not compromise the overlap of observations with similar values of X.

[10] This partially derives from the way we built one of the subgroups (by construction, for the academics with previous co-publication experience, the variable under examination never assumes a value of zero).

Table 6 Average treatment effect on the treated (ATT) of spinoff on publications joint with co-authors from firms. Radius matching estimates (caliper 0.05) by sample

Dependent variable (Y)	Mean among treated	Mean among controls	ATT	T-stat
Panel a. Full sample				
(1) Publications with firms after spinoff	4.48	3.24	1.24	1.54
(2) Publications with firms after spinoff (publications with spinoff excluded)	2.97	3.24	−0.27	−0.36
(3) Publications only with the spinoff	1.50	3.24	−1.73**	−2.48
Panel b. Academics with no previous co-publication with firms				
(1) Publications with firms after spinoff	2.08	0.50	1.58***	3.11
(2) Publications with firms after spinoff (publications with spinoff excluded)	1.19	0.50	0.69**	2.01
(3) Publications only with the spinoff	0.89	0.50	0.40	0.97
Panel c. Academics with some previous co-publication with firms				
(1) Publications with firms after spinoff	7.25	7.05	0.19	0.10
(2) Publications with firms after spinoff (publications with spinoff excluded)	5.01	7.05	−2.04	−1.05
(3) Publications only with the spinoff	2.24	7.05	−4.82**	−2.56

Significance levels: ***1%, **5%, *10%. Source: authors' elaboration

Table 7 Average treatment effect on the treated (ATT) of spinoff on patenting joint with co-authors from firms. Radius matching estimates (caliper 0.05) by sample

Dependent variable (Y)	Mean among treated	Mean among controls	ATT	T-stat
Panel a. Full sample				
(1) Patents with firms after spinoff	0.66	0.34	0.31**	2.35
(2) Patents with firms after spinoff (publications with spinoff excluded)	0.36	0.35	0.02	0.19
(3) Patents only with the spinoff	0.30	0.35	−0.05	−0.50
Panel b. Academics with no previous co-publication with firms				
(1) Patents with firms after spinoff	0.20	0.96	−0.76***	−5.61
(2) Patents with firms after spinoff (patents with spinoff excluded)	0.12	0.97	−0.84***	−6.54
(3) Patents only with the spinoff	0.08	0.96	−0.88***	−6.95
Panel c. Academics with some previous co-publications with firms				
(1) Patents with firms after spinoff	1.15	0.25	0.89***	3.60
(2) Patents with firms after spinoff (patents with spinoff excluded)	0.56	0.25	0.31**	2.21
(3) Patents only with the spinoff	0.58	0.25	0.33*	1.81

Significance levels: ***1%, **5%, *10%. Source: authors' elaboration

group in scientific works directed mainly towards academia, which uses citations as a means of recognition, rather than towards industry.

Next, we report the results of the matching. Tables 6 and 7 show the ATT of creating a spinoff on publishing (6) and patenting (7) with firms.

We first analyze co-publications (Table 6). Looking at the estimates calculated for the full sample (Panel a), we find that creating a spinoff does not have any statistically significant impact on the total number of publications with firms (variable 1, which includes publications with coauthors from the spinoff). Nevertheless, once the spinoff is created, some of the publications that would have been coauthored with firms are substituted with publications with coauthors from the spinoff, as the results for variable 3 suggest. In other words, by creating a spinoff, part of the work researchers would have carried out with other firms is substituted with co-publishing with their own company.

Splitting the sample into the two groups provides additional new insights. When looking at the sample that includes only academics with co-publishing experience (panel c), the results are in line with those calculated for the full sample: founding a spinoff may have a substitution effect on co-publications with other firms. Nevertheless, the sample of academics with no previous co-publishing activity (panel b) shows a different trend. Indeed, for this subgroup, creating a spinoff positively impacts the amount of scientific production carried out in collaboration with other firms (variable 1), which is expected. However, such a positive impact does not result from publishing with the spinoff, as the coefficient for publications with only spinoff (variable 3) is not significant. Instead, it is driven by publications with other firms

Table 8 Balancing test statistics

Matched/unmatched	Ps R^2	LR Chi^2	p > Chi^2	MeanBias	MedBias	B	R	%Var
Panel a. Academics with no previous co-publication with firms								
Unmatched	0.318	132.98	0.000	11.5	9.1	112.3*	1.12	50
Radius (caliper 0.05)	0.089	18.21	1.000	8.8	4.4	65.0*	0.41*	50
Alternative matching procedures								
Radius (caliper 0.08)	0.091	19.21	1.000	9.2	4.1	67.3*	0.53	50
Radius (caliper 0.03)	0.088	17.03	1.000	8.4	5.0	63.2*	0.43*	50
Kernel	0.075	14.89	1.000	7.4	4.5	57.9*	0.32*	50
NN	0.279	62.58	0.317	20.8	10.8	84.9*	16.29*	67
Panel b. Academics with some previous co-publications with firms								
Unmatched	0.267	92.64	0.009	11.5	8.8	108.7*	0.58	50
Radius (caliper 0.05)	0.093	23.00	1.000	8.3	6.9	64.9*	3.02*	33
Alternative matching procedures								
Radius (caliper 0.08)	0.082	20.11	1.000	6.9	5.3	58.4*	2.32*	17
Radius (caliper 0.03)	0.085	19.50	1.000	7.8	5.8	69.5	1.07	50
Kernel	0.067	15.89	1.000	7.3	6.4	61.4*	1.41	0
NN	0.197	40.63	0.531	14.1	12.3	89.0*	6.77*	67

Significance levels: ***1%, **5%, *10%. Source: authors' elaboration

(variable 2). According to these findings, for those who had no previous experience collaborating with firms, creating a spinoff represents a tool for gaining access to the entrepreneurial world, which increases noncommercial knowledge transfer activities that involve not only the spinoff but also other firms. In other words, for this group of scholars, the beginning of a commercialization activity (spinoff) also has a positive effect on noncommercial forms of knowledge transfer.

We now turn our attention to co-patenting activities (Table 7). For the full sample (Panel a), the results suggest that co-patenting activities appear to increase after founding a spinoff (variable 1). However, it is not clear whether this effect comes from patenting with other firms (variable 2) or academic entrepreneurs' ventures (variable 3), as neither of the two ATTs is statistically significant.[11] Instead, the subgroups that we have identified once again exhibit different behaviors. The academic entrepreneurs without a co-publishing history with firms (panel b) display worse performance than their controls in terms of their patenting collaborations with other firms (variable 1); this is both because their patenting rate with their spinoff is low (variable 3) and because they patent far less with other enterprises than the control group (variable 2). On the other hand, the academic entrepreneurs who had previously co-published with firms (panel c) show a higher degree of collaboration in patenting with firms (variable 1), a finding that also holds when excluding those patents obtained with the spinoff (variable 2).

[11] Both the results for co-publications and co-patents for the full sample are in line with the findings of Barbieri et al. (2018) that use the same database as the present one.

Table 9 Publications joint with co-authors from firms, ATTs with different matching estimators

Dependent variable (Y)	Radius matching, caliper 0.03		Radius matching, caliper 0.08		Kernel matching (on common support)	
	ATT	Std. Err.	ATT	Std. Err.	ATT	Std. Err.
Panel a. Academics with no previous co-publication with firms						
Publications with firms after spinoff	1.586***	(0.510)	1.549***	(0.504)	1.637***	(0.506)
Publications with firms after spinoff (publications with spinoff excluded)	0.685**	(0.331)	0.655*	(0.347)	0.693**	(0.329)
Publications only with the spinoff	0.417	(0.400)	0.379	(0.405)	0.471	(0.397)
Panel b. Academics with some previous co-publications with firms						
Publications with firms after spinoff	0.279	(1.322)	06	(1.812)	0.619	(1.979)
Publications with firms after spinoff (publications with spinoff excluded)	−2.106*	(1.173)	−1.330	(1.723)	−1.699	(1.891)
Publications only with the spinoff	−4.431***	(1.125)	−4.106**	(1.665)	−4.451**	(1.835)

Significance levels: ***1%, **5%, *10%. Source: authors' elaboration

5 Robustness checks

To check the reliability of our main results, we run a series of robustness checks. First, we inspect the balancing test statistics, as reported in Table 8.[12] Panel a shows the comparison between the unmatched and matched samples for the academics with no experience in publishing with firms, while Panel b reports the statistics for the experienced scholars.

These measures substantially confirm the efficacy of matching in significantly lowering the explanatory power of the covariates, therefore dramatically limiting the bias related to selection on observables. Indeed, the matched analysis allows us to (i) decrease the explicative power that the covariates included in the *X* vector of Eq. (2) exert on the outcome; (ii) significantly reduce mean and median bias; and (iii) remarkably reduce the Rubin B value, although it is still above the recommended threshold. Rubin R values are above the commonly accepted threshold, especially for the subsample of academics with some co-publishing history. However, this should not be of too much concern, given the large number of covariates included in the model as well as the relatively limited number of observations for the two subsamples, which may give rise to moderate imbalance even when the model is correctly specified (Austin 2009).

To increase our analysis's robustness, we add the balancing statistics when alternative types of matching procedures are used. Specifically, we report radius

[12] For completeness, we also report the main balancing statistics for the noncategorical covariates*** in Table A1 in the Appendix.

Table 10 Patenting joint with co-authors from firms, ATTs with different matching estimators

Dependent variable (Y)	Radius matching, caliper 0.03		Radius matching, caliper 0.08		Kernel matching (on common support)	
	ATT	Std. Err.	ATT	Std. Err.	ATT	Std. Err.
Panel a. Academics with no previous co-publication with firms						
Patents with firms after spinoff	−0.541***	(0.127)	0.619	(1.979)	−0.449***	(0.127)
Patents with firms after spinoff (patents with spinoff excluded)	−0.612***	(0.119)	−1.699	(1.891)	−0.533***	(0.119)
Patents only with the spinoff	−0.668***	(0.117)	−4.452**	(1.835)	−0.574***	(0.118)
Panel b. Academics with some previous co-publications with firms						
Patents with firms after spinoff	0.827***	(0.227)	0.915***	(0.245)	0.946***	(0.257)
Patents with firms after spinoff (Patents with spinoff excluded)	0.297**	(0.137)	0.331**	(0.133)	0.335**	(0.141)
Patents only with the spinoff	0.308*	(0.170)	0.353**	(0.178)	0.393**	(0.188)

Significance levels: ***1%, **5%, *10%. Source: authors' elaboration

matching with different calipers, kernel matching and 1-to-1 nearest neighbor (NN) matching. While NN performs far worse than the method we chose for our analysis, the alternative caliper radius matching procedures and kernel matching on the common support show comparable balancing power. Therefore, we rerun the model for both subsamples using each procedure. The results are reported in Table 9 (for co-publications) and Table 10 (for co-patenting).

For the group of academics with a co-publishing history, the results all confirm those of our main models. For the group of academics with no experience publishing with firms, some different outcomes are obtained in terms of statistical significance—specifically, only co-publishing with other firms has a statistically significant negative impact in the model with radius matching with caliper 0.03, while the co-patenting results are nonsignificant in the model using radius matching with caliper 0.08. However, even in this case, the interpretation remains similar to that of our main results. In fact, while the main result for co-publishing is not statistically significant—and that from the robustness check is significant and negative—we can confirm that *a substitution effect* between spinoffs and co-publication exists. At most, our main model is more conservative in terms of the actual amount of co-publishing work that is substituted after founding a spinoff. Additionally, for co-patenting, the nonsignificant results still signal that the academic scientist who has founded a spinoff would have applied for the same number of patents had he/she not established his/her venture.

Finally, Figs. 1, 2, 3 visualize the distribution of propensity scores obtained by applying the radius matching (caliper 0.05) procedure by treatment status. They reveal that both distributions run almost across the whole range of the propensity score values when the three samples are considered.

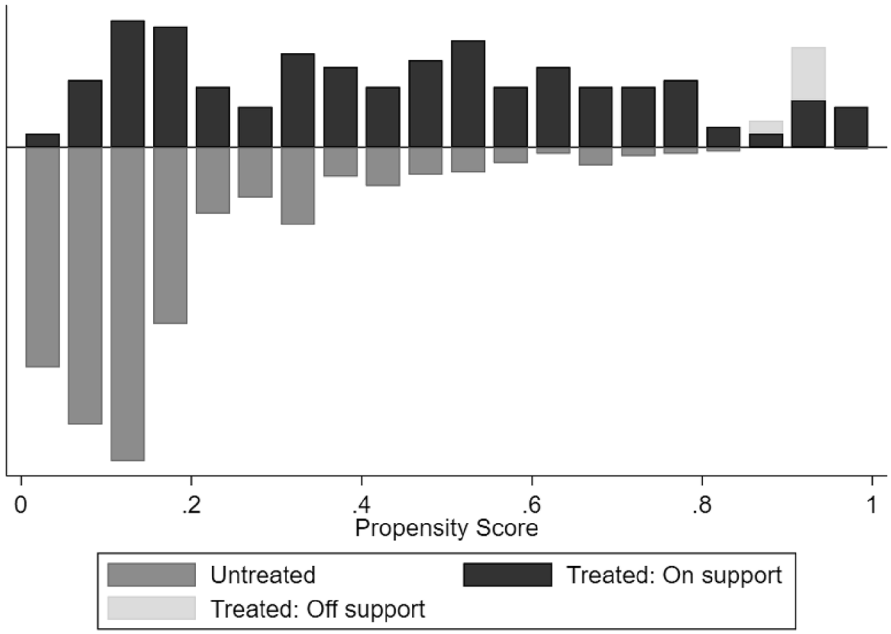

Fig. 1 Distribution of propensity scores by treatment status (radius matching with caliper 0.05)—full sample. Source: authors' elaboration

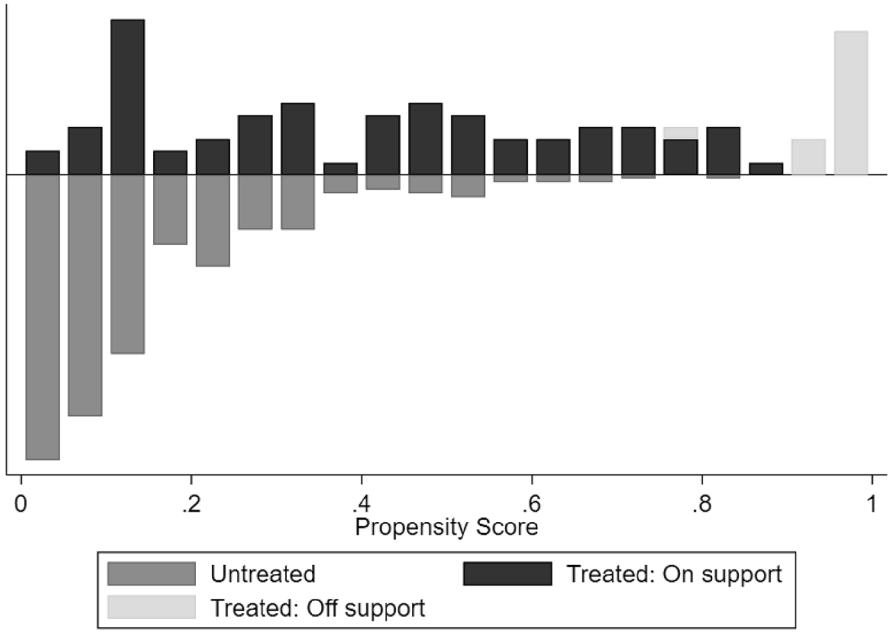

Fig. 2 Distribution of propensity scores by treatment status (radius matching with caliper 0.05)—academics with no previous co-publications with firms. Source: authors' elaboration

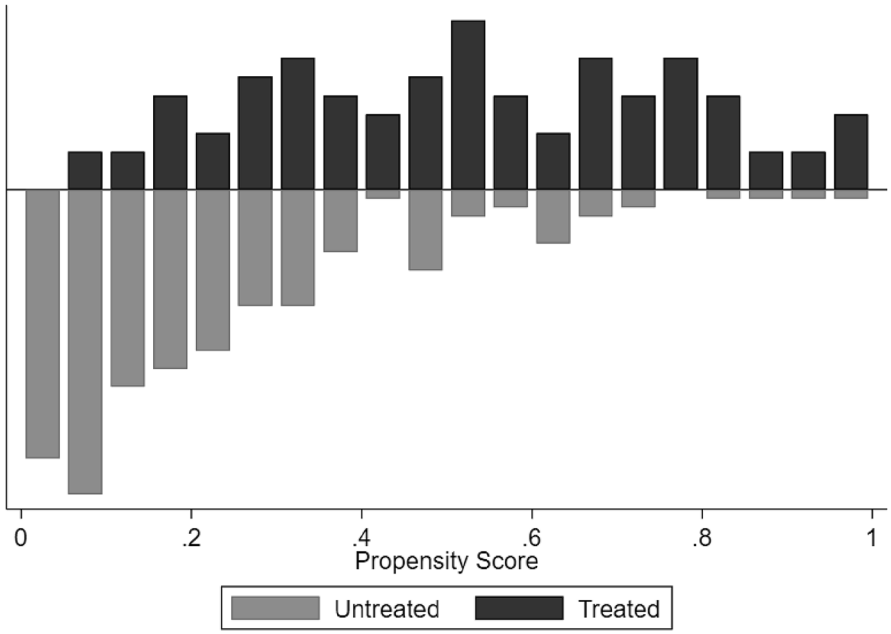

Fig. 3 Distribution of propensity scores by treatment status (radius matching with caliper 0.05)—academics with some previous co-publications with firms. Source: authors' elaboration

6 Discussion

The combination of results presented in Tables 5 and 6 suggests that the subgroup analysis identifies new, interesting insights regarding the effect of creating a spinoff on knowledge transfer and the interaction between various forms of technology transfer.

For spinoff founders with previous co-publishing experience, positive impacts are observed in terms of co-patenting (HP 1.a confirmed). At the same time, a substitution effect seems to hold for co-publications (HP 1.b confirmed). In other words, academic entrepreneurs who had already been exposed to collaborations with firms tend to engage more in cooperation related to the commercialization of their research products. On the other hand, they dismiss collaborations that are more linked to academic activity, such as co-publications. Founding a spinoff should then increase cooperation on commercial products for these academics, while a substitution effect in noncommercial collaborations holds. This finding is consistent with the idea that entrepreneurial activities might crowd out pure academic research, making researchers more prone to engage in research with a commercial focus (Larsen 2011; Baldini 2008; Fabrizio and Di Minin 2008).

Conversely, academic entrepreneurs with no previous co-publications with firms appear to co-publish more with other companies (HP 2.b confirmed) but are far more conservative than their peers in sharing patenting activities (HP 2.a supported). In this case, after the spinoff is established, these academics seem to better recognize

the opportunities for research provided by collaboration within the industrial environment, as the positive effect on co-publications signals. However, these academic entrepreneurs do not engage in the parts of collaboration more closely related to potentially immediate marketable activities, such as patents. In other words, founding a spinoff could facilitate the recognition of opportunities to collaborate with firms in noncommercial activities and to generate competitive commercial behavior.

The interpretation we give to these different behaviors deals with academics' learning processes connected with technology transfer. Co-publications and co-patenting represent two different forms of technology transfer, as stressed by the previous literature (Arza 2010; Haeussler and Colyvas 2011, and so forth). Co-publishing allows for nonrival and/or nonexcludable technology and knowledge transfer. It favors knowledge dissemination and open innovation. For any academic entrepreneur, co-publishing might help build up a new network in the industry sector that might ease the acquisition of information and managerial capabilities. This might be incredibly valuable for academics without any previous co-publication experience.

Instead, co-patenting generates market benefits for the firms involved and provides academic entrepreneurs with direct information about and experience in managing and commercializing inventions. This is presumably more valuable for academics who already have experience in terms of collaboration with firms. When founding a spinoff, this group of scholars has already acquired a certain degree of information, both on the risks of competition with other firms and on cooperation opportunities. In other words, these academics do not need to acquire more "soft" knowledge about the entrepreneurial environment and are ready to exploit their new status as an entrepreneur, driving collaborations with other firms towards more marketable results.

On the other hand, for scholars without a co-publishing history, spinoffs represent the first occasion of interacting with market actors and the first opportunity to gather information on business and managerial practices through direct interactions with other companies. In this case, the newborn academic entrepreneur seems to be more prone to utilize a more explorative channel of collaboration with other firms, i.e., joint publications. At the same time, the lack of knowledge, relative to the other group, of the market environment might restrain academics from engaging in collaborations with potentially marketable results, such as co-patenting, as most such efforts are dedicated to their venture—at least in the period we observe. Additionally, a detailed inspection of our data reveals that academic entrepreneurs with no previous co-publications increase their co-patenting. However, they do so at a lower rate than their peers. This, coupled with a low number of co-patents realized with their spinoff, suggests a net substitution effect, which we hypothesize is mainly due to the time cost of administrating a new venture (Toole and Czarnitzki 2010).

7 Policy implications and final remarks

Within the vast literature on technology transfer, our work focuses on a somewhat overlooked topic: individual behavior and the effect of academic entrepreneurship on other forms of technology transfer. The issue is particularly relevant when taking

into account the fact that governments in many areas of the world consider academic entrepreneurship to be a powerful source of innovation for industry and that specific policy instruments are devoted to promoting such entrepreneurship (see, e.g., Caiazza et al. 2014; Meoli et al. 2018). Henceforth, deepening our understanding of the conditions in which the establishment of spinoffs fosters or hampers university contributions to technology transfer will be crucial for achieving the broader aim of increasing technology and innovation in the industrial environment.

In particular, this paper highlights the potential interconnections existing among some of the different technology transfer channels and clarifies the extent to which they are mutually complementary or substitutive.

Our findings suggest that a certain degree of substitution between founding a spinoff and other knowledge transfer activities such as co-publications and co-patenting exists. More specifically, our evidence shows that the features and the extent of such a substitution differ across individuals, depending, among other factors, on their previous experience with the entrepreneurial environment.

We believe that these results contradict the idea that promoting spinoffs is an appropriate "one-size-fits-all" initiative and that they have important implications for policy design.

Suppose the goal of the policy is to generate larger gains in knowledge dissemination and open innovation. In that case, the measures implemented should incentivize forms of technology and knowledge transfer with nonrival and/or nonexcludability features such as co-publishing. According to our results, such a policy design should target a specific group of academics, e.g., those with no previous experience in the entrepreneurial environment. On the other hand, such a measure might be detrimental to different, more marketable activities, such as technology transfer through patenting with firms. Conversely, suppose policymakers aim to generate gains in knowledge commercialization in order to increase, for instance, financial resources for universities and scholars. In that case, they may need to push academics that already interact with companies towards founding a spinoff. On the other hand, this may decrease the degree of knowledge diffusion through negative effects on co-publications.

In summary, our analysis suggests the need to tailor technology transfer initiatives to scholars' features, paying specific attention to which kind of transfer is the right target for the policy strategy. This implies careful policy design and the comprehensive gathering of information and knowledge about the academic environment and its existing linkages with industry.

Finally, we argue that future research lines can be further developed from this contribution. First, given the emphasis on academic entrepreneurship in the European Union since Lisbon 2020, understanding whether the results achieved in this paper differ depending on Europe's national contexts might help identify policy implications at the European level. Second, the trade-offs and strict interconnections from the individual's point of view among various forms of technology transfer also call for an analysis of the possible benefits or damages that incentivizing such academic activity may have on the other missions of universities. In particular, while the mutual influences between research and technology transfer have been explored, there are at least two further points that we believe are worth studying. On the one

hand, the relations between technology transfer and other forms of transfer—social and cultural, for instance—to the community where academics operate are covered within the broader concept of the university's third mission and academic engagement. On the other hand, studying what happens to the quality of the first mission—students' education—when a growing number of academics are involved in different activities mainly oriented outside the academic environment is still a promising, policy-relevant, and relatively unexplored research field. Finally, our paper has proxied previous collaboration activities with firms through co-publishing. However, the range of possible collaborations is wider, and exploring these further via analytical tools different from those we have used in the present work, such as surveys and direct interviews, might improve our understanding of the existing interdependencies among technology transfer activities.

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References

Abramo, G., D'Angelo, C. A., Ferretti, M., & Parmentola, A. (2012). An individual-level assessment of the relationship between spin-off activities and research performance in universities. *R&D Management, 42*(3), 225–242.

Aldridge, T. T., & Audretsch, D. (2011). The Bayh-Dole Act and scientist entrepreneurship. *Research Policy, 40*(8), 1058–1067. https://doi.org/10.1016/j.respol.2011.04.006.

Algieri, B., Aquino, A., & Succurro, M. (2013). Technology transfer offices and academic spin-off creation: The case of Italy. *Journal of Technology Transfer, 38*(4), 382–400. https://doi.org/10.1007/s10961-011-9241-8.

Arza, V. (2010). Channels, benefits and risks of public-private interactions for knowledge transfer: Conceptual framework inspired by Latin America. *Science and Public Policy, 37*(7), 473–484. https://doi.org/10.3152/030234210X511990.

Austin, P. C. (2009). Balance diagnostics for comparing the distribution of baseline covariates between treatment groups in propensity-score matched samples. *Statistics in Medicine, 28,* 3083–3107. https://doi.org/10.1002/sim.3697.

Azoulay, P., Ding, W., & Stuart, T. (2009). The impact of academic patenting on the rate, quality and direction of (public) research output. *The Journal of Industrial Economics, 57*(4), 637–676.

Baglieri, D., Baldi, F., & Tucci, C. L. (2018). University technology transfer office business models: One size does not fit all. *Technovation, 76–77,* 51–73. https://doi.org/10.1016/j.technovation.2018.05.003.

Baldini, N. (2008). Negative effects of university patenting: Myths and grounded evidence. *Scientometrics, 75*(2), 289–311.

Barbieri, E., Pollio, C., & Prota, F. (2020). The impacts of spatially targeted programmes: Evidence from Guangdong. *Regional Studies, 54*(3), 415–428. https://doi.org/10.1080/00343404.2019.1635688.

Barbieri, E., Rubini, L., Pollio, C., & Micozzi, A. (2018). What are the trade-offs of academic entrepreneurship? An investigation on the Italian case. *Journal of Technology Transfer, 43*(1), 198–221. https://doi.org/10.1007/s10961-016-9482-7.

Bekkers, R., & Bodas Freitas, I. M. (2008). Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter? *Research Policy, 37*(10), 1837–1853. https://doi.org/10.1016/j.respol.2008.07.007.

Belaid, L., & Ridde, V. (2015). Contextual factors as a key to understanding the heterogeneity of effects of a maternal health policy in Burkina Faso? *Health Policy and Planning, 30*(3), 309–321. https://doi.org/10.1093/heapol/czu012.

Belderbos, R., Carree, M., Lokshin, B., & Fernández Sastre, J. (2015). Inter-temporal patterns of R&D collaboration and innovative performance. *Journal of Technology Transfer, 40*(1), 123–137. https://doi.org/10.1007/s10961-014-9332-4.

Bhullar, S. S., Nangia, V. K., & Batish, A. (2017). Channels of interaction and past collaborative experience as imperatives in academia–industry collaboration. *Technology Analysis and Strategic Management, 29*(10), 1210–1224. https://doi.org/10.1080/09537325.2016.1277694.

Breschi, S., Lissoni, F., & Montobbio, F. (2008). University patenting and scientific productivity: A quantitative study of Italian academic inventors. *European Management Review, 5*(2), 91–109.

Caiazza, R., Audretsch, D., Volpe, T., & Singer, J. D. (2014). Policy and institutions facilitating entrepreneurial spin-offs: USA, Asia and Europe. *Journal of Entrepreneurship and Public Policy, 3*(2), 186–196. https://doi.org/10.1108/JEPP-04-2013-0013.

Caliendo, M., & Kopeinig, S. (2008). Some practical guidance for the implementation of propensity score matching. *Journal of Economic Surveys, 22*(1), 31–72. https://doi.org/10.1111/j.1467-6419.2007.00527.x.

Castillo Holley, A., & Watson, J. (2017). Academic entrepreneurial behavior: Birds of more than one feather. *Technovation, 64–65*(July), 50–57. https://doi.org/10.1016/j.Technovation.2017.07.001.

Chiesa, V., & Piccaluga, A. (2000). Exploitation and diffusion of public research: The case of academic spin-off companies in Italy. *R&D Management, 30*(4), 329–340. https://doi.org/10.1111/1467-9310.00187.

Clarysse, B., Tartari, V., & Salter, A. (2011). The impact of entrepreneurial capacity, experience and organizational support on academic entrepreneurship. *Research Policy, 40*(8), 1084–1093. https://doi.org/10.1016/j.respol.2011.05.010.

Colombo, M. G., & Piva, E. (2012). Firms' genetic characteristics and competence-enlarging strategies: A comparison between academic and non-academic high-tech start-ups. *Research Policy, 41*(1), 79–92. https://doi.org/10.1016/j.respol.2011.08.010.

Crescenzi, R., Filippetti, A., & Iammarino, S. (2017). Academic inventors: Collaboration and proximity with industry. *The Journal of Technology Transfer, 42*(4), 730–762.

Crescenzi, R., Nathan, M., & Rodríguez-Pose, A. (2016). Do inventors talk to strangers? On proximity and collaborative knowledge creation. *Research Policy, 45*(1), 177–194.

Crespi, G., D'Este, P., Fontana, R., & Geuna, A. (2011). The impact of academic patenting on university research and its transfer. *Research Policy, 40*(1), 55–68.

Cypher, J. M., & Dietz, J. L. (2009). *The process of economic development* (3rd ed.). London: Routledge.

Czarnitzki, D., & Toole, A. A. (2010). Is there a trade-off between academic research and faculty entrepreneurship? Evidence from US NIH supported biomedical researchers. *Economics of Innovation and New Technology, 19*(5), 505–520.

Delapierre, M., Madeuf, B., & Savoy, A. (1998). NTBFs—The French case. *Research Policy, 26*(9), 989–1003. https://doi.org/10.1016/S0048-7333(97)00055-3.

D'Este, P., Mahdi, S., Neely, A., & Rentocchini, F. (2012). Technovation inventors and entrepreneurs in academia: What types of skills and experience matter ? *Technovation, 32*(5), 293–303. https://doi.org/10.1016/j.technovation.2011.12.005.

D'Este, P., & Patel, P. (2007). University—industry linkages in the UK: What are the factors underlying the variety of interactions with industry ? *Research Policy, 36,* 1295–1313. https://doi.org/10.1016/j.respol.2007.05.002.

D'Este, P., & Perkmann, M. (2011). Why do academics engage with industry? The entrepreneurial university and individual motivations. *Journal of Technology Transfer, 36*(3), 316–339. https://doi.org/10.1007/s10961-010-9153-z.

Dubois, P., Griffith, R., & O'Connell, M. (2020). How well targeted are soda taxes? *American Economic Review, 110*(11), 3661–3704. https://doi.org/10.1257/aer.20171898v.

Evans, J. A. (2010). Industry collaboration, scientific sharing, and the dissemination of knowledge. *Social Studies of Science, 40,* 757–791. https://doi.org/10.1177/0306312710379931.

Fabrizio, K. R., & Di Minin, A. (2008). Commercializing the laboratory: Faculty patenting and the open science environment. *Research Policy, 37*(5), 914–931.

Feldman, J. M., & Klofsten, M. (2010). Medium-sized firms and the limits to growth: A case study in the evolution of a spin-off firm. *European Planning Studies, 8*(5), 631–650. https://doi.org/10.1080/713666429.

Filippetti, A., & Savona, M. (2017). University–industry linkages and academic engagements: Individual behaviours and firms' barriers. Introduction to the special section. *Journal of Technology Transfer, 42*(4), 719–729.

Fontes, M. (2005). The process of transformation of scientific and technological knowledge into economic value conducted by biotechnology spin-offs. *Technovation, 25*(4), 339–347. https://doi.org/10.1016/j.technovation.2003.08.004.

Franco, M., & Haase, H. (2015). Journal of Engineering and University—Industry cooperation: Researchers' motivations and interaction channels. *Journal of Engineering and Technology Management, 36,* 41–51. https://doi.org/10.1016/j.jengtecman.2015.05.002.

Franzoni, C., & Lissoni, F. (2006). *Academic entrepreneurship, patents and spin-offs: Critical issues and lessons for Europe* (pp. 1–33). Milano: Università commerciale Luigi Bocconi.

Godin, B., & Gingras, Y. (2000). Impact of collaborative research on academic science. *Science and Public Policy, 27*(1), 65–73.

Goel, R. K., & Göktepe-Hultén, D. (2019). Risk attitudes, patenting and invention disclosures by academic researchers. *The Journal of Technology Transfer, 44*(1), 155–166.

Green, K. M., & Stuart, E. A. (2014). Examining moderation analyses in propensity score methods: Application to depression and substance use. *Journal of Consulting and Clinical Psychology, 82*(5), 773. https://doi.org/10.1037/a0036515.

Gulbrandsen, M., & Smeby, J. C. (2005). Industry funding and university professors' research performance. *Research Policy, 34*(6), 932–950. https://doi.org/10.1016/j.respol.2005.05.004.

Gümüsay, A. A., & Bohné, T. M. (2018). Individual and organizational inhibitors to the development of entrepreneurial competencies in universities. *Research Policy, 47*(2), 363–378. https://doi.org/10.1016/J.RESPOL.2017.11.008.

Han, J. (2020). Identifying the effects of technology transfer policy using a quantile regression: The case of South Korea. *The Journal of Technology Transfer*, *45*(6), 1690–1717. https://doi.org/10.1007/s10961-019-09768-3.

Haeussler, C., & Colyvas, J. A. (2011). Breaking the Ivory Tower: Academic entrepreneurship in the life sciences in UK and Germany. *Research Policy, 40*(1), 41–54. https://doi.org/10.1016/j.respol.2010.09.012.

Hayter, C. S. (2011). In search of the profit-maximizing actor: Motivations and definitions of success from nascent academic entrepreneurs. *Journal of Technology Transfer, 36*(3), 340–352. https://doi.org/10.1007/s10961-010-9196-1.

Hayter, C. S. (2015). Public or private entrepreneurship? Revisiting motivations and definitions of success among academic entrepreneurs. *Journal of Technology Transfer, 40*(6), 1003–1015. https://doi.org/10.1007/s10961-015-9426-7.

Iazzolino, G., Greco, D., Verteramo, S., Attanasio, A. L., Carravetta, G., & Granato, T. (2019). An integrated methodology for supporting the development and the performance evaluation of academic spin-offs. *Measuring Business Excellence*, *24*(1), 69–89. https://doi.org/10.1108/MBE-09-2019-0097.

Imbens, G. W. (2004). Nonparametric estimation of average treatment effects under exogeneity: A review. *The Review of Economics and Statistics, 86*(1), 4–29. https://doi.org/10.1162/003465304323023651.

Jain, S., George, G., & Maltarich, M. (2009). Academics or entrepreneurs? Investigating role identity modification of university scientists involved in commercialization activity. *Research Policy*, *38*(6), 922–935. https://doi.org/10.1016/j.respol.2009.02.007.

Kalar, B., & Antoncic, B. (2016). Social capital of academics and their engagement in technology and knowledge transfer. *Science and Public Policy, 43*(5), 646–659. https://doi.org/10.1093/scipol/scv062.

Krabel, S., & Mueller, P. (2009). What drives scientists to start their own company? An empirical investigation of Max Planck Society scientists. *Research Policy, 38*(6), 947–956. https://doi.org/10.1016/j.respol.2009.02.005.

Lafuente, E., & Berbegal-Mirabent, J. (2017). Assessing the productivity of technology transfer offices: An analysis of the relevance of aspiration performance and portfolio complexity. *Journal of Technology Transfer*. https://doi.org/10.1007/s10961-017-9604-x.

Lam, A. (2011). What motivates academic scientists to engage in research commercialization: "Gold", "ribbon" or "puzzle"? *Research Policy, 40*(10), 1354–1368. https://doi.org/10.1016/j.respol.2011.09.002.

Landry, R., Amara, N., Pablos-Mendes, A., Shademani, R., & Gold, I. (2006). The knowledge-value chain: A conceptual framework for knowledge translation in health. *Bulletin of the World Health Organization, 84*(8), 597–602. https://doi.org/10.2471/BLT.06.031724.

Landry, R., Saïhi, M., Amara, N., & Ouimet, M. (2010). Evidence on how academics manage their portfolio of knowledge transfer activities. *Research Policy, 39,* 1387–1403. https://doi.org/10.1016/j.respol.2010.08.003.

Larsen, M. T. (2011). The implications of academic enterprise for public science: An overview of the empirical evidence. *Research Policy, 40*(1), 6–19.

Maine, E., & Garnsey, E. (2007). The commercialisation environment of advanced materials ventures. *International Journal of Technology Management, 39*(1/2), 49. https://doi.org/10.1504/ijtm.2007.013440.

Meoli, M., Pierucci, E., & Vismara, S. (2018). The effects of public policies in fostering university spin-offs in Italy. *Economics of Innovation and New Technology, 27*(5–6), 479–492.

Narula, R. (2004). R&D collaboration by SMEs: New opportunities and limitations in the face of globalisation. *Technovation, 24*(2), 153–161. https://doi.org/10.1016/S0166-4972(02)00045-7.

O'Kane, C. (2018). Technology transfer executives' backwards integration: An examination of interactions between university technology transfer executives and principal investigators. *Technovation, 76–77,* 64–77. https://doi.org/10.1016/j.technovation.2016.08.001.

Ortín-Ángel, P., & Vendrell-Herrero, F. (2014). Technovation University spin-offs vs. other NTBFs: Total factor productivity differences at outset and evolution. *Technovation, 34*(2), 101–112. https://doi.org/10.1016/j.technovation.2013.09.006.

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., et al. (2013). Academic engagement and commercialisation: A review of the literature on university–industry relations. *Research Policy, 42*(2), 423–442. https://doi.org/10.1016/j.respol.2012.09.007.

Powell, W. W., Koput, K. W., & Smith-doerr, L. (1996). Interorganizational and the Collaboration Locus of Innovation: Networks of learning in biotechnology. *Administrative Science Quarterly, 41*(1), 116–145. https://doi.org/10.2307/2393988.

Rasmussen, E., Mosey, S., & Wright, M. (2011). The evolution of entrepreneurial competencies: A longitudinal study of university spin-off venture emergence. *Journal of Management Studies, 48*(6), 1314–1345. https://doi.org/10.1111/j.1467-6486.2010.00995.x.

Rasmussen, E., & Wright, M. (2015). How can universities facilitate academic spin-offs? An entrepreneurial competency perspective. *Journal of Technology Transfer, 40*(5), 782–799. https://doi.org/10.1007/s10961-014-9386-3.

Rizzo, U. (2015). Why do scientists create academic spin-offs? The influence of the context. *Journal of Technology Transfer, 40*(2), 198–226. https://doi.org/10.1007/s10961-014-9334-2.

Rosenbaum, P. R., & Rubin, D. B. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika, 70*(1), 41–55. https://doi.org/10.1093/biomet/70.1.41.

Rothaermel, F. T., Agung, S. D., & Jiang, L. (2007). University entrepreneurship: A taxonomy of the literature. *Industrial and Corporate Change, 16*(4), 691–791. https://doi.org/10.1093/icc/dtm023.

Ruokonen, M., Nummela, N., Puumalainen, K., & Saarenketo, S. (2008). Market orientation and internationalisation in small software firms. *European Journal of Marketing, 42*(11–12), 1294–1315. https://doi.org/10.1108/03090560810903682.

Toole, A. A., & Czarnitzki, D. (2010). Commercializing science: Is there a university "brain drain" from academic entrepreneurship? *Management Science, 56*(9), 1599–1614. https://doi.org/10.1287/mnsc.1100.1192.

Un, C. A., & Asakawa, K. (2015). Types of R&D collaborations and process innovation: The benefit of collaborating upstream in the knowledge chain. *Journal of Product Innovation Management, 32*(1), 138–153. https://doi.org/10.1111/jpim.12229.

Van Looy, B., Callaert, J., & Debackere, K. (2006). Publication and patent behavior of academic researchers: Conflicting, reinforcing or merely co-existing? *Research Policy, 35*(4), 596–608.

Van Looy, B., Landoni, P., Callaert, J., Van Pottelsberghe, B., Sapsalis, E., & Debackere, K. (2011). Entrepreneurial effectiveness of European universities: An empirical assessment of antecedents and trade-offs. *Research Policy, 40*(4), 553–564. https://doi.org/10.1016/j.respol.2011.02.001.

Walter, S. G., Schmidt, A., & Walter, A. (2016). Patenting rationales of academic entrepreneurs in weak and strong organizational regimes. *Research Policy, 45*(2), 533–545. https://doi.org/10.1016/j.respol.2015.11.008.

Zedtwitz, M., & Grimaldi, R. (2006). Are service profiles incubator-specific? Results from an empirical investigation in Italy. *Journal of Technology Transfer, 31*(4), 459–468. https://doi.org/10.1007/s10961-006-0007-7.

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