The Journal of Technology Transfer (2021) 46:961–988
https://doi.org/10.1007/s10961-020-09802-9

University-SME collaboration and innovation performance: the role of informal relationships and absorptive capacity

Roberta Apa[1] · **Valentina De Marchi**[2] · **Roberto Grandinetti**[2] · **Silvia Rita Sedita**[2]

Published online: 28 May 2020

Abstract
This work analyzes the impact of university–industry collaborations (UICs) on the innovation performance of a sample of small and medium enterprises (SMEs) located in Veneto, a region in the north-east of Italy, which is considered particularly representative of the often-cited "innovation without research" model. We consider two aspects of such UICs that have never been at the center of theoretical and empirical debates on the innovation capacity of SMEs and whose importance has only recently been recognized. The first aspect is the variety of forms that UIC can take. Specifically, we distinguish between formal and informal collaborations. The second aspect is the possible influence of the absorptive capacity of SMEs on their ability to gaining from UICs in terms of innovation performance. We combine statistical analysis of the results of a survey administered to 179 SMEs in Veneto with a collection of anecdotal evidence to show that UICs effectively increase SMEs' innovation performance.

Keywords University–industry collaboration · Innovation · SME · Formal and informal collaboration

JEL Classification L14 · O31 · O32

✉ Silvia Rita Sedita
silvia.sedita@unipd.it

Roberta Apa
roberta.apa@unimi.it

Valentina De Marchi
valentina.demarchi@unipd.it

Roberto Grandinetti
roberto.grandinetti@unipd.it

[1] Department of Environmental Science and Policy, University of Milan, via Celoria 2, 20133 Milan, Italy

[2] Department of Economics and Management, University of Padova, Via del Santo 33, 35123 Padua, Italy

1 Introduction

The increasing importance of collaborations between firms and academic institutions in ensuring the effectiveness of an innovation ecosystem has been emphasized in the literature on innovation and in a variety of policy documents (Rajalo and Vadi 2017; Kobarg et al. 2018). In particular, optimizing the outcomes of university–industry collaborations (UICs) is considered a major issue for firms willing to capture opportunities at the technological frontier (Reischauer 2018) through significant incoming knowledge spillovers (Cassiman and Veugelers 2002).

Innovation studies have largely stressed how innovation-driven UICs have mainly favored large corporations. This is particularly true for European countries, where the various editions of the Community Innovation Survey (CIS) report that only a minority of SMEs use universities or research centers as sources of information for innovation. Even fewer SMEs engage in fruitful collaborations with these research structures (Cooke et al. 2000; Mohnen and Hoareau 2003; Ebersberger et al. 2012a, b; Rõigas et al. 2018).

The problematic interactions between university and SMEs can be explained by examining both sides of these relationships. From the point of view of SMEs, these companies generally lack the absorptive capacity and scientific approach to problem-solving needed to benefit from tapping into academic knowledge (Spithoven et al. 2010; Messeni Petruzzelli and Rotolo 2015). From the point of view of universities, these institutions often prefer to participate in larger consortia and longer-term efforts (Caloghirou et al. 2001) and do not seem to have invested much in the development of partnerships with SMEs (Bodas Freitas et al. 2013). Other factors that might influence the effectiveness of UICs (i.e., the probability of successful interactions between the two sides) include technological and geographical proximity (e.g., Messeni Petruzzelli 2011), firms' search strategies (e.g., Messeni Petruzzelli and Rotolo 2015) and researchers' characteristics (e.g., Zucker and Darby 1996; Baba et al. 2009; Subramanian et al. 2013; Tijssen 2018).

Specific and ad hoc policy interventions can foster dialogue between universities and SMEs, as represented by the well-known triple helix model, which can be applied at both the national and regional government levels (Etzkowitz and Leydesdorff 2000). Nevertheless, policies concerning SMEs that are merely oriented at funding UICs but that do not remove obstacles to interaction do not change the status quo (Oughton et al. 2002).

The possibilities for SMEs to engage in UICs have proved to be limited in several respects. Furthermore, the effectiveness of such collaborations in improving innovation performance has found weak and inconsistent support in the literature (Dornbusch and Neuhäusler 2015; Jones and Corral de Zubielqui 2017). Therefore, our main research question is as follows: *Under what conditions do UICs effectively increase SMEs' innovation performance?*

It is worth noting that there are significant differences between sectors (e.g., low tech versus high tech) and geographical and institutional boundaries (countries and regions) concerning the three components of the triple helix model (SMEs, universities, policies) and especially their harmonious interaction For instance, many contributions cite Japan as a case of excellence in the design of efficient policy interventions for strengthening the innovation capacity of SMEs and the birth and survival of innovative start-ups through networking activities in general and collaboration with universities in particular (Motohashi 2005; Kitagawa and Woolgar 2008; Walsh et al. 2008). By contrast, Italy represents a case where interactions between the three actors in the triple helix model have been minimal. This is reflected in the results of a comparative analysis of nine European countries

conducted in the 90 s by Colombo and Lanzavecchia (1997, p. 488), which states, "Italy's innovation system is weak. As a knowledge-generating factor, universities and public research organizations are less effective in Italy than in the other EU countries examined. Moreover, the role of support facilities, such as technical assistance programs and patent consulting, is far less significant in Italy. Lastly, public research plays a very limited role in Italy as a source of applied knowledge, new techniques and prototypes."

Despite these generally unfavorable conditions, the authors claimed that the innovative capacity of the so-called Third Italy, which is characterized by a proliferation of SMEs and industrial districts, could not be considered scarce and introduced the concept of "innovation without research." Around 10 years later, Moncada-Paternò-Castello et al. (2006) confirmed the persistence of the situation. This makes Italy an interesting setting for an empirical analysis of types of UICs and the conditions under which they can benefit SMEs by increasing innovation performance.

Our research aims to contribute to filling this gap by verifying the impact of UICs on a sample of SMEs located in Veneto, a region in the north-east of Italy, which is considered particularly representative of the often-cited model of "innovation without research" (see also De Marchi and Grandinetti 2017). We consider two aspects that have never been central to theoretical and empirical debates on the innovation capacity of SMEs and that have only recently begun to be regarded as crucial. The first pertains to the variety of forms UICs can take. We pay particular attention to formal versus informal collaborations (Perkmann et al. 2013). The second aspect concerns the possible influence the absorptive capacity of SMEs can have on gains in innovation performance from UICs (Kobarg et al. 2018). To detect the absorptive capacity of a firm, we especially consider the presence of an internal research and development (R&D) structure, which is a widely used proxy for absorptive capacity that was first proposed in the seminal contribution of Cohen and Levinthal (1990). Statistical analysis of the results of a survey administered to 179 SMEs in Veneto and the collection of anecdotal evidence enabled us to answer our research question. The most surprising result was that, in the case of manufacturing SMEs, formal UICs are not effective per se and that, overall, informal collaborations are the most suitable for increasing the innovation performance of firms, either alone or to complement a formal partnership. Moreover, absorptive capacity is a necessary condition for a firm to be able to transform a formal collaboration into an innovation output; it also multiplies the effectiveness of informal collaborations. Interestingly, a firm's internal R&D effort is found to be influential both with and without UICs.

The paper proceeds as follows. In Sect. 2, we review the literature on UICs, focusing on formal and informal ties and the effects of absorptive capacity on the innovation performance of SMEs. We also present the research hypotheses in this section. In Sect. 3, we define the empirical setting and the methodology. Section 4 presents the empirical analysis and the results, and Sect. 5 offers a discussion of the results and some concluding remarks.

2 Theoretical background

2.1 University–industry collaborations: formal and informal ties

As stated in the introduction, the literature on UICs is extensive. However, much of it focuses on measuring formal collaborations in terms of co-patenting and co-publishing activities, which generally involve large firms with solid R&D departments. One exception

is a study by Lasagni (2012), which analyzes a sample of 490 SMEs in six EU countries and shows that SMEs engagement in UICs can increase their innovative capacity.

In a recent systematic literature review, Ankrah and Al-Tabbaa (2015) found that the forms of UIC mostly pursued in practice and discussed in the literature are formal, namely joint ventures, networks, consortia, and alliances. Informal UICs are underexplored and warrant investigation. Perkmann et al. (2013) highlighted the need for further research on this topic and specifically on the types of informal activities that belong to what they label "academic engagement". Nevertheless, they do not mention explicitly which can be the marginal impact of formal and informal collaborations on the innovation performance of SMEs. Ankrah and Al-Tabbaa (2015) claim that studying the impact of informal relations and social interactions, as well as formal collaborations, is essential for an understanding of innovation processes in UICs, because this process is rooted in the nature of knowledge creation as a socially embedded process (Sirmon et al. 2007; Dess and Shaw 2001). We believe our work can make an important contribution to the study of this topic. In the interest of clarity, we define informal UICs as personal relationships that focus primarily on non-contractual interactions between the agents involved and for which strong motivation, mutual trust, and underlining social ties are important pre-conditions. Formal UICs are ruled through a contract and are either stimulated by formal programs established at the university or are formed to exploit opportunities for accessing research funds or for commercializing a scientific output. These definitions are based on the results of a systematic literature review conducted by Ankrah and Al-Tabbaa (2015), which provides an insightful overview of the variety of UICs explored in the literature and builds on the seminal work of Bonaccorsi and Piccaluga (1994). Table 1 presents a summary of their results.

As Mitsuhashi (2002) explained, formal collaborations are established by a legal contract that explicitly states the purpose of the partnership and allows the relationship to enter an operational phase. It is to be expected that innovation-oriented collaborations with universities benefit SMEs by enhancing their innovation performance. This is the natural strategic effect of a UIC with converging objectives, where the inter-organizational relationship is perceived as a rational process with common goals and the type and level of commitment of both parties specified in advance. This is typical of a science, technology and innovation mode of knowledge transfer, which is oriented at finding technological applications of scientific discoveries. Following this approach, firms "that connect more systematically to sources of codified and scientific knowledge are able to find new solutions and develop new products that make them more competitive" (Jensen et al. 2007, p. 690). From this information, we draw our first hypothesis:

H1 Formal collaborations with universities positively impact the innovation performance of SMEs.

Even though formal UICs are bound by legal contracts (Kanter 1994), commitment is essential and is maintained and underpinned by friendship and reciprocal trust (Baba et al. 2009). Informal interactions between firms and university personnel are also important for the transfer of tacit knowledge, which makes the two channels—formal and informal—mutually reinforcing (Grimpe and Hussinger 2013). Informal relations with a university can also allow an enterprise to acquire "basic" knowledge that has no direct commercial application. This is often observed in both large enterprises (Cassiman et al. 2010) and SMEs (Garcia-Perez-de-Lema et al. 2017). However, the types of collaboration presented in Table 1 clearly show that there are other benefits of such collaborations. For example,

Table 1 Formal and informal UICs: an overview

Formal collaborations	Informal collaborations
Personal formal collaborations	*Personal informal relationships*
• Student internships and sandwich courses	• Academic spin-offs
• Students' involvement in industrial projects	• Individual consultancies (paid or unpaid)
• Scholarships, studentships, fellowships, and post-graduate linkages	• Information exchange forums
	• Collegial exchanges, conferences, and publications
• Joint supervision of PhDs and masters theses	• Joint and individual lectures
• Exchange programs (e.g. secondment)	• Personal contact with university academic staff or
• Sabbaticals for professors	• industrial staff
• Hiring of graduate students	• Co-location arrangements
• Employment of scientists by industry	
• Use of university or industrial facilities (e.g., labs, databases)	
Formal non-targeted agreements	
• Broad agreements for UICs	
• Endowed chairs and advisory boards	
• Funding of university posts	
• Industrially sponsored R&D in university departments	
• Research grants, gifts, endowment, trusts, donations	
• (financial or equipment), general or for specific departments or academics	
Formal targeted agreements	
• Contract research (including technical services contracts)	
• Patenting and licensing agreements (licensing of intellectual property rights)	
• Cooperative research projects	
• Equity holding in companies by universities or faculty members	
• Joint research programs	
• Training programs for employees	

Source adapted from Ankrah and Al-Tabbaa (2015)

a company that is developing a new product may face a technical problem which it does not have adequate knowledge to solve and may be aware of a researcher from a nearby university who has this specialized knowledge. Among all the possible options listed in Table 1, individual consultancies are likely to be preferred in this case (Ankrah and Al-Tabbaa 2015). Such informal UICs, based on trust and learning developed through personal bonds, are representative of the "doing, using and interacting" knowledge exchange model conceptualized by Jensen et al. (2007) and complement the interaction-driven mode of knowledge absorption adopted usually by SMEs (Grandinetti 2016). However, very little investigation of this aspect of UICs is found in the extant literature, even though it is "an important and complementing theoretical lens when examining the nature of UIC"

(Ankrah and Al-Tabbaa 2015, p. 399). One work that does explore this topic is Jones and Corral de Zubielqui's (2017) study of 153 Australian SMEs that aimed for sustainable innovation objectives and were found to benefit more from human resources transfer (a form of embodied knowledge transfer [Frederiksen and Sedita 2012]) than from structured joint research projects. Our second hypothesis is as follows:

H2 Informal collaborations with universities positively impact the innovation performance of SMEs.

2.2 The moderating role of absorptive capacity on university–industry collaborations

As first observed by Cohen and Levinthal (1990) in their seminal contribution, absorptive capacity is of paramount importance when considering the networking abilities of firms. Even firms who outsource their technology requirements should maintain a minimal level of in-house technological capacity (Veugelers 1997; Paoli and Prencipe 1999) and engage in managerial and organizational practices that enable them to achieve superior innovation performance through a strategy of openness (Lazzarotti et al. 2015). While the importance of absorptive capacity has been established in the literature, especially for innovation and growth-oriented firms (Liao et al. 2003), its mediating role in determining the effectiveness of UICs has not yet been investigated. Kobarg et al. (2018) observed that "while the performance implications of university–industry collaboration (UIC) have been the subject of extensive research, no study thus far has investigated the potential influence of absorptive capacity and innovation competencies on the relationship between UIC and product innovation performance" (p. 1). Focusing particularly on SMEs, Fontana et al. (2006) and Muscio (2007) investigated the role of absorptive capacity on the propensity to establish innovation-oriented collaborations (including those with universities and research centers) and found evidence of positive relationships. Nevertheless, no contribution has focused on the relationship between absorptive capacity and the innovative output of UIC collaborations involving SMEs. Narula (2004) observed that SMEs can utilize external networks even more efficiently than large corporations when a certain level of absorptive capacity is retained but did not provide evidence of this in specific relation to UICs.

Formal collaborations between firms and universities encourage the production and use of codified scientific and technological knowledge. However, requires a minimum threshold of scientific understanding on the part of firms (Grandinetti 2016). Thus, firms must have knowledge codification capabilities, which are sustained by investment in corporate R&D and can help SMEs reduce information asymmetry between themselves with universities, making it possible for them to benefit from UICs. Formal collaborations with universities often take place within structured research projects. These collaborations require personnel that are fully devoted to innovation activities and can dedicate enough time to project management. These individuals are more likely to develop the ability to assimilate and better transform the knowledge retained by the university (Zahra and George 2002). Thus, we can hypothesize that firms with an R&D department -(i.e., with personnel devoted to innovation) benefit more from formal UICs than firms without such a department. In line with Bougrain and Haudeville (2002), we expect that firms without an R&D office do not manage formal collaborative relationships with universities well.

Internal activities for developing innovation are often less formalized in SMEs than in large firms (Patel and Pavitt 1994) that develop innovations through formally established R&D departments. This might not be an obstacle when establishing initial contact with universities but can impair future exploitation of the relationship. Interpersonal relationships are based on relational governance (Garcia-Perez-de-Lema et al. 2017), which is heavily dependent on tacit knowledge transfer. Moreover, interpersonal relationships can be considered social ties, and therefore associated to personal bonds based on mutual trust (Gilsing and Nooteboom 2005). Within an exploration–exploitation framework of analysis (March 1991), informal collaborations might be seen as crucial in the exploration stage. However, organizational investment is required to transform embodied knowledge and personal trust into social capital for the organization (Nooteboom 2007).

Consequently, whether collaboration is realized through formal or informal channels, the knowledge codification process is crucial for the exploitation of university knowledge. Only after this transformation process can formal and informal collaborations with universities lead to the development of products, processes, or organizational innovations and, thus, to the exploitation of knowledge transfer. For this to be realized, the organization must have the internal capabilities to re-process the information that comes from interpersonal relationships. This aligns with the definition of absorptive capacity proposed by Cohen and Levinthal (1990), which includes both the assimilation of external knowledge and its use within the receiving organization. Since the exploitation of formal and informal collaborations is fueled by absorptive capacity and since absorptive capacity is an important component in the process of transforming networking ability into increased innovation capacity, we propose our third and fourth hypotheses as follows:

H3 An SME's absorptive capacity positively moderates the impact of formal collaborations with universities on the firm's innovation performance

H4 An SME's absorptive capacity positively moderates the impact of informal collaborations with universities on the firm's innovation performance.

3 The empirical setting

To test the hypotheses postulated above, we performed a quali-quantitative analysis of original data on firms located in Veneto, a particularly appropriate empirical setting due to the peculiar characteristics of its regional innovation model. Since the 1990s, Italy has been a preferred empirical setting for studies aiming to test the innovation patterns of SMEs. Indeed, the Italian economy is characterized by a large number of SMEs, which represent the backbone of its development in international markets, especially when they are localized within industrial districts or clusters. A vast body of literature focusing on various districts across the country testifies to the interesting innovation capabilities that can be developed within this form of industrial organization, which facilitates effective knowledge transfer across local actors (Bellandi 1996; Belussi and Gottardi 2000; Camuffo and Grandinetti 2011). However, innovation capabilities differ significantly across regions (De Marchi and Grandinetti 2017). Therefore, we decided to focus on the Veneto region, where SMEs specializing in low-tech manufacturing play a significant role in the local economy, where networks are considered more important than R&D for innovation, and where there

is a long-standing industrial tradition rooted in industrial districts and clusters (Belussi and Sammarra 2009).

Veneto, in the north-east of Italy, is among the most developed regions in Europe in terms of employment rate and gross domestic product (GDP) per capita and is relatively innovative. It ranks as a moderate-plus innovator region, according to the European Innovation Scoreboard (Regional Innovation Scoreboard Report, 2017),[1] and is among the top five regions in the country (De Marchi and Grandinetti 2017).

The region hosts numerous manufacturing firms, mostly specialized in low-tech manufacturing. As of 2015, employment in manufacturing was responsible for 38.7% of total employment in the region (the national average was 27.4%).[2] The majority of local companies are SMEs; 94.1% of the regions active companies are small and 5.2% are medium-sized, with the latter developing into an increasingly influential stratum of the economy (Coltorti et al. 2013). The economy of the region is characterized by the presence of several industrial districts (Becattini 1990), with SMEs localized in specific territories and specialized in different stages of product development within one or related industries. These are generally low-tech manufacturing industries, such as footwear (Riviera del Brenta district), sports footwear and clothing (Montebelluna district), eyewear (Belluno district), and jewelry (Vicenza district) (Belussi et al. 2011; De Marchi et al. 2018). District firms' activities are linked to the recombination of symbolic and synthetic knowledge bases, rather than analytical (Sedita et al. 2017), Within this form of organization, innovation processes are realized by recombining knowledge acquired via diverse collaborations. Learning within districts is mostly based on learning-by-doing processes and inter-firm, intra-district knowledge transfers. Such transfers take diverse forms, such as interpersonal relations, imitation, mobility of human resources, and the creation of new spin-off ventures (Camuffo and Grandinetti 2011; Belussi and Sedita 2012). Veneto has also been described as emblematic of the concept of innovation without research (Colombo and Lanzavecchia 1997; Moncada-Paternò-Castello et al. 2006) because of its low public and private investments in R&D. Our analysis of the data provided by the European Regional Innovation Scoreboard Report (2017) revealed that R&D expenditure by the business and public sectors in Veneto is, respectively, 39% and 37% lower than the average R&D expenditure of the regions defined as "leaders."[3]

3.1 Sample and methods

To test our hypotheses, we employed a mixed-method approach, combining data from an original survey with anecdotal evidence from face-to-face and phone interviews with SME entrepreneurs and following the methodology adopted by Narula (2004). Such a mixed-method approach overcomes the limitations of surveys and case studies by enabling data triangulation and ensuring robust results (Mathison 1988; Jick 1979; Bryman 2015). All interviews with entrepreneurs or, where applicable, the head of R&D departments were conducted after the survey, in the period April–May 2018. Detailed information on the

[1] This report classifies European regions into four categories, ranging from the most innovative to the least innovative: innovation leaders, strong innovators, moderate innovators, and modest innovators. Each category is subdivided into three groups, and "plus" is the most innovative within each group.

[2] These figures represent our calculations based on data provided by the Italian National Institute of Statistics (ISTAT) on the online data source: dati.istat.it.

[3] More information on the data source and the variables and data used can be found at http://ec.europa.eu/growth/industry/innovation/facts-figures/regional_en

specific relationship between the SME and the university and, in particular, on the impact of having an R&D department and of informal and formal ties on innovation performance was collected through the interviews.[4] Due to the sensitive nature of the information provided, the interviewees requested that their responses remain confidential. Therefore, when reporting the anecdotal evidence, we excluded certain details that might have revealed the identity of a firm.

For the quantitative analysis based on survey data, our population consists of all 5166 manufacturing SMEs (10–250 employees) that operate in the Veneto region and that are included in the AIDA database (Bureau Van Dijk). We drew our sample from this population of firms using a stratified sampling procedure (Ding et al. 1998; Laine and Karras 2011) based on firm size and access to public regional support for innovation. We considered four sizes of firms based on number of employees (10–19, 20–49, 50–99, and 100–249 employees) and whether or not firms had access to public support (yes or no). Using a simple random sampling method (where every firm had an equal chance of being selected), we drew companies from each stratum to reach a minimum sample size of 200 SMEs. However, since some responses were missing, we only included 179 firms in the analysis. On average, the firms interviewed had 35 employees (20% had 50 employees or more), and 27% of them had used public funding. Based on the European classification of industries based on technological intensity, only 2% of the sampled firms belonged to high-tech industries (mostly the manufacture of communication equipment), while medium–high-tech industries accounted for 25% of the sample (mainly firms specializing in the manufacture of other general-purpose machinery, metal-forming machinery, or machine tools). The rest of the firms operated in medium–low- or low-tech industries, such as the production of metal products, non-metallic minerals, leather-based goods, or jewelry, all of which are typical "Made in Italy" sectors. A detailed description of the sample is presented in Sect. 4.

The survey was conducted between December 2015 and January 2016 through the administration of a structured questionnaire using the computer-assisted telephone interviewing procedure. The questionnaire investigated SMEs' innovation activities over the period 2012–2014 and was composed of 40 items divided into five sections: firm characteristics, innovation outputs, firm's activities and resources for innovation, external resources for innovation, and public support for innovation.[5]

Using the data collected through the survey, we estimated a set of negative binomial regressions to investigate the impact of collaborations with universities on the innovation capacity of SMEs. The following section describes in detail the variables used, and further information on the variables can be found in Tables 5 and 6 in the "Appendix".

4 Empirical analysis

4.1 Dependent variable

Measuring innovation is complex. However, as Smith (2005) noted, the indicators adopted in the CIS—by far the most widely used source for investigating innovation dynamics—have been designed to overcome the limitations associated with other approaches. Built on two decades of efforts by experts at OECD, Eurostat, and DG-Enterprise, CIS adopts a

[4] During the interviews, we specified the differences between the various types of collaborations (shown in as Table 1) by carefully instructing the interviewers.

[5] The questionnaire is available upon request.

subjective approach to measuring innovation (see Archibugi and Planta [1996] for a discussion of the advantages and disadvantages of a subjective approach to measuring innovation). While the CIS collected information using a dichotomous form, we use firms' self-reported measure of their innovation performance analyze the innovation performance of SMEs. The questions asked firms to rate their innovation intensity on a 0–7 scale (and in comparison to the industry average) for each of the four general types of innovation considered by the CIS: product, process, organizational, and marketing innovation. The variable *Inno_perf* is a sum of the values for the four innovation types and, therefore, varies from 0 to 28. In contrast to other measures of innovation (e.g., sales of products new to the market), this proxy captures both incremental and radical innovations and takes non-technological innovations into account, which is particularly relevant in the context of SMEs. Furthermore, by using a Likert scale, this variable captures nuances in the innovation performance of firms.

As reported in Table 2, which presents the descriptive statistics of all variables considered, the sample is composed of innovative firms, as the average self-reported score of

Table 2 Descriptive statistics of the variables included in the analysis

	Obs.	Mean	Std. Dev.	Min.	Max.
Dependent var.					
Inno_perf	180	11.8778	7.6631	0	28
Independent var.					
R&D	174	0.3391	0.4748	0	1
UI_coll	180	0.1722	0.3786	0	1
Formal_coll	180	0.0667	0.2501	0	1
Informal_coll	180	0.0778	0.2686	0	1
Both_coll	180	0.0278	0.1648	0	1
YesColl_YesR&D	174	0.0778	0.2686	0	1
YesColl_NoR&D	174	0.0944	0.2933	0	1
NoColl_YesR&D	174	0.2500	0.4342	0	1
NoColl_NoR&D	174	0.5444	0.4994	0	1
YesForm_YesR&D	174	0.0278	0.1648	0	1
YesForm_NoR&D	174	0.0389	0.1939	0	1
YesInform_YesR&D	174	0.0333	0.1800	0	1
YesInform_NoR&D	174	0.0444	0.2067	0	1
YesBoth_YesR&D	174	0.0167	0.1284	0	1
YesBoth_NoR&D	174	0.0111	0.1051	0	1
Controls					
Ln_age	180	3.3663	0.5160	1.6094	4.4998
Size	180	36.5000	34.1262	9	225
Low-tech	180	0.3333	0.4727	0	1
Med-low tech	180	0.3944	0.4901	0	1
Med-high tech	180	0.2722	0.4463	0	1
Pub_funds	180	0.2056	0.4052	0	1
Export	179	0.8379	0.3694	0	1
District	180	0.1444	0.3525	0	1

Robust standard errors in parentheses. ***$p<0.01$, **$p<0.05$, *$p<0.1$

the firms was approximately 11.8 out of 28. A third of the companies (33.2%) reported low innovation performance (7 or less out of 28), and a fifth (16.5%) very high innovation performance (21 or more out of 28). To assess the internal consistency of this multi-item scale, we used the coefficient alpha, which is the mean of all split-half coefficients (Cronbach 1951). This approach is widely used to assess the reliability of various measures derived from the CIS questionnaire (Garriga et al. 2013; Ebersberger et al. 2012a, b; Laursen and Salter 2006). Our reliability analysis proved that the measure had good internal consistency as Cronbach's alpha was 0.84, which is well above the minimum threshold of 0.7 identified in the literature (Nunnally and Bernstein 1994).

4.2 Explanatory variables

To analyze the collaborations between universities and firms we use a set of dummy variables to represent the different forms of collaborations. First, we constructed a dummy variable (*UI_coll*) to identify whether firms had collaborated with universities for innovation purpose in the period 2012–2014. We created three other dummy variables to determine the type of collaboration between the firm and the university: *Formal_coll*, *Informal_coll*, and *Both_coll,* one of which is assigned a value of 1 if the firm had engaged with a university in only formal collaborations, only informal collaborations, or both formal and informal collaborations, respectively. A significant share of the companies in our sample (17.7%) had collaborated with universities: 6.6% had only collaborated formally, 7.7% had only collaborated informally, and 3.3% had engaged in both forms of collaboration.

To measure absorptive capacity, which is the ability of firms to identify, assimilate, transform, and use external knowledge, we used information on the structured R&D efforts of the companies. The presence or strength of an R&D department has so far been the most widely used measure of absorptive capacity in the literature (see e.g., Jiménez-Barrionuevo et al. 2011 for a review of different proxies), even though studies have highlighted that this measure might not fully capture the complexity of the phenomenon and have proposed alternative approaches, (Liao et al. 2003; Jiménez-Barrionuevo et al. 2011; Lazzarotti et al. 2015). In this paper, we adopt the proxy used by Veugelers (1997); the dummy variable *R&D* is assigned a value of 1 if the firm has an R&D department (with at least one person working in it). While we acknowledge that it is a simple measure, which does not enable us to control for differences in the intensity of the company's R&D activities, we believe this proxy fits the analysis proposed as it allows us to distinguish more clearly the effect of having an R&D department on innovation when combined with a UIC (see Sect. 4.4). Only 33.9% of the firms in our sample had personnel specifically devoted to R&D.

4.3 Control variables

To support the consistency of the results we included a number of control variables. A firm's age—measured as the natural logarithm of the number of years the firm existed as of 2014 (*Ln_age*)—controls for the fact that the probability of innovation tends to be higher in younger firms (Huergo and Jaumandreu 2004). Young firms, defined as firms existing for less than 10 years, constituted a minority of our sample (1.7%); the majority (53.6%) of firms were between 10 and 30 years old, and only 13.8% had been active for more than 50 years.

Additionally, we controlled for a firm's size (*Size*) because larger firms may have more resources than smaller firms, which may affect their innovation performance, and

differences across medium and small firms might not be trivial (Acs and Audretsch 1988; Cakar and Erturk 2010). For this purpose, we used the UE classification of SMEs, which is based on the number of employees. Small firms are classified as having 10 to 49 employees and medium firms as having 50 to 249 employees. Of the firms in our final sample, 43% had 10–19 employees, 37% had 20–49 employees, 13% had 50–99 employees, and 7% had 100–249 employees.

To control for the industry to which the firms belonged, we adopted the Eurostat classification of the manufacturing industry by technological intensity, which identifies four classes: high-technology, medium–high-technology, medium–low-technology, and low-technology firms.[6] Given the low incidence of high-tech firms in our sample, we decided to include three dummies: *Med-high tech* (taking a value of 1 if a firm belonged to a high- or medium–high-tech manufacturing sectors), *Med-low tech*, and *Low-tech.* Of the firms in our sample, 27% belonged to a high-tech and medium–high-tech industry, whereas the majority specialized in medium–low-(39.2%) or low-tech (33.7%) manufacturing, which is representative of the Italian setting.

We also controlled for the role of public support, which previous studies have highlighted is important for the innovation performance of SMEs (Hewitt-Dunda and Roper 2010; Audretsch 2004; Love and Roper 2015). Access to public (regional, national, or European) funds was measured with a dummy variable (*Pub_funds*) that takes a value of 1 if the firm had access to public regional, national, or European funds during the period 2012–2014 and a value of 0 otherwise. Just 20.4% of the firms in our sample had been financed.

In line with previous studies aimed at understanding the impact of UIC on innovativeness (e.g., Hewitt-Dundas 2013), we also controlled for export propensity. Exporters can gain advantages from accessing knowledge and technologies not available in their own country, thereby increasing their innovation performance through learning-by-exporting (Salomon and Shaver 2005; Love and Ganotakis 2013). The variable *Export* is a dummy variable which takes a value of 1 if at least part of the turnover of the company as of 2014 was developed in international markets.

Finally, studies have suggested that an SME's location within an industrial district might support its innovativeness (see e.g., Cainelli and De Liso 2005, Boix and Galletto, 2009). Noting the presence of several industrial districts in the Veneto region (see Sect. 3), we control for location within an industrial district. For this purpose, we adopted the Italian National Statistical Office's (ISTAT) definition of industrial districts, which is based on two dimensions: a geographical one (the local labor system [LLS] where the company is located) and a sectorial one (the specialization of the company, for which we use NACE codes). Accordingly, the variable *District* takes a value of 1 if the company is located in an LLS that is associated with a particular industry, according to ISTAT's classification, and specializes in that same industry.[7]

4.4 Model estimations

In this study, we investigate the impact of UICs on the innovation performance of SMEs and examine whether the firm's absorptive capacity plays a moderating role. A nonlinear

[6] The details of the industry, included its identification using the NACE Rev. 2 at the 2-digit level, can be accessed at http://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf.

[7] For more information about the methodology adopted and the districts identified in each region can be found at https://www.istat.it/it/archivio/150320.

Table 3 Incidence of innovation activities (percentages)

		No R&D (%)	Yes R&D (%)
UI collaboration (UI_coll)	NO (%)	56.3	25.9
	YES (%)	9.8	8.0
	Formal (Formal_coll)	4.0	2.9
	Informal (Informal_coll)	4.6	3.4
	Both (Both_coll)	1.1	1.7

regression approach, which avoids heteroskedastic, non-normal residuals, is appropriate for this investigation because the outcome variable has non-negative integer values. As the variance of the dependent variable is much larger than its mean (58.97 vs. 11.93), we adopted a negative binomial regression model (Cameron and Trivedi 2009). The presence of over-dispersion is confirmed by the likelihood ratio test, which shows that the negative binomial regression model is preferred over the Poisson regression model (Poisson vs. Negative Binomial: $\chi 2 = 289.20$, p value $= 0.000$, for the full model). The choice of the negative binomial regression model is supported by the log-likelihood and the Akaike's information criterion, both of which show that negative binomial regression models outperform the Poisson ones.

Since *UI_coll* and *R&D* are both dichotomous variables, we could not introduce direct interaction terms into the regression model and test for the sign of the interaction parameters (Antonioli et al. 2013; Mohnen and Röller 2005; Wiersema and Bowen 2009). Therefore, we followed an approach that involves the estimation of an objective function (innovation function), which we used to test a series of interaction variables to capture complementary relationships (Brynjolfsson et al. 2002; Laursen and Foss 2003, Schmiedeberg 2008; Antonioli et al. 2013). Rather than including the interaction variables between *R&D* and *UI_coll*, we developed four dummies to represent all possible combinations. This enabled us to identify which of the four possible states of the world was significant. The interaction variables are dummy variables that isolate the following mutually exclusive and collectively exhausting cases:

- Firms that collaborate with a university and have an R&D department (*YesColl_YesR&D*)
- Firms that collaborate with a university and do not have an R&D department (*YesColl_NoR&D*)
- Firms that do not collaborate with a university and have an R&D department (*NoColl_YesR&D*)
- Firms that do not collaborate with a university and do not have an R&D department (*NoColl_NoR&D*)

This approach allows us to determine whether the impact of a UIC on innovation performance is greater for firms that have an R&D department. We perform a similar analysis to understand the relationship between R&D and the different types of UIC considered: formal, informal, or both. In our regression analysis, the coefficients of the interaction terms should be interpreted taking into consideration the differences between the sample cases (Table 3).

Table 4 Negative Binomial Regression models (Dependent variable: Innovation performance)

Variables	Model I	Model II	Model III	Model IV
Independent variables				
UI_coll	0.161*			
	(0.0965)			
R&D	0.500***			
	(0.0997)			
Formal_coll		0.0513		
		(0.155)		
Informal_coll		0.281**		
		(0.139)		
Both_coll		0.504***		
		(0.173)		
NoColl_YesR&D			0.480***	0.471***
			(0.115)	(0.115)
YesColl_NoR&D			0.120	
			(0.141)	
YesColl_YesR&D			0.686***	
			(0.119)	
YesForm_NoR&D				− 0.135
				(0.151)
YesForm_YesR&D				0.638***
				(0.131)
YesInform_NoR&D				0.154
				(0.174)
YesInform_YesR&D				0.663***
				(0.159)
YesBoth_NoR&D				0.583***
				(0.115)
YesBoth_YesR&D				0.762***
				(0.226)
Controls				
Ln_Age	0.308***	0.248***	0.312***	0.308***
	(0.0946)	(0.0959)	(0.0959)	(0.0980)
Size	− 0.00156	0.00112	− 0.00150	− 0.00136
	(0.00138)	(0.00145)	(0.00139)	(0.00139)
Pub_funds	0.317***	0.342***	0.325***	0.336***
	(0.0938)	(0.0944)	(0.0943)	(0.0927)
Export	− 0.0231	0.164	− 0.0239	− 0.0233
	(0.147)	(0.173)	(0.147)	(0.147)
Med-low tech	− 0.0502	− 0.0977	− 0.0484	− 0.0567
	(0.116)	(0.130)	(0.116)	(0.118)
Med-High-tech	0.0127	0.0141	0.0153	0.0210
	(0.116)	(0.121)	(0.116)	(0.116)
District	− 0.0220	− 0.0764	− 0.0223	− 0.00993
	(0.167)	(0.184)	(0.167)	(0.166)

Table 4 (continued)

Variables	Model I	Model II	Model III	Model IV
Constant	1.253***	1.362***	1.242***	1.253***
	(0.374)	(0.395)	(0.377)	(0.383)
Observations	173	179	173	173
Pseudo R-squared	0.0299	0.0184	0.0299	0.0318
Log pseudolikelihood	− 581.00988	− 610.4235	− 580.95857	− 579.81779

4.5 Results

Table 4 presents the results of the negative binomial model estimations, which enable us to address our hypotheses on the connection between formal and informal collaborations between universities and SMEs and innovation performance. Model I tests the correlation between an SME's collaboration with a university, either formal or informal, and the SMEs innovation performance. The coefficient of the variable *UI_coll* is positive and significant, which suggests a positive relationship between UICs and innovation performance. Similarly, *R&D* is positive and significant; as expected, the magnitude of its coefficient is larger than that of *UI_coll.* Interviews with firms' executives corroborate the finding that collaboration with universities is important for firms' innovation performance. Indeed, UICs are generally initiated to enable a firm to access knowledge that is relevant to the traditional domain of the firm and that is often related to specific problems.

> Collaboration with the university gave us access to knowledge and skills and opened our minds; it gave us the chance to think about what we would otherwise never have thought about (R&D manager, company A).

> The UIC is the only tool for helping SMEs to be innovative and competitive (Entrepreneur, company B).

Model II enables us to test hypotheses 1 and 2, which postulate that formal and informal collaborations with universities positively impact SMEs' innovation performance. Interestingly, the results of the negative binomial regressions only support hypothesis 2. When the three types of collaborations with universities (*UI_coll*) are distinguishing, the importance of informal collaborations emerges clearly. The coefficient of the variable *Formal_coll* is not significant, which suggests that formal collaborations with universities, such as joint research projects, do not necessarily lead to improved innovation. Rather, informal collaborations, such as consulting with professors, support this outcome. Interestingly, the importance of informal collaborations is supported not only by the results for the variable *Informal_coll*, which captures purely informal connections but also by those for the variable *Both_coll,* which is positively and significantly correlated with innovation performance. The interviews revealed that initial contact with a university professor is often made through word of mouth and that recommendations to engage in a UIC often come from a trustworthy supplier or a trade association. Consequently, the relationship starts informally, and it is only when the opportunities linked to a UIC become apparent that SMEs engage in formal relationships.

> The university supports us; we can improve the quality of our ideas and have access to large databases (R&D manager, company C).

> Through the university, we can apply for European funds, and partnering with the university increases our success rate (Entrepreneur, company B).

> We went to MIT asking them for best practices in business models… as a company, we were born with occasional good ideas… the real challenge then was how to become permanent innovators. We wanted to understand how to create a method that allowed us to 'self-generate' new ideas constantly. From this meeting at MIT, what we brought home was knowledge of consumer experience; we were familiar with the technology but lacked the expertise on the consumer (Entrepreneur, company A).

> We have collaborated with a professor at the University of Padova. We were looking for a metallurgy expert to solve a problem that emerged in an old product as a result of changes in our customer's products, a problem for which we didn't have in-house expertise. We asked our purchasing manager to ask the suppliers of that component who could help us to find a solution, and they suggested the name of a professor in Padua whom we asked for advice. We did not go through the department… it would have meant going through two channels and an unnecessary loss of time (R&D manager, company A).

Many companies reported that the costs of a UIC were less than expected and that the results were surprisingly better than expected.

Models III and IV enable us to investigate the effects of UICs and internal R&D efforts, in combination and alone, on innovation performance. Model III includes three dummy variables for measuring the effects on innovation performance of all possible states of the world in relation to the presence or absence of an R&D department (*R&D)* and collaborations with universities (*UI_coll).* The benchmark is the absence of both a formalized R&D department in the company and university collaborations. The sign and significance of the variables show that having an R&D department and not collaborating with universities (*NoColl_YesR&D*) or having an R&D department and collaborating with universities (*YesColl_YesR&D*) both have a positive impact on innovation performance compared to not having either of the two. However, the magnitude of the coefficient of *YesColl_YesR&D* is higher than that of the coefficient of *NoColl_YesR&D,* informing of the greater impact of the coexistence of collaborations with universities and of an R&D department on the innovation performance of SME. By contrast, collaborating with a university but not having and internal R&D department (*YesColl_NoR&D*) does not result in a significant difference in innovation performance compared to not having either of the two. A large majority of the interviewed companies that had an internal R&D department benefited from a UIC because it allowed them to enlarge the spectrum of possible solutions to a technological problem by enabling them to access a larger and more multidisciplinary knowledge base.

> We realized there are needs whose satisfaction requires competences that we are not even able to identify (Entrepreneur, company D).

When asked to provide more qualitative information about the way they engaged with universities, a third of the companies mentioned internships. This is a formal way of collaborating with universities, which can provide companies with ready-to-use solutions to focused problems by enabling them to access knowledge developed within universities and to have it applied directly to their specific needs. The interviews also revealed that collaboration with universities are perceived as a way of "structuring" the internal R&D endowment of a firm and enabling the firm to access distant and unrelated knowledge owned by universities.

Model IV enables us to further explore these issues by considering the mediating role of R&D for the three types of collaborations studied above, thereby testing hypotheses 3 and 4. Again, the benchmark is no collaboration with universities and no R&D department. The results

show that R&D plays a mediating role in each of the three forms of collaboration as the coefficients of the variables *YesForm_YesR&D*, *YesInform_YesR&D*, and *YesBoth_YesR&D* are all positive and highly significant. The magnitude of the variable is higher for informal collaborations than for formal collaborations and highest for both formal and informal UICs. These results confirm hypotheses 3 and 4 and demonstrate the importance of knowledge translation processes associated with informal UICs. Interestingly, collaborating with universities but not having an R&D department showed no additional advantage in terms of innovation performance compared to not collaborating with universities and not having R&D department in all cases except for collaborations entailing both a formal and an informal component (*YesBoth_NoR&D)*.

Finally, the control variables are consistent across the four models. Older companies have greater ability to introduce technological or non-technological innovations to the market than younger companies (*Ln_Age)*. Interestingly, size, export propensity, industry specialization, and location within an industrial district were not found to influence the a firm's innovation performance. However, access to public funds (*Pub_funds)* was found to be positively associated with higher levels of innovativeness.

5 Discussion and conclusions

The objective of this paper is to contribute to filling a research gap in the vast literature on UICs by focusing on the cases when the industry partner is an SME and the collaboration is analyzed in terms of its contribution to a company's innovation performance. Consideration was given to the fact that a UIC can develop in either a formal or informal manner or can take both forms. We also considered that the presence of an internal R&D structure in a company can influence the relationship between a UIC and innovation performance. We addressed our research question using the Veneto region in Italy as an empirical setting and its manufacturing firms as the units of analysis. This allowed us to shed light on the outcome of collaborations between SMEs and universities in a context where firms that do not operate within a high-tech sector can pursue innovations through UICs and where many firms do engage in such interactions.

5.1 Summary and discussion of the results

In general, we found that engagement in UICs had a positive impact on the innovation performance of SMEs. This result is in line with the findings in the extant literature on UICs and further supports what has been reported about SMEs. More interestingly, our results reveal the importance of informal UICs and absorptive capacity for the innovation performance of SMEs. In this respect, this analysis, which combines quantitative and qualitative research methods, adds to previous research on the topic in two main directions.

First, for SMEs targeting universities, the informal dimension of the relationship is of considerable importance: informal collaborations have a positive influence on innovation performance even in the absence of formal collaboration. However, formal collaborations that are not accompanied by an informal relationship do not influence innovation performance. Informal collaborations with universities do not limit the innovativeness of firms but are rather perceived as more effective for achieving positive outcomes.

Second, the presence of an R&D structure and, therefore, of an adequate and structured absorptive capacity is a distinctive feature of innovative SMEs embedded in regional innovation systems that lack strong interaction between knowledge institutions and firms (De Marchi and Grandinetti 2017). This variable has a positive effect on innovation

performance as it moderates the effects of formal or informal collaborations with universities. It also has a positive influence on innovation performance in the absence of collaboration.

To give proper weight to this second set of results, it is useful to recall some descriptive data (Table 2). The share of the surveyed SMEs that had an internal R&D structure (33.9%) was about twice that of those that supported innovation by collaborating with universities (17.7%). In addition, the R&D departments of the companies tended to be small (an average of 2.9 company employees work there). We can then explain the innovation paradox related to the Veneto region, where, while the statistics report a substantial absence of R&D activities, there are many SMEs in this region that manage to be innovative, thanks to their commitment to R&D, also outside the boundary of an ùr6d department. This important aspect tends to disappear in the relationship between R&D expenditure in the business sector (which includes large companies) and regional GDP, the most widely used of regional innovation measures. Further research should address how the innovation efforts of SMEs can be more effectively measured in the light of this evidence.

5.2 Implications for theory

The first result is consistent with the findings of other studies that have shown how reductive it can be to consider UICs solely as formal arrangements (e.g., Grimpe and Hussinger 2013; Perkmann et al. 2013; Ankrah and Al-Tabbaa 2015). With respect to this extant literature, which does not consider a firm's size, our paper adds the finding that informal relationships are particularly important for SMEs, especially those that specialize in low-and medium-tech industries, which is the case in our sample. Indeed, informal cooperation is more frequent than formal cooperation, and the impact of such informal collaboration on innovation performance emerges clearly, regardless of the presence or absence of a formal relationship. The former situation indicates a complementarity between the two channels, whereby informal interaction coexists with and integrates what is codified - especially with regard to tacit, sticky components of knowledge—in the formal relationship. The more a firm engages in both formal and informal interactions with professors and departments, the better its ability to leverage their knowledge to realize effective innovations. This effect is no different from the effect that Grimpe and Hussinger (2013) found in their sample of German manufacturing companies. However, their sample was not limited to SMEs and had a sectorial composition whose average technological intensity was certainly higher than that of the Veneto manufacturing sector. The latter situation, where a formal relationship is absent, indicates a positive association (albeit a weaker one) between informal collaboration and innovation performance, which Grimpe and Husinger's study did not detect. Informal collaboration with a university does not limit the innovativeness of a firm; rather, it is perceived as a more effective way of improving innovation performance. For example, drawing on the case studies that have enriched our quantitative analysis, we can think of employees of a small company engaged in an innovation project to develop a new product. They encounter a problem regarding the possibility of using a certain material and turn to a university researcher or research team with the knowledge and skills to solve that problem. The probability that this ad hoc UIC follows a purely informal path is relatively high. Interestingly, formal collaboration alone has a considerable probability of proving unproductive. Here again, our results coincide with those of Grimpe and Hussinger (2013), who report that it is not enough for a company to sign an agreement with a university or department or to participate in a European-funded project to enable "the UIC tree to produce edible fruits".

With regard to the second result, concerning the link between R&D and innovation, the moderating effect of R&D on the innovation performance of companies that collaborated with universities is clear. This is as expected and is suggested in a study by Kobarg et al. (2018). This moderating effect, which emerges for all types of collaborations (formal and informal) listed in Table 1, confirms the need to supplement the knowledge transfer between universities and industry with appropriate structures devoted to enhancing the absorptive capacity of SMEs. The coupling of formal collaborations and absorptive capacity, which is a necessary condition for turning a formal collaboration into an innovative output, is of particular interest as it indicates that when a company lacks absorptive capacity, a contract signed with a university department will not generate useful results. Equally notable is the moderating effect of absorptive capacity in the case of informal UICs. Finally, the interplay between formal and informal relationships appears to overcome limitations resulting from the absence of an R&D department. While these results should be interpreted with caution, considering the low number of observations, they point to interesting avenues for future research. Such research could address why and the extent to which engaging simultaneously in formal and informal UICs might compensate for the absence of an internal R&D department. The role of internships could be an interesting topic for study, as students can play the role of additional internal employees with strong connections to a university. Interactions with the university can be strengthened by the knowledge proximity between the students and their university professors.

This outcome sheds further light on the role of informal UICs and causes us to rethink the idea, frequently found in the literature on the geography of innovation, that internal R&D and formal collaboration with external research structures are two sides of the same coin, that of analytical knowledge (Asheim and Coenen 2005). The image that emerges from our research is different, at least for the case of SMEs active in medium- and low-tech sectors. We find that both formal and informal relationships between corporate R&D departments and university departments have positive effects on the innovation performance of companies. Combined, our results provide clear evidence that collaboration with universities alone might not be enough to improve innovation performance: the joint presence of a structured internal R&D department internal is necessary to achieve a positive outcome. The results might be also interpreted in terms of the theory of absorptive capacity, according to which firms must be equipped with personnel able to interpret and adapt the knowledge provided by universities to effectively transform this knowledge into valuable and marketable solutions.

It is interesting to note that R&D is positively related to innovation performance, even in the absence of any collaboration with a university. In the above example of a small company that encounters a problem in the course of its new product development, the company can address the problem by drawing on the knowledge and skills at its disposal (its internal R&D) or by interacting with other firms, including providers of knowledge-intensive business services, which is a service sector with a wide presence in the region we address in this study (Bettiol et al. 2013).

5.3 Implications for practitioners and policy-makers

The results of our survey of manufacturing SMEs in Veneto can offer interesting insights for other regional contexts. Veneto is a region with an important manufacturing base. It has a low number of large companies, and its main focus is on low-tech (furniture, fashion, food, and beverage, etc.) and medium-tech (quality mechanical components, machine tools) sectors. These characteristics are shared by many other European regions, which can

be classified as "moderate" innovator regions, according to the Regional Innovation Scoreboard. Nevertheless, the Veneto region shows a high capability to produce innovation outputs, similar in value to those of the top-ranking European regions. Regarding this point, our results have two important implications.

The first is that the activities of small companies with small R&D departments show that the "innovation without research" model can be effective (Colombo and Lanzavecchia 1997). The results of our analysis indicate that SMEs do conduct internal R&D activities but that they often remain invisible if read through the lenses of the dominant paradigm. The problem is how to help companies without R&D departments to start investing in such activities through appropriate policies that promote innovation. To capture the value of UICs, policy interventions should be directed at fostering the establishment of R&D departments, which might increase the absorptive capacity of SMEs. To stimulate this process, companies should enlarge their boards of directors to include members of the scientific community and other external stakeholders who might bridge the gap between science and industry. On the other side, from the point of view of innovation policy, companies might benefit from certification of their innovative efforts, which should not be limited to simply counting patents. Strategic orientation, human resources composition, learning-on-the-job practices, and participation in regional and European funding programs are innovation strategies that could be considered in the development of certification for SMEs, for which quality or B-Corp certifications could be used as a model. Such certification could signal the orientation of the company for potential investors, suppliers, and clients and initiate a positive gain spiral of resources, collaborations, and innovation performance. These strategies are surely not only relevant for the Veneto region but might be extended to other regions with the same features.

The second point is that while UICs should undoubtedly be more widely practiced, the question of which type of UIC to engage in bears consideration. The importance of the informal dimension of such collaborations, which emerged in our research, leads us to question how the enterprises in our sample succeeded in identifying the right person in the university to approach to solve their technical problems or to work with on new product development and how such relationships are established. The cases in this study reveal that the answer lies in the company's social capital. However, these relationships are not widespread. If the situation does not change, there will inevitably remain many SMEs that, even though they may recognize the need for university collaboration, will not be able to tap into the academic competence provided by a UIC, which will be detrimental to the UIC process. This remains an urgent topic faced by policy-makers and university managers. Resolving this issue requires thinking beyond existing practices and schemes, such as those associated with technology transfer offices. In practice, the latter structures have proven not to be the solution for all types of UICs and all types of firms as they may lack the ability to engage SMEs in the process.

Possible ways forward could be the organization of events to connect members of universities and research centers with corporate representatives and the promotion of networking and team-building activities. Moreover, the links between universities and industry might be stimulated by promoting activities launched by university alumni associations as opportunities to create vibrant communities of scholars and practitioners. New forms of collaboration might be exploited, such as those related to private–public partnerships, which are extremely rare in Italy despite the fact that they offer opportunities to generate convergence between public and private goals. Again, these suggestions do not apply to the Veneto region alone. The importance of monitoring all these initiatives by developing

indicators that track progress in the field of innovation policy and facilitate the evaluation of established policy measures should also be noted.

Our results can be used to inform managers about the importance of planning a UIC strategy that fits the needs of a company. There is no one-size-fits-all solution to improving the innovation performance of SMEs through collaborations with universities. Strategies should be shaped differently depending on whether the firm an R&D department or not and should be planned in accordance with the evolution of the relationship over time. There might be differences in the types of support required by the company, and initial informal contact with university researchers (for instance at a special event organized by the university) might be the best way to co-design a solution for the specific problem the company wants to solve. Human resource managers should be willing to recruit university graduates through special programs implemented by universities, which might include hiring young graduates after a period of internship, which might be planned in the phase of thesis development. This might give firms opportunities to engage in fruitful collaborations with university professors and use the technologies and infrastructures of the university to experiment with new technological solutions. Similarly, firms might support corporate researchers' participation in PhD programs or partner with the universities through ad hoc master programs.

5.4 Limitations and future research trajectories

This study has certain limitations, the first of which is related to the fact that our sample of firms is geographically bounded. Even though the Veneto region offers an ideal empirical environment to test our hypotheses, covering other Italian and European regions might improve our understanding of the issues tackled in this paper and support the generalization of the results. The second limitation concerns the dependent variable used to capture innovation performance. This variable is self-reported—which is the case for many of the variables adapted from the CIS and used in empirical studies on innovation—and is a newly developed proxy. Therefore, caveats should be considered when comparing the results with those in the existing literature. The third limitation is the relatively short period of time considered. It might be interesting to evaluate the effect of UICs over different time periods and adopt a longitudinal perspective on the impact of UICs on the innovativeness of SMEs.

Nevertheless, given the scarcity of previous empirical investigations of the role of formal and informal UICs in fostering innovation among SMEs, our results provide some interesting cues for further theoretical and empirical studies on this subject and on the complementarity between internal innovation activities and external collaborations as a critical aspect of innovation performance. We encourage further investigations into the relationship between different forms of UICs and the innovation performance of SMEs and evaluations of different types of policy interventions and university initiatives for fostering fruitful relationships.

Funding Funding was provided by Regione del Veneto.

Appendix

See Tables 5 and 6.

Table 5 Descriptions of variables

Type	Name	Description
Dependent Variable	Inno_perf	Sum of the declared innovation (0-7) of the four types of innovation (product, process, marketing, and organizational) in the period 2012–2014 (0–28)
Independent variable	UI_coll	Dummy, which equals 1 if the firm engaged in university–industry collaborations (UICs) in the period 2012–2014
	R&D	Dummy, which equals 1 if the firm had an R&D department in the period 2012–2014
	Formal_coll	Dummy, which equals 1 if the firm engaged in formal UICs in the period 2012–2014
	Informal_coll	Dummy, which equals 1 if the firm engaged in informal UICs in the period 2012–2014
	Both_coll	Dummy, which equals 1 if the firm engaged in both formal and informal UICs in the period 2012–2014
	YesColl_YesR&D	Dummy, which equals 1 if the firm engaged in UICs and had an R&D department in the period 2012–2014
	YesColl_NoR&D	Dummy, which equals 1 if the firm engaged in UICs and did not have an R&D department in the period 2012–2014
	NoColl_YesR&D	Dummy, which equals 1 if the firm did not engage in UICs and had an R&D department in the period 2012–2014
	NoColl_NoR&D	Dummy, which equals 1 if the firm did not engage in UICs and did not have an R&D department in the period 2012–2014
	YesForm_YesR&D	Dummy, which equals 1 if the firm engaged in formal UICs and had an R&D department in the period 2012–2014
	YesForm_NoR&D	Dummy, which equals 1 if the firm engaged in formal UICs and did not have an R&D department in the period 2012–2014
	YesInform_YesR&D	Dummy equals 1 if the firm engaged in Informal UICs and had an R&D department in the period 2012-2014
	YesInform_NoR&D	Dummy equals 1 if the firm engaged in Informal UICs and had not an R&D department in the period 2012-2014
	YesBoth_YesR&D	Dummy, which equals 1 if the firm engaged in both formal and informal UICs and had an R&D department in the period 2012–2014
	YesBoth_NoR&D	Dummy, which equals 1 if the firm engaged in both formal and informal UICs and did not have an R&D department in the period 2012–2014
Control variables	Ln_age	Number of years from the firm's establishment to 2014 (natural logarithm)
	Size	Number of employees in 2014

Table 5 (continued)

Type	Name	Description
	Pub_funds	Dummy, which equals 1 if the firm had access to public funds (regional, national, or European) in the period 2012–2014
	Export	Dummy, which equals 1 if the export on turnover in 2014 was greater than zero
	Districts	Dummy, which equals 1 if the firm was located in a local labor system characterized by a district specialization and specialized in that same industry specialization
	Low-tech	Dummy, which equals 1 if the firm specialized in one of the industries classified by Nace Rev. 2 Codes 10–18, 21, and 32
	Med-low tech	Dummy, which equals 1 if the firm specialized in one the industries classified by Nace Rev. 2 Codes 19, 22–25, and 33
	Med-high tech	Dummy, which equals 1 if the firm specialized in one of the industries classified by Nace Rev. 2 Codes 20, 21, and 26–30

Table 6 Correlation matrix

	Inno_perf	UI-coll	R&D	Formal_coll	Informal_coll	Both_coll	Age	Size	Pub_funds	Export	Low tech	Med-low tech	High tech	District
Inno_perf	1													
UI-coll	0.294	1												
	0.000													
R&D	0.364	0.111	1											
	0.000	0.146												
Formal_coll	0.060	0.586	0.045	1										
	0.426	0.000	0.559											
Informal_coll	0.241	0.637	0.056	− 0.078	1									
	0.001	0.000	0.464	0.300										
Both_coll	0.193	0.371	0.095	− 0.045	-0.049	1								
	0.010	0.000	0.213	0.547	0.513									
Age	0.210	0.124	− 0.143	− 0.054	0.200	0.041	1							
	0.005	0.098	0.060	0.470	0.007	0.582								
Size	0.124	0.059	0.385	0.083	− 0.046	0.085	0.114	1						
	0.096	0.435	0.000	0.271	0.537	0.257	0.128							
Pub_funds	0.301	0.387	0.132	0.250	0.263	0.081	0.008	0.177	1					
	0.000	0.000	0.082	0.001	0.000	0.278	0.916	0.017						
Export	0.123	0.161	0.157	0.118	0.072	0.075	0.017	0.120	0.112	1				
	0.100	0.031	0.039	0.116	0.341	0.321	0.821	0.110	0.135					
Low tech	− 0.013	− 0.167	− 0.034	− 0.095	− 0.073	− 0.120	0.126	− 0.027	− 0.097	− 0.176	1			
	0.859	0.026	0.653	0.207	0.328	0.110	0.093	0.722	0.194	0.019				
Med-low tech	− 0.136	− 0.097	− 0.134	− 0.125	− 0.022	0.002	− 0.090	− 0.059	− 0.073	0.016	− 0.571	1		
	0.069	0.194	0.078	0.096	0.768	0.980	0.230	0.434	0.330	0.836	0.000			
High tech	0.163	0.283	0.183	0.237	0.102	0.125	− 0.035	0.093	0.183	0.168	− 0.433	− 0.494	1	
	0.029	0.000	0.016	0.001	0.173	0.096	0.646	0.216	0.014	0.025	0.000	0.000		
District	− 0.103	− 0.104	− 0.029	− 0.047	− 0.060	− 0.070	− 0.126	− 0.100	0.026	− 0.034	− 0.022	0.218	− 0.216	1
	0.169	0.166	0.708	0.536	0.421	0.354	0.091	0.182	0.733	0.652	0.766	0.003	0.004	

References

Acs, Z. J., & Audretsch, D. B. (1988). Innovation in large and small firms: An empirical analysis. *American Economic Review, 78*(4), 678–690.

Ankrah, S., & Al-Tabbaa, O. (2015). Universities–industry collaboration: A systematic review. *Scandinavian Journal of Management, 31*(3), 387–408.

Antonioli, D., Mancinelli, D., & Mazzanti, M. (2013). Is environmental innovation embedded within high-performance organisational changes? The role of human resource management and complementarity in green business strategies. *Research Policy, 42*(4), 975–988.

Archibugi, D., & Planta, M. (1996). Measuring technological change through patents and innovation surveys. *Technovation, 16*(9), 451–519.

Asheim, B. T., & Coenen, L. (2005). Knowledge bases and regional innovation systems: Comparing Nordic clusters. *Research Policy, 34*(8), 1173–1190.

Audretsch, D. B. (2004). Sustaining innovation and growth: Public policy support for entrepreneurship. *Industry and Innovation, 11*(3), 167–191.

Baba, Y., Shichijo, N., & Sedita, S. R. (2009). How do collaborations with universities affect firms' innovative performance? The role of "Pasteur scientists" in the advanced materials field. *Research Policy, 38*(5), 756–764.

Becattini, G. (1990). The Marshallian industrial district as a socio-economic notion. In F. Pyke, G. Becattini, & W. Sengenberger (Eds.), *Industrial districts and inter-firm co-operation in Italy* (pp. 37–51). Geneva: International Institute for Labour Studies.

Bellandi, M. (1996). Innovation and change in the Marshallian industrial districts. *European Planning Studies, 4*(3), 357–368.

Belussi, F., & Gottardi, G. (2000). Models of localised technological change. In F. Belussi & G. Gottardi (Eds.), *Evolutionary patterns of local industrial systems* (pp. 13–48). Aldershot: Ashgate.

Belussi, F., & Sammarra, A. (Eds.). (2009). *Business networks in clusters and industrial districts: The governance of the global value chain*. New York: Routledge.

Belussi, F., & Sedita, S. R. (2012). Industrial districts as open learning systems: Combining emergent and deliberate knowledge structures. *Regional Studies, 46*(2), 165–184.

Belussi, F., Sedita, S. R., Aage, T., & Porcellato, D. (2011). Inward flows of information and knowledge in low-tech industrial districts: Contrasting the "few firms gatekeeper" and "direct peer" models. In P. Robertson & D. Jacobson (Eds.), *Knowledge transfer and technology diffusion* (pp. 64–89). Cheltenham: Edward Elgar.

Bettiol, M., De Marchi, V., Di Maria, E., & Grandinetti, R. (2013). Determinants of market extension in knowledge-intensive business services: Evidence from a regional innovation system. *European Planning Studies, 21*(4), 498–515.

Bodas Freitas, I. M., Marques, R. A., & de Paula e Silva, E. M. (2013). University–industry collaboration and innovation in emergent and mature industries in new industrialized countries. *Research Policy, 42*(2), 443–453.

Boix, R., & Galletto, V. (2009). Innovation and industrial districts: a first approach to the measurement and determinants of the I-district effect. *Regional Studies, 43*(9), 1117–1133.

Bonaccorsi, A., & Piccaluga, A. (1994). A theoretical framework for the evaluation of university-industry relationships. *R&D Management, 24*(3), 229–247.

Bougrain, F., & Haudeville, B. (2002). Innovation, collaboration and SMEs internal research capacities. *Research Policy, 31*(5), 735–747.

Bryman, A. (2015). *Social Research Methods*. Oxford: Oxford University Press.

Brynjolfsson, E., Hitt, L., & Yang, S. (2002). Intangible assets: Computers and organizational capital. *Brookings Papers on Economic activity: Macroeconomics, 1,* 137–181.

Cainelli, G., & De Liso, N. (2005). Innovation in industrial districts: Evidence from Italy. *Industry and Innovation, 12*(3), 383–398.

Cakar, N. D., & Erturk, A. (2010). Comparing innovation capability of small and medium-sized enterprises : Examining the effects of organizational culture. *Journal of Small Business Management, 48*(3), 325–359.

Caloghirou, Y., Tsakanikas, A., & Vonortas, N. S. (2001). University-industry cooperation in the context of the European framework programmes. *The Journal of Technology Transfer, 26*(1–2), 153–161.

Cameron, A. C., & Trivedi, P. K. (2009). *Microeconometrics: Methods and applications*. Cambridge: Cambridge University Press.

Camuffo, A., & Grandinetti, R. (2011). Italian industrial districts as cognitive systems: Are they still reproducible? *Entrepreneurship & Regional Development, 23*(9–10), 815–852.

Cassiman, B., Di Guardo, M. C., & Valentini, G. (2010). Organizing links with science: Cooperate or contract? *A project-level analysis. Research Policy, 39*(7), 882–892.
Cassiman, B., & Veugelers, R. (2002). R&D cooperation and spillovers: Some empirical evidence from Belgium. *American Economic Review, 92*(4), 1169–1184.
Cohen, W. L., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly, 35*(1), 128–152.
Colombo, U., & Lanzavecchia, G. (1997). Science and technology in Italian industry: A unique model. *Technology in Society, 19*(3–4), 467–491.
Coltorti, F., Resciniti, R., Tunisini, A., & Varaldo, R. (Eds.). (2013). *Mid-sized manufacturing companies: The new driver of Italian competitiveness*. Milan: Springer-Verlag Italia.
Cooke, P., Boekholt, P., & Tödtling, F. (2000). *The governance of innovation in Europe: Regional perspectives on global competitiveness*. London: Pinter.
Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika, 16*(3), 297–334.
De Marchi, V., Gereffi, G., & Grandinetti, R. (2018). Evolutionary trajectories of industrial districts in global value chains. In V. De Marchi, E. Di Maria, & G. Gereffi (Eds.), *Local clusters in global value chains: Linking actors and territories through manufacturing and innovation* (pp. 33–50). Abingdon: Routledge.
De Marchi, V., & Grandinetti, R. (2017). Regional innovation systems or innovative regions? evidence from Italy. *Tijdschrift voor Economische en Sociale Geografie, 108*(2), 234–249.
Dess, G. G., & Shaw, J. D. (2001). Voluntary turnover, social capital, and organizational performance. *Academy of Management Review, 26*(3), 446–456.
Ding, C. S., Wu, Q., Hsieh, C. T., & Pedram, M. (1998). Stratified random sampling for power estimation. *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems, 17*(6), 465–471.
Dornbusch, F., & Neuhäusler, P. (2015). Composition of inventor teams and technological progress: The role of collaboration between academia and industry. *Research Policy, 44*(7), 1360–1375.
Ebersberger, B., Bloch, C., Herstad, S. J., & van de Velde, E. (2012a). Open innovation practices and their effect on innovation performance. *International Journal of Innovation and Technology Management, 9*(6), 1–22.
Ebersberger, B., Bloch, C., Herstad, S. J., & Van De Velde, E. L. S. (2012b). Open innovation practices and their effect on innovation performance. *International Journal of Innovation and Technology Management, 9*(06), 1250040.
Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. *Research Policy*, *29*(2), 109–123.
Fontana, R., Geuna, A., & Matt, M. (2006). Factors affecting university–industry RD projects: The importance of searching, screening and signalling. *Research Policy*, *35*(2), 309–323.
Frederiksen, L., & Sedita, S. R. (2012). Embodied knowledge transfer for innovation: Comparing interfirm labor mobility between music and manufacturing industries. In F. Belussi & U. Staber (Eds.), *Managing networks of creativity* (pp. 121–143). New York: Routledge.
Garcia-Perez-de-Lema, D., Madrid-Guijarro, A., & Martin, D. P. (2017). Influence of university-firm governance on SMEs innovation and performance levels. *Technological Forecasting and Social Change, 123,* 250–261.
Garriga, H., Von Krogh, G., & Spaeth, S. (2013). How constraints and knowledge impact open innovation. *Strategic Management Journal, 34*(9), 1134–1144.
Gilsing, V., & Nooteboom, B. (2005). Density and strength of ties in innovation networks: an analysis of multimedia and biotechnology. *European Management Review, 2*(3), 179–197.
Grandinetti, R. (2016). Absorptive capacity and knowledge management in small and medium enterprises. *Knowledge Management Research & Practice, 14*(2), 159–168.
Grimpe, C., & Hussinger, K. (2013). Formal and informal knowledge and technology transfer from academia to industry: Complementarity effects and innovation performance. *Industry and Innovation, 20*(8), 683–700.
Hewitt-Dundas, N. (2013). The role of proximity in university-business cooperation for innovation. *The Journal of Technology Transfer, 38*(2), 93–115.
Hewitt-Dundas, N., & Roper, S. (2010). Output additionality of public support for innovation: Evidence for Irish manufacturing plants. *European Planning Studies, 18*(1), 107–122.
Huergo, E., & Jaumandreu, J. (2004). How does probability of innovation change with firm age? *Small Business Economics, 22*(3–4), 193–207.
Jensen, M. B., Johnson, B., Lorenz, E., & Lundvall, B. Å. (2007). Forms of knowledge and modes of innovation. *Research Policy, 36*(5), 680–693.
Jick, T. D. (1979). Mixing qualitative and quantitative methods: Triangulation in action. *Administrative Science Quarterly, 24*(4), 602–611.

Jiménez-Barrionuevo, M. M., García-Morales, V. J., & Molina, L. M. (2011). Validation of an instrument to measure absorptive capacity. *Technovation, 31*(5–6), 190–202.
Jones, J., & Corral de Zubielqui, G. (2017). Doing well by doing good: A study of university-industry interactions, innovationess and firm performance in sustainability-oriented Australian SMEs. *Technological Forecasting and Social Change, 123,* 262–270.
Kanter, R. B. (1994). Collaborative advantage: The art of alliances. *Harvard Business Review, 72*(4), 96–108.
Kitagawa, F., & Woolgar, L. (2008). Regionalisation of innovation policies and new university–industry links in Japan: Policy review and new trends. *Prometheus, 26*(1), 55–67.
Kobarg, S., Stumpf-Wollersheim, J., & Welpe, I. M. (2018). University-industry collaborations and product innovation performance: The moderating effects of absorptive capacity and innovation competencies. *The Journal of Technology Transfer, 43*(6), 1696–1724.
Lasagni, A. (2012). How can external relationships enhance innovation in SMEs? new evidence for Europe. *Journal of Small Business Management, 50*(2), 310–339.
Laursen, K., & Foss, N. J. (2003). New human resources management practices, complementarities and the impact on innovation performance. *Cambridge Journal of Economics, 27*(2), 243–263.
Laursen, K., & Salter, A. (2006). Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms. *Strategic Management Journal, 27*(2), 131–150.
Lazzarotti, V., Manzini, R., & Pellegrini, L. (2015). Is your open-innovation successful? The mediating role of a firm's organizational and social context. *International Journal of Human Resource Management, 26*(19), 2453–2485.
Liao, J., Welsch, H., & Stoica, M. (2003). Organizational absorptive capacity and responsiveness: An empirical investigation of growth-oriented SMEs. *Entrepreneurship Theory and Practice, 28*(1), 63–86.
Love, J. H., & Ganotakis, P. (2013). Learning by exporting: Lessons from high-technology SMEs. *International Business Review, 22*(1), 1–17.
Love, J. H., & Roper, S. (2015). SME innovation, exporting and growth: A review of existing evidence. *International Small Business Journal, 33*(1), 28–48.
March, J. (1991). Exploration and exploitation in organizational learning. *Organization Science, 2,* 101–123.
Mathison, S. (1988). Why triangulate? *Educational Research, 17*(2), 13–17.
Messeni Petruzzelli, A. M. (2011). The impact of technological relatedness, prior ties, and geographical distance on university–industry collaborations: A joint-patent analysis. *Technovation, 31*(7), 309–319.
Messeni Petruzzelli, A., & Rotolo, D. (2015). Institutional diversity, internal search behaviour, and joint-innovations: Evidence from the US biotechnology industry. *Management Decision, 53*(9), 2088–2106.
Mitsuhashi, H. (2002). Uncertainty in selecting alliance partners: The three reduction mechanisms and alliance formation processes. *International Journal of Organizational Analysis, 10*(2), 109–133.
Mohnen, P., & Hoareau, C. (2003). What type of enterprise forges close links with universities and government labs? evidence from CIS 2. *Managerial and Decision Economics, 24*(2–3), 133–145.
Mohnen, P., & Röller, L. H. (2005). Complementarities in innovation policy. *European Economic Review, 49*(6), 1431–1450.
Moncada-Paternò-Castello, P., Ciupagea, C., & Piccaluga, A. (2006). L'innovazione industriale in Italia: persiste il modello "senza ricerca"? *L'industria, 27*(3), 533–552.
Motohashi, K. (2005). University–industry collaborations in Japan: The role of new technology-based firms in transforming the National Innovation System. *Research Policy, 34*(5), 583–594.
Muscio, A. (2007). The impact of absorptive capacity on SMEs' collaboration. *Economics of Innovation and New Technology, 16*(8), 653–668.
Narula, R. (2004). R&D collaboration by SMEs: New opportunities and limitations in the face of globalisation. *Technovation, 24*(2), 153–161.
Nooteboom, B. (2007). Social capital, institutions and trust. *Review of Social Economy, 65*(1), 29–53.
Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory*. New York: McGraw-Hill.
Oughton, C., Landabaso, M., & Morgan, K. (2002). The regional innovation paradox: Innovation policy and industrial policy. *The Journal of Technology Transfer, 27*(1), 97–110.
Paoli, M., & Prencipe, A. (1999). The role of knowledge bases in complex product systems: Some empirical evidence from the aero engine industry. *Journal of Management and Governance, 3*(2), 137–160.
Patel, P., & Pavitt, K. (1994). The continuing, widespread (and neglected) importance of improvements in mechanical technologies. *Research Policy, 23*(5), 533–545.

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.

Rajalo, S., & Vadi, M. (2017). University-industry innovation collaboration: Reconceptualization. *Technovation, 62–63,* 42–54.

Reischauer, G. (2018). Industry 4.0 as policy-driven discourse to institutionalize innovation systems in manufacturing. *Technological Forecasting and Social Change*. https://doi.org/10.1016/j.techfore.2018.02.012.

Rõigas, K., Mohnen, P., & Varblane, U. (2018). Which firms use universities as cooperation partners? a comparative view in Europe. *International Journal of Technology Management, 76*(1–2), 32–57.

Salomon, R. M., & Shaver, J. M. (2005). Learning by exporting: New insights from examining firm innovation. *Journal of Economics & Management Strategy, 14*(2), 431–460.

Schmiedeberg, C. (2008). Complementarities of innovation activities: An empirical analysis of the German manufacturing sector. *Research Policy, 37*(9), 1492–1503.

Sedita, S. R., De Noni, I., & Pilotti, L. (2017). Out of the crisis: An empirical investigation of place-specific determinants of economic resilience. *European Planning Studies, 25*(2), 155–180.

Sirmon, D., Hitt, M. A., & Ireland, R. (2007). Managing firm resources in dynamic environments to create value: Looking inside the black box. *Academy of Management Review, 32*(1), 273–292.

Smith, K.H. (2005). Measuring innovation. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), The Oxford Handbook of Innovation (pp. 148–177) New York, US: Oxford University Press.

Spithoven, A., Clarysse, B., & Knockaert, M. (2010). Building absorptive capacity to organise inbound open innovation in traditional industries. *Technovation, 30*(2), 130–141.

Subramanian, A. M., Lim, K., & Soh, P. H. (2013). When birds of a feather don't flock together: Different scientists and the roles they play in biotech R&D alliances. *Research Policy, 42*(3), 595–612.

Tijssen, R. J. (2018). Anatomy of use-inspired researchers: From Pasteur's Quadrant to Pasteur's Cube model. *Research Policy, 47*(9), 1626–1638.

Veugelers, R. (1997). Internal R&D expenditures and external technology sourcing. *Research Policy, 26*(3), 303–315.

Walsh, J. P., Baba, Y., Goto, A., & Yasaki, Y. (2008). Promoting university–industry linkages in Japan: Faculty responses to a changing policy environment. *Prometheus, 26*(1), 39–54.

Wiersema, M. F., & Bowen, H. P. (2009). The use of limited dependent variable techniques in strategy research: Issues and methods. *Strategic Management Journal, 30*(6), 679–692.

Zahra, S. A., & George, G. (2002). Absorptive capacity: a review, reconceptualization, and extension. *Academy of Management Review, 27*(2), 185–203.

Zucker, L. G., & Darby, M. R. (1996). Star scientists and institutional transformation: Patterns of invention and innovation in the formation of the biotechnology industry. *Proceedings of the National Academy of Sciences*, *93*(23), 12709–12716.