CIRCLE

LUND UNIVERSITY

International knowledge flows between industry inventors and universities: The role of multinational companies

Claudio Fassio (claudio.fassio@fek.lu.se)
Department of Business Administration and CIRCLE, Lund University, Sweden
Aldo Geuna (aldo.geuna@unito.it)
Department of Economics and Statistics, University of Torino, Italy
Federica Rossi (f.rossi@bbk.ac.uk)
School of Business, Economics and Informatics, University of London, UK

Papers in Innovation Studies
Paper no. 2019/13

This is a pre-print version of paper, which has been submitted to a journal.

Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE)

Lund University

P.O. Box 117, Sölvegatan 16, S-221 00 Lund, SWEDEN

http://www.circle.lu.se/publications

WP 2019/13

International knowledge flows between industry inventors and universities: The role of multinational companies

Claudio Fassio, Aldo Geuna, Federica Rossi

Abstract: We investigate the determinants of industry researchers' interactions with universities in different localities, distinguishing between local and international universities. We analyze the extent to which local and international interactions are enabled by different types of individual personal networks (education, career based), and by their access to different business networks through their employer companies (local vs. domestic or international multinational company networks). We control for selection bias and numerous other individual and firm-level factors identified in the literature as important determinants of interaction with universities. Our findings suggest that industry researchers' personal networks play a greater role in promoting interactions with local universities (i.e. in the same region, and other regions in the same country) while researcher employment in a multinational is especially important for establishing interaction with universities abroad.

Keywords: University-industry interaction; international knowledge flows; MNEs; social network; education network; career network

JEL Classification: F23; I23; L24; O31

International knowledge flows between industry inventors and universities: The role of multinational companies

Claudio Fassio[1]
Department of Business Administration & CIRCLE, University of Lund

Aldo Geuna[2]
Department of Economics and Statistics Cognetti De Martiis, University of Torino
BRICK, Collegio Carlo Alberto

Federica Rossi[3]
School of Business, Economics and Informatics, Birkbeck College, University of London

Acknowledgements:

The authors are grateful to Francesco Lissoni for the access to the EP-INV database produced by CRIOS-Bocconi. We thank Guido Romano and Andrea Gavosto for the access to CERVED data, Paolo Checchelli for his contribution in the creation of the PIEMINV database and Carlo Bottai for companies' analysis and patenting data collection. We are grateful for financial support from: the IAMAT Project coordinated by Fondazione Rosselli; the European Union (FP7) Project "An Observatorium for Science in Society based in Social Models – SISOB" Contract no.: FP7 266588; and the RENIR/AIR project financed by the Compagnia di San Paolo.

Abstract

We investigate the determinants of industry researchers' interactions with universities in different localities, distinguishing between local and international universities. We analyze the extent to which local and international interactions are enabled by different types of individual personal networks (education, career based), and by their access to different business networks through their employer companies (local vs. domestic or international multinational company networks). We control for selection bias and numerous other individual and firm-level factors identified in the literature as important determinants of interaction with universities. Our findings suggest that industry

[1] Department of Business Administration, University of Lund, Scheelevägen 15 B 223 63, Lund, Sweden; email: claudio.fassio@fek.lu.se

[2] Department of Economics and Statistics Cognetti De Martiis, University of Torino, Lungo Dora Siena 100 A - 10153 Torino, Italy; BRICK, Collegio Carlo Alberto; Tel: +39 0116703891, Fax: +39 0116703895; email: aldo.geuna@unito.it

[3] Department of Management, School of Business, Economics and Informatics, Birkbeck, University of London, Malet Street, London WC1E 7HX, UK, Tel. +44 2070790685; email: f.rossi@bbk.ac.uk

researchers' personal networks play a greater role in promoting interactions with local universities (i.e. in the same region, and other regions in the same country) while researcher employment in a multinational is especially important for establishing interaction with universities abroad.

Keywords: University-industry interaction, international knowledge flows, MNEs, social network, education network, career network

JEL Classification: F23; I23; L24; O31;

1. Introduction

The rapid pace of technological change combined with the increasing technology complexity are among the factors driving firms' increasing reliance on external sources of knowledge for their innovation processes (Auerswald et al., 2005; Chesbrough, 2006; Yusuf, 2008). The transition to more open innovation models is facilitated also by the fragmentation of value chains, the globalization of education and skills markets, and the increasing openness of academia and government to interactions with industry that are proving productive. Although universities are not the most frequent external knowledge source for firms (Cohen et al., 2002; Arundel and Geuna, 2004; Abreu et al., 2008), they are among the most *valuable* (Crescenzi et al., 2017; Messeni Petruzzelli, 2011) since interactions with universities allow firms to access a range of benefits including advanced knowledge, high level skills, state-of-the-art facilities, and wider scientific networks (Hughes and Martin, 2012).

This paper investigates the following: How do firms establish international collaborations with universities? How does this process differ from collaborations with local universities? We build on the innovation and economic geography literatures which focus on university-industry interactions, and also on the international business literature which analyzes how firms source and exchange knowledge internationally.

While there is a large body of the innovation and economic geography literatures which explore the presence of interactions between firms and local universities (Fritsch, 2001; D'Este and Iammarino, 2010; Laursen et al., 2011; Bouba-Olga et al., 2012), and the role of geographical distance as a mediating factor in university-industry interactions (Mansfield and Lee, 1996; Hanel and St-Pierre, 2006), research on what drives collaborations between firms and *distant* universities - particularly those beyond national borders (Rõigas et al., 2014; Muscio, 2012) is scarce. Those studies that exist so far emphasize that since collaborations with distant universities entail higher transaction costs than collaborations with local universities, they are likely to occur only when the benefits are particularly large; in fact, most firms consider distant collaborations to be more valuable (Weterings and Ponds, 2009). Collaborations with distant universities are more likely to occur when firms need to access frontier scientific knowledge that is not available locally (Fritsch and Schwirten, 1999; Asheim and Isaksen, 2002; Monjon and Waelbroeck, 2003; Asheim and Coenen, 2006), particularly from top ranked departments (Mansfield and Lee, 1996; D'Este and Iammarino, 2010).

At the same time, firms need high levels of absorptive capacity to be able to benefit from distant interactions (Laursen et al., 2011).

The international business literature focuses on how firms source knowledge internationally, especially if they belong to a multinational group. A distinctive feature of multinational enterprises (MNEs) is the ability of their subsidiaries to benefit from knowledge from distant locations, based on structured intra-firm knowledge transfer processes (Mudambi and Navarra, 2004; Castellani and Zanfei, 2006; Phene and Almeida, 2008) This is described in the literature as subsidiaries' "internal embeddedness" within the multinational group which refers to the overall integration of the innovation processes within a firm (Bartlett and Goshal, 1988)(Meyer et al., 2011; Figuereido, 2011). A key advantage obtained from being part of a MNE is the ability to transfer knowledge across borders which increases the overall connectedness of MNE subsidiaries (Jensen and Szulanski, 2004; Kotabe et al., 2007). However, there are no investigations of how MNEs affect their subsidiaries' access to international academic knowledge. We expect that the global reach provided by the MNE will affect its subsidiaries' access to international academic knowledge.

In this paper, we combine these literature streams to understand how firms establish international collaborations with distant universities. We propose that both individual and firm-level factors might influence the ability of firms to collaborate with universities more generally. Individual factors include the personal networks of employees involved in the innovation process. Existing work (Uzzi, 1996) shows that university-industry collaborations depend strongly on reciprocal trust. Trust is often built on individuals' personal interactions. Hence, the personal networks of the firm's employees - their networks of trusted collaborators – are important for reducing the search and screening costs involved in the establishment of collaborations. More specifically, we expect two types of personal networks to play a role in this context. One is the networks built by individuals throughout their education i.e. their personal relations with researchers who might be university teachers, or with fellow university students who go on to become academic researchers. The other main type of personal network is built after education during the individual's career. In the course of an individual's work career, the researcher will accumulate personal contacts made in his or her job positions. These can include academic researchers (from joint projects with universities) which could be useful for establishing future collaborations with both local and distant universities.

The firm level factors affecting the firm's overall capabilities include level of absorptive capacity, existence of already established relationships with specific academic institutions, and internal routines for searching for and screening local and international academic knowledge. In the context of establishing international academic relationships, being part of a MNE can increase the firm's ability to form international academic linkages because MNEs are specialized in promoting the transfer of relevant knowledge from one location to another (Jensen and Szulanski, 2004; Phene and Almeida, 2008). Also, MNE subsidiaries in different countries allows these firms to act as *bridging institutions* facilitating the creation of connections with universities which might be distant from a specific firm in the group but be close to another subsidiary or the MNE headquarters (Kelchtermans et al., 2017).

To investigate the role of individual and firm-level factors as facilitators of interactions with universities in different localities, we distinguish between universities in the same region, in another region in the same country, and abroad, and rely upon an original survey of university-industry relationships involving 915 industry inventors based in the Italian region of Piedmont. We analyze the extent to which interactions with universities in these different localities are enabled by different types of individual personal networks and firm-level factors, controlling for selection bias and numerous other (individual and firm-level) factors identified in the literature as important determinants of interactions with universities. Our findings show that personal networks provide channels for establishing academic collaborations but that the roles of education-based and career-based personal networks differ. In particular, we find education-based networks are important for local interactions. We find also that in the case of career-based personal networks, having a non-local network increases the probability of international collaboration with academic institutions. Last, we find a strong effect of being part of an MNE on the establishment of international collaborations which suggests that international university collaborations depend crucially on the existence of firm-level capabilities such as being part of a multinational group.

This paper is original in several respects. First, it is one of the few papers which focuses explicitly on the determinants of international collaborations between firms and universities. Many analyses of the role of geographical proximity for fostering university-industry collaboration use national data and do not examine international relationships. Among those works that consider geographic proximity, this tends to be measured on a continuous scale which does not consider international collaboration as a special category. However, it can be expected that compared to collaborations between firms and universities in the same country, international collabrrative efforts might encounter some additional barriers (language, cultural, institutional) and hence might involve higher transaction costs. A second novelty of the present paper is its focus on the perspectives of industry researchers. Most works focus on the factors that increase the likelihood of academics interacting with industry rather than the likelihood of industry researchers interacting with universities (e.g. D'Este and Patel, 2007; Bekkers and Bodas Freitas, 2008; Bercovitz and Feldman, 2008; Boardman and Ponomariov, 2009). The few studies that consider an industry perspective mostly use the firm as the unit of analysis, and do not investigate the role of the individual industry researcher involved in the innovation process (Rõigas et al., 2014; Crescenzi et al., 2017; Hong and Su, 2013). While individual characteristics are important for initiating university-industry collaborations (D'Este and Fontana, 2007; Giuliani et al., 2010), they are difficult to derive from secondary sources. Third, our paper is the first study to highlight the role of MNEs as drivers of collaborations with distant universities. The existing research on MNE knowledge transfer practices places great emphasis on understanding how knowledge created within the multinational group is transferred to different subsidiaries (Meyer et al., 2011; Nell and Ambos, 2013) but overlooks the ability of MNEs to transfer and spread external knowledge within their subsidiary networks.

2. Literature review and hypotheses

2.1. The importance of interactions between distant firms and universities

Geographical proximity is significant for facilitating university-industry collaborations. Firms are more likely to collaborate with geographically proximate universities for several reasons including easier transmission of tacit knowledge (Boschma, 2005; Salter and Martin, 2001; Storper and Venables 2004), greater trust favored by social proximity (Uzzi, 1996), easier communication due to common cultural norms (Balconi et al., 2004; D'Este et al., 2013), and institutional factors such as policies and funding which promote local cooperation (Hong and Su, 2013).

However, collaborating with distant universities including universities in other countries might also be important. Developing links with universities beyond the firm's home region can provide access to frontier knowledge not available locally (Fritsch and Schwirten, 1999; Asheim and Isaksen, 2002; Monjon and Waelbroeck, 2003; Asheim and Coenen, 2006) but valuable for the firm's innovation processes. The evidence suggests that compared to university-industry collaborations within national borders, international collaborations are more likely to focus on basic and cutting-edge research rather than applied research (Frame and Carpenter, 1979), R&D rather than business consulting and other social science-based knowledge transfer (Bodas Freitas et al., 2013a; Bouba-Olga et al., 2012), and long term R&D projects rather than projects with a short time to market (Broström, 2010), and are likely also to involve top ranked institutions (Mansfield and Lee, 1996; Adams, 2005; D'Este and Iammarino, 2010). Therefore, while much of the literature on the role of geographical proximity would seem to suggest that while all else being equal, many firms may prefer to work with local universities (Mansfield and Lee, 1996), there are advantages to be gained from interactions with distant universities if the firm is willing to sustain the higher transaction costs involved.

There is empirical evidence suggesting that firm collaborations with distant universities are commonplace. For example, US and Japanese biotechnology firms (Audretsch and Stephan, 1996; Zucker and Darby, 2001) tend to interact with non-local academics and universities. Also, evidence for Germany (Grotz and Braun, 1997; Beise and Stahl, 1999) and Austria (Schartinger et al., 2002) emphasizes the frequency of non-local links.

Firm collaborations with distant universities can generate spillovers which benefit other firms. Collaborating firms act as conduits for flows of knowledge into the local economy (Barnard et al., 2012) allowing other local firms to benefit from these knowledge spillovers (Ponds, 2009; Montobbio and Sterzi, 2011).

2.2. The role of social networks for promoting interactions with distant universities

Existing work on university-industry interactions investigates some of the factors *enabling* firms to interact with distant universities. These studies focus on aspects which reduce the transaction costs involved in alliancing with distant partners. Several such studies refer to proximity and how geographical distance can be offset by other types of proximity than geographic proximity. Institutional proximity or similarity of the actors' informal constraints and formal rules (North, 1990) is considered to support knowledge transfer (Knoben and Oerlemans, 2006) including in the context of university-industry interactions. Institutional proximity is increased by similar formal regulation, or informal behavior norms based on previous collaboration with the same partner or a similar type of partner. In both cases, this common institutional background reduces transaction costs by reducing the uncertainty related to the partner's behavior. Hong and Su (2013) for the case of China, found that institutional proximity engendered by being part of the same administrative unit significantly enhanced the probability of collaboration, and these effects increased with increased distance. Several studies show that having collaborated previously with the same or a similar partner on a industry-university project, increases the probability of collaboration (Balland, 2012; Crescenzi et al., 2017).

Social proximity also plays a role in establishing interactions with distant universities. Social proximity – also described as personal or relational proximity - refers to the common relationships between the partners. Overlapping social networks support the development of interactions between organizations, for several reasons (Thune, 2007). First, pre-existing social relationships between organizations, either directly among members or via relationships with mutual third parties, provide organizations with information about potential partners, and opportunities to form new linkages, and reduce the transaction cost involved in searching for potential collaborators. Referrals connecting previously unconnected actors lead to new ties and "equip the new exchange with resources from preexisting embedded ties" (Uzzi, 1996, p. 679). Second, direct interactions between organizations promote trust, obligation, expectations, and reputation (Gulati, 1995; Uzzi, 1996) which by increasing coordination, facilitating exchange, and restricting opportunistic behavior reduce transaction costs (Uzzi, 1997). Third, pre-existing social relationships between organizations increase the partners' knowledge about mutual needs, capabilities, and competences, and increases each partner's capacity to manage the relationship (Larson, 1992; Nahapiet and Ghosal, 1998). All of these aspects reduce transaction costs, and therefore can be presumed to facilitate the establishment of interactions and particularly in the absence of geographical proximity.

Some argue that social networks are especially important to enable interactions between geographically distant organizations. Longer distances reduce the likelihood of chance encounters between individuals who have not met previously, and therefore, reduce the chances of interactions based on social proximity (Bell and Zaheer, 2007; Agrawal et al., 2008; Oettl and Agrawal, 2008). Social proximity is often considered as an organizational rather than an individual factor despite it arising from individual employees' personal social networks. Few works explore the individual antecedents of social proximity; i.e. the individual social networks on which it is based (Thune, 2007). A focus on the individual level provides an understanding of the mechanisms involved in the diffusion of knowledge (Balland, 2012; Weterings and Ponds, 2009).

2.3. Hypotheses

The role of personal networks

We can identify at least two types of personal networks which increase the social proximity between industry and university researchers: education-based and career-based. When faced with problems during innovation activity, industry employees can benefit from the network of their academic contacts built during their tertiary education. This network persists after graduation and is available to enable collaboration with academia in the future. Also, universities make efforts to maintain contact with their alumni in part to obtain future benefits (contract income, donations, prestige) from their association with reputable and wealthy individuals. The importance for future interactions of the relationships established during tertiary education or employment are confirmed in work in several fields including auditing. It has been shown that companies are more likely to appoint an auditing firm if one of their employees was formerly employed in that company (see e.g. Lennox and Park, 2007). Also, in the case of entrepreneurship, it has been shown that entrepreneurs disproportionately localize their startups in the region where they studied (Broström and Baltzopoulos, 2010). In the case of university-industry collaboration, graduates often rely on connections established during their university education when faced with a problem whose resolution requires theoretical or applied academic knowledge. While acknowledged in practice, the effect of the relationships and networks established during an industry researcher's university education for promoting subsequent university-industry interactions is considered only rarely in the literature (Bekkers and Bodas Freitas, 2008), and perhaps for data reasons has not been studied quantitatively. Bodas Freitas et al. (2014) use the same dataset analyzed in this paper, and provide some preliminary econometric evidence showing that industry researchers are more likely to establish personal contract-based interactions with university researchers from their alma mater (alumni). In the presence of this significant effect, industry researchers who graduated from a local (regional, national) university will be more likely to collaborate with a local (regional, national) university, while industry researchers who graduated from a university in a foreign country will be more likely to collaborate internationally. This international cooperation is due primarily to direct personal relationships of the researcher who graduated from a foreign university with academics in that university. It depends also on the network of contacts abroad built during their education which can be exploited to make an initial connection with a distant institution. This experience and network allow a better understanding of the foreign institution and its culture which facilitate future interactions with the distant university. Therefore, we hypothesize that:

H1: Having a degree awarded by a local/non-local university increases the individual's likelihood to interact with local/non-local universities.

The second type of personal network which can increase social proximity is the network of contacts built in the course of a work career, and typically after completion of education. Over time, individuals accumulate numerous personal contacts that include previous co-workers and employers. Oettl and Agrawal (2008) show the strong links among inventors who move across national borders and researchers in countries where they had previous employment. This suggests that these individuals benefit from their personal networks of former colleagues, built over time, and sometimes referred to as the "invisible college" (Crane, 1969). In some cases, the career-based networks of an industry researcher's personal contacts will include academics involved in previous collaborative projects (Perri et al., 2017). In addition, these networks of current and former colleagues may allow the industry researcher to access otherwise closed academic networks. Foreign colleagues may be able to connect inventors with academic contacts in their local university. In the presence of significant career-based network effects, we can expect industry researchers with international career-based personal networks to be more likely to engage in international academic collaborations. Therefore, we hypothesize that:

H2: Having a non-local career network increases the individual's likelihood to interact with distant universities

The role of multinational group affiliation

The organization's overall capabilities can influence their researchers' abilities to collaborate with distant organizations. The firm's academic knowledge recognition capabilities are correlated to its level of absorptive capacity (Cohen and Levinthal, 1990). In the case of internationally sourced academic knowledge, what matters is the combination of absorptive capacity and search and screening capabilities for effective use of distant knowledge. Also important is the ability to transfer knowledge from different local contexts. MNEs are likely to perform well on both aspects. By definition, MNEs are organizations with ownership advantages (Dunning, 1977) which include technological leadership - typically associated to an ability to identify relevant external knowledge (including academic knowledge), that is a high level of absorptive capacity. MNEs also are capable of sourcing knowledge globally and transferring it within their subsidiary networks (Mudambi and Navarra, 2004; Phene and Almeida, 2008; Nell and Ambos, 2013).

Work on firm-university collaborations provides some preliminary confirmation of the importance of MNEs for establishing international university collaborations. Rõigas *et al.* (2014) show that European firms which are part of a foreign multinational group (and are exporters) are more likely to collaborate with foreign universities.

Castellani and Zanfei (2006) suggest that MNEs bridge across different national innovation systems. This allows their local subsidiaries to exploit the knowledge created elsewhere (at a distance) in the MNE (Kotabe et al., 2007), while also allowing the MNE to exploit the knowledge produced by the external local actors collaborating with its subsidiaries. The MNE allows the relationships created by one of its subsidiaries with its local economic actors to be exploited by other of its subsidiaries. In the case of relationships with universities, this facilitates links by each of the MNE's subsidiaries and the possibility of collaborations with distant researchers. The MNE provides an infrastructure which boosts its subsidiaries' abilities to search for and screen academic knowledge.

Moreover, Cantwell and Piscitello (2005) and Suzuki et al. (2017) show that MNEs often choose to locate some of their facilities, especially R&D laboratories, close to academic centers of excellence in order to benefit from their proximity. This potentially allows all of its subsidiary firms to access centers of academic excellence. Each subsidiary firm can exploit the relationships forged by other of the MNE's subsidiaries with their nearby universities.

We need to distinguish between firms that are part of a domestic MNE i.e. with headquarters in the same country, and firms belonging to foreign-owned multinationals. While the above arguments hold in both cases, for foreign-owned groups there are additional factors suggesting that subsidiaries might find it easier to establish international collaborations with foreign universities. The empirical results in Busom and Fernándes-Ribas (2008) show that foreign-owned subsidiary firms generally have a higher probability of cooperation with any type of foreign partner. In our case, since the MNE tends to have stronger links with its country of origin, and in particular, to invest more in R&D close to the headquarters, we can expect enduring relationships with universities in that country of origin. Hence, a firm belonging to a foreign owned-group might have comparatively easier access to foreign universities, at least those in the country of origin of the MNE. In the case of domestic MNEs, this will apply to relationships with national universities. Hence, we hypothesize that:

H3: Working for a firm that is part of a domestic or foreign-owned multinational group increases the individual's likelihood to interact with distant universities.

H4: Working for a firm that is part of a foreign-owned multinational group compared to working for a firm that belongs to a domestic multinational increases the individual's likelihood to interact with distant universities.

3. Data and methodology

3.1. The PIEMINV survey

For the empirical analysis, we rely on an original survey aimed specifically at investigating university-industry interactions including their geographical dimension. The PIEMINV survey questionnaire[4] was sent to the population of inventors with addresses in the Italian region of Piedmont who had applied for at least one European Patent Office (EPO) patent in the period 1998-2005 (3,922 patents and 3,027 inventors were identified). Addresses were collected from EPO patent applications, and updated based on telephone registry information and telephone contact with the companies. After cleaning and confirming the address data, we administered 2,916 questionnaires to industry inventors by email and surface mail between autumn 2009 and spring 2010. We obtained 938 valid responses (response rate 31%).

The questionnaire is organized in four sections which ask for different types of information:

[4] For a detailed analysis of the PIEMINV survey see Cecchelli et al. (2012). The database is available upon request from the corresponding author.

1. General information about the inventor (age, gender, education, mobility) and the inventor's inventive activity (age at first patent, office where patents were first filed, invention to innovation ratio);
2. Role of university knowledge in the development of the inventions;
3. Frequency and nature of the inventor's involvement in university-industry interactions;
4. Assessment of the economic impact of university knowledge.

The questions related to the frequency and nature of inventors' involvement in university-industry interactions included asking which universities the inventor collaborated with, and how often, allowing for eight possible categories of answers: each of the three universities in the region (described in section 3.2); other universities in neighboring regions; other universities in other Italian regions; other universities in Europe, the US, or other countries. These responses to these questions provided crucial information to explore the extent to which inventors collaborated with universities in different locations nationally and internationally, as discussed in more detail in the methodology section.

Additional information on the firms employing the inventors was collected from the CERVED database of Italian companies' accounts, and other public online sources.[5] This information was available for 298 out of 363 firms in the sample (or 738 inventors); it was difficult to find information about non-public small/micro firms. We also collected the number of patents filed by the firms during 1998 to 2005, from the Derwent Innovations Index. Information on inventors' patents included number of patent applications and patent granted between 1998 and 2005, types of assignees, average number of backward citations, average number of forward citations, citations to academic papers, date of first patent application, most common technology class.[6] These data were available for all the inventors in our sample. Finally, 23 inventors were excluded because they were employed in a public institution (university, public research organization, government body) rather than a firm; this left 915 industry inventors for our analysis. After taking account of observations, we have 671 observations for our analysis.

[5] Firm-related information classifications are according to United Nations International Standard Industrial Classification (ISIC) (Rev. 4) (UN, 2008).

[6] Classification by macro-technology classes is according to OST-DT7 (OST, 2004NOT IN REFS).

3.2. The regional context

Piedmont is located in the north west of Italy. It has a population of about 4.376 million and accounts for 7.7% of Italian gross domestic product (GDP). GDP per capita in purchasing power parity (PPP) is €30,700, 102% of the EU28 average (Eurostat, 2017). Piedmont is ranked fourth in Italy for level of exports, and had a positive trade balance of about €48 billion of exports in 2017. About 59% of its exports go to other EU-28 countries, the main destinations being Germany and France. The US and Switzerland are the most important non-EU export destinations (ISTAT, 2018).

Of the 438,966 companies active in the region in 2017, about 44,000 are manufacturing firms. Employment in manufacturing is relatively more important, representing about 25% of the total (compared with 21% nationally). Although micro-firms (less than 10 employees) are slightly less important than for the rest of Italy, they make up around 81% of all manufacturing companies in Piedmont (Vitali et al., 2011). High and medium-high technology manufacturing is particularly strong, representing some 12% of total employment. The unemployment rate in 2017 was 9.1%, lower than the Italian average, while participation for the 15-64 age cohort was 65.2%, slightly lower than the 70% target set in the Lisbon strategy (Eurostat, 2017).

Piedmont has strong specialization in automotive components: the home base of Italy's main car producer FCA is in Turin. Among the R&D intensive companies in the region, many belong to the FCA group, and some are well-known designers, specialized primarily but not exclusively in automobile design. There are also companies producing trains, and aeronautics and aerospace firms. In addition to the large R&D intensive firms, the regional industrial structure is characterized by a large number of small and medium-sized enterprises (SMEs) organized in traditional industry clusters. Regional specializations include wool, plumbing fittings and valves, textiles and apparel, mechanics, jewelry, kitchen utensils and appliances, food, and wine.

Piedmont is also quite attractive for foreign multinationals, and is the fourth region in Italy for inward foreign direct investment (FDI). The majority of foreign multinationals are active in the manufacturing sector (56% of employment), and multinational companies are predominantly from France, Germany, the US, Switzerland, and the UK. Among the multinationals present in the region many are active in high and medium-high technology sectors: these include, among others, Delphi Technologies (UK - auto propulsion systems), Freudenberg group (Germany - components for machinery), Agilent Technologies (US - instruments and software), SKF (Sweden - bearing and seal manufacturing), ABB (Swiss-Swedish - robotics and electrical machinery), and Denso (Japan - automotive components).

While Italy as a whole suffers from structural weaknesses in R&D investment, Piedmont has the highest value of R&D expenditure as a percentage of regional GDP among the Italian regions (2.2%) (Eurostat, 2017). The region is characterized by a high incidence of private R&D expenditure as a share of GDP (1.9%), with respect to the Italian average of 0.78% (ISTAT, 2018). This is due mostly to the sizeable R&D investments made by a few large Piedmontese firms, particularly FCA and Telecom Italia.

The universities and the many public research centers based in the region make a significant contribution to local knowledge production. Piedmont has four universities: a small private university specialized in food science (Università di Scienze Gastronomiche), and three public universities (Università degli Studi di Torino, Politecnico di Torino, Università degli Studi del Piemonte Orientale "Amedeo Avogadro").[7] The University of Torino and the Politecnico are the oldest and largest institutions with student enrollment of respectively 70,500 and 30,800 (MIUR, 2017). Politecnico di Torino is quite narrowly specialized in engineering and architecture, while Università di Torino offers undergraduate and postgraduate courses in a wide range of other disciplines

In sum, although Piedmont is a specific setting, its economy is quite diverse and in many respects is similar to other industrial regions focused on manufacturing, allowing interesting parallels with other contexts. While most employment is in the service sector, manufacturing employment is relatively high; Piedmont's industrial base is quite diverse in terms of high and low technology industries, and compared to the national average, has relatively high incidence of medium and large firms; science and technology indicators position the region near the EU-15 average. Piedmont's four universities have different and complementary characteristics. This diverse context provides an appropriate setting for an investigation of university-industry collaboration.

3.3. Methodology

We investigate what drives Piedmont's industry inventors choice of a university to collaborate with, focusing in particular on the determinants of collaborations with

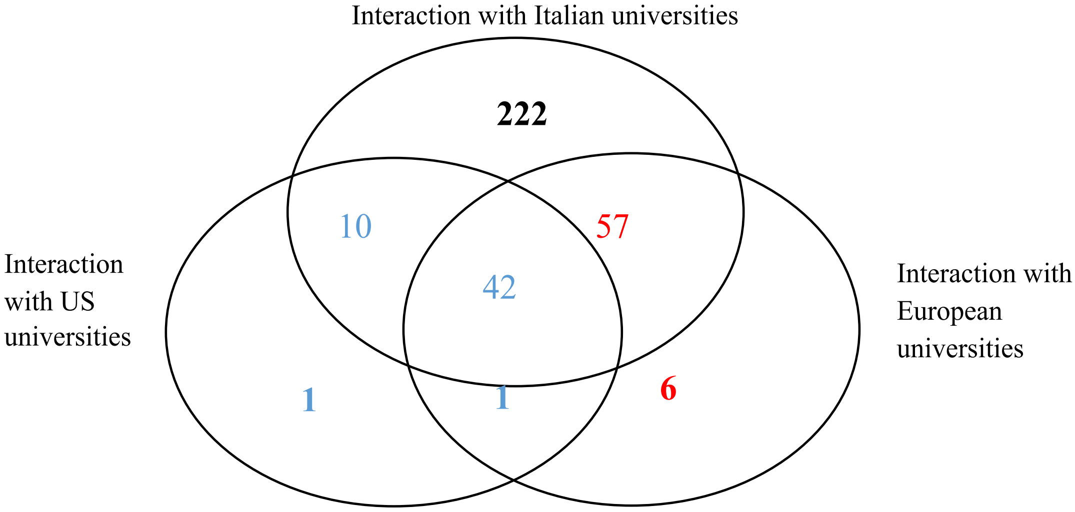
[7] There are numerous public research centers in the region which are not discussed here.

international universities. The PIEMINV survey asks inventors whether they have interactions with certain institutions in Italy and abroad: this information was used to build our dependent variables. The dependent variables are four ordinal variables indicating inventors' frequency of interactions with the following institutions: (1) regional universities (the University of Torino and/or the Politecnico of Torino), (2) other Italian universities (3) universities in other European countries, (4) universities in the United States. The five possible answers were: "never/no interactions", "rarely" (once every two years), "not often" (once or twice a year), "frequently" (3 to 6 times a year), "very frequently" (every month or two). Based on the responses we built four variables (one for each type of institution), which take values from 1 to 5. These four dependent variables indicate whether inventors have interactions (and with what frequency) with each type of institution (regional/other Italian/other Europe/US).[8]

We built an additional ordinal dependent variable, *distance,* which measures how (geographically) distant are the inventor's interactions. We use this variable to model the geographical distance of their interactions; we drop the distinction between regional and other Italian universities and focus on the difference between European and US universities. The variable takes the following values (see figure 1): zero if the inventor interacted at least once a year only with Italian universities (including the two in the Piedmont region) (222 inventors); 1 if the inventor interacted at least once a year also -or exclusively- with universities in another European country (but not with a US university) (63 inventors); 2 if the inventor interacted at least once a year also (or exclusively) with US universities (54 inventors). In figure 1 the black color represents zero distance (collaboration with Italian universities), red indicates distance 1 (European universities), and blue indicates 2 (US universities).

Figure 1: Venn diagram of distance.

[8] Only a few inventors stated having frequent interactions with the other two universities in Piedmont (Università di Scienze Gastronomiche, Università degli Studi del Piemonte Orientale) or with universities in other continents than Europe or the US; therefore we do not consider these in the analysis.



Notes: Note that not all these inventors enter the regressions, since we have some missing data on education, age and other characteristics.

3.3.1. Main equation: independent variables

To test H1 (*Having a degree awarded by a local/non-local university increases the individual's likelihood to interact with local/non-local universities)* for each inventor we built three dummy variables to capture the inventor's personal educational network. The first *Piedmont Degree* is equal to 1 if the inventor graduated from a university in Piedmont. The second *Italian Degree* is equal to 1 if the inventor graduated from an Italian university in another region. The third *International Degree* is equal to 1 if the inventor's highest degree was granted by a foreign university. This variable does not capture the direct effect of relationships with academics at university (alumni) since the PIEMINV questionnaire does not ask for the name of the foreign university with which the inventor collaborated but rather assesses whether the inventor has developed an international network and international propensity during his/her education which might facilitate interaction with distant institutions.

To test H2 (*Having a non-local career network increases the individual's likelihood to interact with distant universities*) we built two dummy variables to capture the international reach of the inventors' personal career network. The variable *worked outside Piedmont* is equal to 1 if the inventor has worked for at least 6 months outside Piedmont. This variable allows us to measure the embeddedness of the inventor in the region of employment: inventors who have worked only in Piedmont can be considered to be strongly embedded in the region. The second variable *Personal international* *network* relies on the patent information available for each inventor and is equal to 1 if the inventor's patent portfolio includes at least one co-inventor based outside of Italy.

Working for a foreign-owned MNE gives the local inventor access to the international networks of the mother company, and increases the probability of searching for a collaborative partner abroad. Also, working for a domestic (Italian-owned) company which is head of an international group is expected to have a similar effect. To capture these two effects we built two additional variables for the individual's business network. To test H3 (*H3: Working for a firm that is part of a domestic or foreign-owned multinational group increases the individual's likelihood to interact with distant universities*) and H4 (*H4: Working for a firm that is part of a foreign-owned multinational group compared to working for a firm that belongs to a domestic multinational increases the individual's likelihood to interact with distant universities*) we built two variables using data from ORBIS. The first is a dummy variable *Employed by an Italian MNE* which is equal to 1 if the inventor's employer is an Italian-owned company with foreign affiliates. The second *Employed by a Foreign MNE* is equal to 1 if the inventor is employed by a foreign-owned company based on the information in ORBIS. Other inventors (not employees of Italian or foreign MNEs) are classified as employed in domestic companies with no affiliates abroad.

3.3.2. Main equation: control variables

We control for several variables that might differently affect the likelihood of collaborating with universities in different locations.

First, we control for type of contract the inventor uses to regulate interactions with firms. The PIEMINV survey asked inventors about the different channels of interaction with universities and their importance. In this study our focus is on two specific types of interactions: personal contractual interactions with individual researchers (*rescontr*), and institutional collaborations between a university and the firm employing the inventor (*instcontr*). We built two dummy variables that take the value 1 if the inventor indicated that during their work career they used one of these two channels of interaction and deem them important for their inventive activity. Depending on the university partner, the inventor might privilege one or other type of interaction (Bodas Freitas et al., 2013b). Personal contracts have been associated to better transmission of tacit knowledge and to partners with high organizational and institutional proximity

(Fassio et al., 2019) which might mean they are likely to be associated to more localized interactions. Institutional contracts have been found more effective to regulate interactions with partners with low organizational and institutional proximity, likely to apply to partners that are geographically distant. Institutional and personal contracts were used and considered important for about 14%-15% of inventors.

Second, we control for the firm's technology intensity and size. Works investigating the characteristics of firms that collaborate with universities in their own as opposed to another region (e.g. Fritsch and Schwirten, 1999; Fritsch, 2001; Laursen et al., 2011; Bouba-Olga et al., 2012) show that larger, more technology intensive firms, are more likely to collaborate with universities outside the region and to have a larger number of collaborations. Hence, to capture absorptive capacity we control for the firm's absolute number of patents, , and control also for firm size. *Less than 50 employees* is considered a small company; ; *50-250 employees* is a medium firm; and *>250 employees* indicates a large firm. Inventors in the PIEMINV sample are employed mostly in large companies (70%), with the remaining 30% distributed fairly equally among micro, small and medium-sized firms.

Finally, we control for several individual inventor characteristics : education (tertiary education, doctoral degree), age (since there might be different propensities to interact with specific universities across generations), gender (*male*), employment at a university at some point in their career. The share of men is about 92%, possibly because most inventors in Piedmont are engineers, where traditionally the share of women is quite low. The share of inventors with a bachelors or masters degree is around 55%, with only 4% of the sample PhDs. About 8% of the sample worked for a limited period in a university.

We control also for the sector in which the inventor operates. The incidence of international collaborations has been found to differ across sectors (Crescenzi et al., 2017). Since we are using individual data, we include several dummies for the most common technology class in the inventor's portfolio according to the OST7 classification: mechanical engineering (*mech*), process engineering (*proceng*), electrical engineering and electronics (*electr*), instruments (*instr*), chemicals and pharmaceutical (*chempharma*), and consumer goods (*consumer*). Electrical engineering and mechanical engineering are the most common technology classes among our inventors, with respectively 36% and 25% patenting in these scientific fields.

3.3.3. Selection equation

We are aware of the risk of selection bias in our estimations of the main equations. Some of the factors influencing the probability to collaborate with a university in a specific location are likely also to influence the probability of collaborating generally. To avoid underestimating these variables, for each of the main equations measuring the effect of different variables on the probability to collaborate with universities in different locations we estimate a selection equation (always the same one) which indicates whether inventors collaborate with a university at all.

This selection equation includes general determinants of industry interactions with universities, identified in the literature. We include both firm-level and individual-level variables.

Among the firm-level variables, firm size has been studied for various countries using different datasets. Most studies show that firm size is related positively to the probability to cooperate with a university. This is because compared to smaller firms larger firms have more internal resources to engage in cooperation with academia, and are more likely to be aware of university capabilities (Tether, 2002). We use the same size variable as in the main equation.

Among individual characteristics, the inventor's absorptive capacity is likely to increase his or her ability to interact with academic researchers in general. We proxy inventor's absorptive capacity by *patents applied for* which measures the number of patents each inventor applied for in the period 1998-2005. We consider inventor's education (*tertiary education* is equal to 1 for inventors with a bachelors or masters degree), age, experience of working in a university (*workuni* is a dummy that equals 1 if the inventor worked for at least one month at a university during his or her career), and career mobility (*mobile inventor* is equal to 1 if the inventor has worked for more than 5 organizations). We expect all these variables to increase the probability to collaborate.

3.3.4. The model

We are interested in why an inventor decides to interact with each of the four types of institutions identified, and the frequency of that interaction. In the first specification we include four ordinal dependent variables, one for each type of university identified. Each equation includes the same set of independent and control variables as described in the previous paragraph.

$$INT_i^s = a + \sum_j \beta_j EDUCATION_{ij} + \sum_l \gamma_l CAREER_{il} + \sum_m \delta_m MNE_{im} + \sum_n \varphi_n X_{in} + \varepsilon_i$$

where INT is an ordinal variable for the frequency of interaction of each inventor *i* with one of the s types of universities (regional university, other Italian university, other European university, US university). *EDUCATION* is a set of variables measuring whether the individual's education network is local or international. *CAREER* is a set of variable for whether the inventor has a local or international career based network of contacts. *MNE* measures whether the inventor is employed by an Italian MNE or a foreign MNE. We estimate equation (1) as four separate ordered probit regressions with sample selection, i.e. including a selection equation in which the dependent variable is equal to 1 for inventors with some kind of interaction with at least one of the different university types, and zero for inventors with no university interactions. The independent variables in the selection equation are those indicated in section 3.3.4.

Our second specification measures the maximum distance for each inventor's university interactions:

$$DISTANCE_i = a + \sum_j \beta_j EDUCATION_{ij} + \sum_l \gamma_l CAREER_{il} + \sum_m \delta_m MNE_{im} + \sum_n \varphi_n X_{in} + \varepsilon_i$$

In equation (2) the independent variables are the same as in equation (1), and the dependent variable is an ordinal variable which measures the maximum level of distance of each inventor's interactions with a university (0 for universities in Italy, 1 for European universities, and 2 for US universities). We estimate equation (2) using an ordered probit. Interpretation of the coefficients of the independent variables is different from equation (1) since instead of measuring the impact of each variable for frequency of collaboration with a specific type of university, here we measure the contribution of each variable to the probability to establish more distant interactions. Also, in this case we introduce a selection equation to model the inventor's probability to collaborate with universities in general.

Table 1: Number of inventors who interact with specific universities

	Total Answers	No Interac.	Some Interac.	Type of interactions with the university

				Rare	Not often	Frequently	Very frequently
Regional Uni	417	47	370	173	104	57	36
	100%	*11%*	*89%*	*47%*	*28%*	*15%*	*10%*
Other Italian Uni	385	134	251	108	63	48	32
	100%	*35%*	*65%*	*43%*	*25%*	*19%*	*13%*
International Uni	360	201	159	72	41	29	17
	100%	*56%*	*44%*	*45%*	*26%*	*18%*	*11%*
European Uni	355	208	147	67	36	28	16
	100%	*59%*	*41%*	*46%*	*24%*	*19%*	*11%*
US Uni	352	276	76	38	24	10	4
	100%	*78%*	*22%*	*50%*	*32%*	*13%*	*5%*

4. Results and discussion

Table 1 presents the distribution of our ordinal dependent variables, distinguishing between university types (regional/other Italian/other Europe/US). As expected, interactions with regional universities are the most common, with 370 inventors declaring some kind of interaction (regardless of frequency). Interactions with other Italian universities are the second most common (251 cases), while in 159 cases inventors indicated some interaction with international universities. The number of inventors interacting with international universities is not negligible: it is slightly less than half the number of those that interact with regional universities. This suggests the importance of this type of knowledge sourcing among inventors in Piedmont. Among international universities we found European universities more frequent collaboration partners (147 cases) than US universities (76). Figure 2 depicts the distribution of the frequency of interactions by university type for inventors declaring some interaction. We observe a rather similar pattern of frequency of interaction among regional, other Italian, and international universities. About half of the inventors who interact with a specific university do it once every year or two ("rare" interaction); 25% of inventors interact more regularly (once or twice a year – "often" interaction); 15%-18% interact "frequently" (3-6 times a year); and 10%-12% interact "very frequently" (every month or two). The share of frequent and very frequent interactions is slightly higher for interactions with other Italian and international universities compared to interactions with regional universities. These descriptive results highlight that the main difference between regional and national interactions with respect to more distant interactions (especially international) is related mainly to the lower number of inventors interacting with a distant university. However, among those who do interact we find no significant differences for frequency of interaction. This suggests that once the channel of interaction has been established, geographical distance is no longer a factor inhibiting contact with distant researchers.

Figure 2. Frequency of interactions (perc. %)

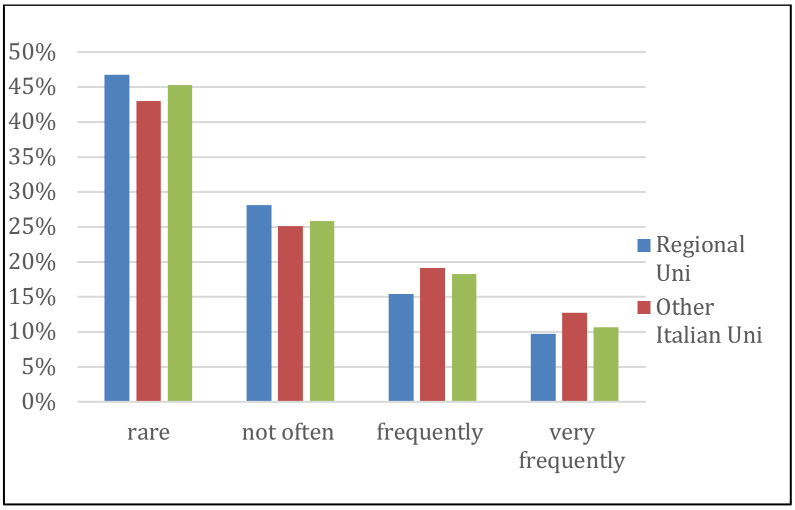


Table 2 presents some descriptive statistics for the sample of inventors used in our analysis. The mean age of inventors with interactions with universities is 47. Most have a tertiary university degree (71%) and 4% are doctoral graduates. About 11% have worked at a university at some point in their career. A large majority (90%) of inventors are men. Most inventors (74%) work in large firms (>250 employees) and more than half of all inventors patent in mechanical engineering and electronics. Again, this is consistent with the technological specialization of the Piedmont region.

Table 2. Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max
Business network				
Employed by a Foreign MNE	0,254	0,436	0	1
Employed by an Italian MNE	0,525	0,500	0	1
Personal career-based network				
Worked outside Piedmont	0,300	0,459	0	1
Personal international network	0,074	0,263	0	1
Personal education-based network (Alumni effect)				
Alumni Piedmont	0,511	0,500	0	1
Alumni Italy	0,146	0,354	0	1
International degree	0,022	0,145	0	1
Preferred type of interactions				
Personal contracts	0,139	0,346	0	1
Institutional contracts	0,156	0,363	0	1

Individual characteristics and education				
Male	0,904	0,295	0	1
Age	47,434	9,628	29	77
Tertiary Education	0,712	0,453	0	1
Ph.D	0,043	0,203	0	1
Worked at Uni	0,108	0,311	0	1
Company characteristics				
Num of patents (company)	4,226	2,188	0	8,478
Size: 50-250 employees	0,110	0,314	0	1
Size: more than 250 employees	0,741	0,439	0	1
Technological field (OST7)				
Electronics	0,290	0,454	0	1
Instruments	0,127	0,333	0	1
Chemistry and materials	0,070	0,255	0	1
Pharmaceutical -Biotech	0,014	0,119	0	1
Mechanical engineering	0,343	0,475	0	1
Consumer goods (And Others)	0,055	0,229	0	1
Process engineering	0,101			
Total number of observations				**417**

About half of the inventors who interact with universities received their tertiary degree from one of the two main universities in the region (University of Torino and Politecnico of Torino). A much lower share (15%) graduated from another Italian university and only 2% graduated abroad. This latter finding suggests that while having studied at a regional or Italian university might play a role with respect to interactions with regional and Italian universities respectively, the limited number of international graduates is not likely to explain the high level of international interactions.

Finally, we found that about half of the inventors are employed by Italian MNEs, and around 25% are employed by foreign MNEs. Only 30% of the inventors had some work experience (at least 6 months) outside of the Piedmont region, suggesting a low level of mobility of this sample of inventors. We found also that only 7% of the inventors have a co-inventor based abroad.

Table 3 distinguishes inventors according to type of university they interact with. Our descriptive statistics are restricted to inventors that collaborate at least "often" with respectively a regional university, other Italian universities, and international universities. This provides some initial descriptive evidence on the relevance of specific inventor characteristics (and the companies employing them) for the decision to interact with a specific university. We found that compared to inventors who collaborate with regional universities, inventors with some interactions with international universities are more commonly employed by foreign MNEs (35% vs. 28%), and slightly more likely to be employed in large companies (81% vs. 77%). They are more likely to have worked outside of Piedmont and to have a foreign co-inventor, and on average are more highly educated (based on the higher share of graduates and PhDs). Finally, they are more specialized in the field of "Instruments" and comparatively less active in the field of "Mechanical engineering". Instead, the share of alumni from regional universities is higher among inventors who interact with regional universities (62%) than those who collaborate with other Italian or international universities (respectively 52% and 57%). However, there is no evidence of a higher share of international graduates among inventors who interact with international universities. Among the other variables we found no substantial differences.

Table 3. Descriptive statistics by type of university (only inventors with at least one or two interactions per year)

Variable	Regional	Italian	International
Business network	***mean***	***mean***	***mean***
Employed by a Foreign MNE	0,284	0,259	0,356
Employed by an Italian MNE	0,543	0,580	0,517
Personal career-based network			
Worked outside Piedmont	0,264	0,210	0,333
Personal international network	0,086	0,091	0,115
Personal education-based network (alumni effect)			
Alumni Piedmont	0,629	0,552	0,575
Alumni Italy	0,107	0,231	0,241
International degree	0,030	0,007	0,011
Preferred type of interactions			
Personal contracts	0,203	0,217	0,241
Institutional contracts	0,213	0,210	0,230
Individual characteristics and education			
Male	0,868	0,832	0,805
Age	46,959	47,350	47,264
Tertiary Education	0,797	0,832	0,851
Ph.D	0,071	0,063	0,092
Worked at Uni	0,117	0,133	0,184
Company characteristics			
Num of patents (company)	4,364	4,684	4,505
Size: less than 50 employees	0,112	0,105	0,149
Size: 50-250 employees	0,112	0,056	0,034
Size: more than 250 employees	0,777	0,839	0,816
Technological field (OST7)			
Electronics	0,315	0,273	0,299
Instruments	0,173	0,217	0,230
Chemistry and materials	0,056	0,112	0,092
Pharmaceutical -Biotech	0,015	0,021	0,000
Mechanical engineering	0,325	0,287	0,241

Consumer goods (And Others)	0,046	0,042	0,057
Process engineering	0,071	0,049	0,080

Table 4 presents the results of the separate ordered probit estimations of equation (1) in relation to the propensity to interact frequently with the four different types of universities. Column (3) presents the results for interaction with international universities without distinguishing between US and European; the results in columns (4) and (5) distinguish between these two university types. The coefficients indicate the extent to which each variable increases the likelihood that an inventor interacts frequently with a specific institution. Since selection bias might be an issue for the small set of inventors who interact with universities (as opposed to those that do not interact at all with a university), we estimate equation (1) including a selection equation that estimates the likelihood of any type of interaction with a university. The selection equation includes the same independent variables for each estimation.

Table 4. Determinants of interaction with different types of universities.

VARIABLES	(1) Regional	(2) Other	(3) Foreign	(3a) European	(3b) US Univ
Business network					
Employed by a Foreign MNE	0.146	-0.132	0.339**	0.346***	0.491**
	(0.171)	(0.181)	(0.139)	(0.129)	(0.250)
Employed by an Italian MNE	0.116	0.125	0.244*	0.258**	0.344
	(0.167)	(0.174)	(0.132)	(0.121)	(0.256)
Personal career-based network					
Worked outside Piedmont	-0.280**	-0.265**	0.127	0.116	0.390**
	(0.119)	(0.127)	(0.104)	(0.101)	(0.160)
Personal international network	0.212	0.208	0.171	0.137	0.355
	(0.212)	(0.225)	(0.162)	(0.159)	(0.224)
Personal education-based network					
Alumni Piedmont	0.444***				
	(0.148)				
Alumni Italy		0.509***			
		(0.158)			
International degree			-0.385	-0.258	-0.362
			(0.342)	(0.338)	(0.399)
personal contract	0.589***	0.343**	0.183	0.226*	0.147
	(0.169)	(0.153)	(0.126)	(0.120)	(0.186)
institutional contracts	0.153	0.226	0.277**	0.267**	0.250
	(0.153)	(0.152)	(0.128)	(0.120)	(0.190)
Individual characteristics and					
Male	-0.139	-0.267	-0.293*	-0.245*	-0.232
	(0.175)	(0.175)	(0.151)	(0.142)	(0.211)
Age	0.003	0.010	0.001	0.001	0.002
	(0.006)	(0.007)	(0.007)	(0.007)	(0.008)
Tertiary education	-0.260	0.027	-0.270	-0.314*	-0.106
	(0.185)	(0.280)	(0.189)	(0.173)	(0.370)
Ph.D	0.777***	0.318	0.471*	0.461*	0.650**
	(0.249)	(0.296)	(0.259)	(0.245)	(0.318)

Worked at Uni	-0.172	0.097	0.075	-0.054	0.270
	(0.191)	(0.211)	(0.193)	(0.194)	(0.334)
Company characteristics					
Num of patents (company)	-0.047	0.020	-0.023	-0.021	-0.043
	(0.036)	(0.044)	(0.035)	(0.033)	(0.051)
benchmark: less than 50 employees					
50-250 employees	0.203	-0.043	-0.358	-0.214	-0.710**
	(0.235)	(0.237)	(0.265)	(0.205)	(0.301)
>250 employees	0.155	0.072	-0.163	-0.096	-0.251
	(0.212)	(0.237)	(0.267)	(0.196)	(0.265)
Selection equation					
Age	0.001	0.001	-0.000	-0.001	-0.001
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Worked at Uni	0.538**	0.612**	0.763***	0.826***	0.680**
	(0.245)	(0.257)	(0.269)	(0.267)	(0.272)
Tertiary education	0.927***	0.989***	0.989***	0.987***	0.968***
	(0.117)	(0.122)	(0.124)	(0.124)	(0.125)
50-250 employees	0.146	0.223	0.349	0.150	0.202
	(0.198)	(0.204)	(0.233)	(0.200)	(0.206)
>250 employees	0.261*	0.326**	0.571***	0.362**	0.366**
	(0.145)	(0.145)	(0.188)	(0.143)	(0.148)
Patents applied for 1998-2005	0.073***	0.067**	0.044*	0.047**	0.064**
	(0.024)	(0.026)	(0.024)	(0.024)	(0.032)
Mobile inventor (worked in more	0.060	0.137	0.261	0.241	0.156
	(0.208)	(0.224)	(0.199)	(0.198)	(0.240)
Constant	-0.561*	-0.722**	-0.880**	-0.653*	-0.677*
	(0.336)	(0.351)	(0.387)	(0.366)	(0.364)
rho	-0.594	-0.488	-0.882	-0.907	-0.611
Observations	644	612	587	582	579
Censored observations	228	228	228	228	228

Result of a ordered probit model estimation with selection. Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The results show that having graduated from, respectively, a regional or Italian university increases the likelihood that an inventor will collaborate with a university localized in the same area where she graduated, suggesting that direct personal interactions with academics at her/his alma mater (alumni) and the presence of a localized personal network developed during university education may play a role in subsequent establishment of university-industry interactions. Being awarded a tertiary degree from a foreign university is not correlated to international collaboration, as shown by the negative and non-significant coefficient of *International degree* in column (3). The variable *International degree* is very weak since we have information on international university degrees for only 17 inventors in our sample, and 14 of them graduated from a European university, 1 from a US university and 2 from a university in another country. This variable might be able to capture a general international propensity since institutions and cultures differ greatly across the countries in our sample, but cannot capture development of an international network or an alumni effect. Thus, we find support for H1 only at the local level.

Next, we focus on the role of a career network for explaining interactions with different types of universities. Columns (1) and (2) show that having worked outside of Piedmont decreases the likelihood of interacting with regional or Italian universities: the coefficient of the dummy *worked outside of Piedmont* is negative and significantly different from zero. This supports the idea that researchers whose careers are embedded more in the Piedmont region are less likely to establish distant interactions with universities. However, if we test H2 (*Having a non-local career network increases the individual's likelihood to interact with distant universities*) directly we find weak support: having worked outside of Piedmont has positive but not significant impact on establishing interactions with international universities, and the coefficient is positive and significant only for US universities (not European ones). Our second measure for international career-based network (having at least a foreign co-inventor) also does not explain the frequency of interactions with international universities, either US or European. Overall, these results provide mixed and quite weak support for H2.

We focus next on the importance of the capabilities of the organizations employing the inventors i.e. whether employment in a MNE (either Italian or foreign) affects the likelihood of collaborations with international universities. The results show that being employed by a foreign or Italian MNE unambiguously increases the probability of frequent interactions with foreign universities, providing strong evidence in favor of H3 (*Working for a firm that is part of a domestic or foreign-owned multinational group increases the individual's likelihood to interact with distant universities).* In the case of H4 (*Working for a firm that is part of a foreign-owned multinational group compared to working for a firm that belongs to a domestic multinational increases the individual's likelihood to interact with distant universities)* we do not find substantial differences between the impact of domestic versus foreign-owned MNEs on international collaborations: the coefficients of both variables are positive and significantly different from zero but the two coefficients are not significantly different. If we distinguish further between European and US universities, we find weak support for H4: while foreign-owned MNEs are not significantly better than domestic MNEs for fostering collaborations with European universities, in the case of more distant interactions - with US universities – only working for a foreign MNE significantly promotes frequent collaboration which supports H4.

We show that regional and national interactions tend to be governed by personal contracts while interactions with international universities rely more on institutional governance mechanisms.

In Table 5 we run a similar analysis using the *distance* ordinal dependent variable: in this case we can interpret the coefficients as the effect of the variables which increase the likelihood that an inventor will interact frequently with geographically distant universities. As explained in section 3.3, this variable equals 0 for inventors who interact only with Italian universities (including regional ones), 1 for inventors who collaborate with European universities, and 2 for inventors who collaborate with US universities. Again, we use an ordered probit model. We check also for the relevance of selection bias and find in this case that the rho coefficient which measures the correlation between the error terms of the selection and main equations is never significantly different from zero. In line with this, we employed a more parsimonious estimation strategy with an ordered probit without selection bias.[9]

Table 5. Determinants of the distance of interactions with universities

VARIABLES	(1) Distance
Business network	
Employed by a Foreign MNE	0.626**
	(0.314)
Employed by an Italian MNE	0.582*
	(0.313)
Personal career-based network	
Worked outside Piedmont	0.328*
	(0.186)
Personal international network	0.283
	(0.278)
Personal education-based network (alumni effect)	
Alumni Piedmont	0.489
	(0.448)
Alumni Italy	0.640
	(0.489)
International degree	-0.791
	(0.712)
Preferred type of interactions	
Personal contract	0.004
	(0.218)
Institutional contracts	0.084
	(0.224)
Individual characteristics and education	
Male	-0.293
	(0.227)
Age	0.001
	(0.010)

[9] Results obtained with an ordered probit model which accounts for selection bias are in line with those presented in the paper and are available from the authors on request.

Tertiary education	-0.283
	(0.473)
Ph.D	0.350
	(0.348)
Worked at Uni	0.423
	(0.273)
Company characteristics	
Num of patents (company)	-0.041
	(0.058)
benchmark: less than 50 employees	
50-250 employees	-1.140***
	(0.432)
>250 employees	-0.323
	(0.351)

Result of a ordered probit model estimation. Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The results for local education-based network are no longer significant since in this model our dependent variable is constructed to capture international effects. The results show also that having worked outside of Piedmont increases the probability to interact with more distant universities: the coefficient of the dummy *worked outside of Piedmont* is positive and weakly significant at the 10% level confirming the findings in table 4. Again, we find no effect of a foreign co-inventor on the probability of distant interactions. When we look at the type of firms employing the inventors we find support for H3: working for an Italian or a foreign MNE increases the likelihood of interacting with more distant universities. However, in this case too we find no significant differences between the impact of Italian versus foreign MNEs, suggesting lack of support for H4.

5. Conclusions

International knowledge flows have become increasingly relevant during the most recent globalization period. International value chains have been accompanied by the development of global knowledge sourcing strategies. MNEs have played a central role as bridging institutions. At the same time, university research has become increasingly important for firms since outsourcing of R&D has increased and new technologies have emerged more frequently. Firms have developed networks of interactions in order to source external knowledge and reduce internal R&D efforts, and this has increased their collaborations with domestic and foreign universities.

The literature on university-industry interactions mostly ignores the drivers of international collaborations. This paper tries to fill this gap. We proposed and tested whether personal and organizational social networks influence firms' interactions with local and international universities, controlling for the factors suggested in the literature to explain the development of local relationships.

We found evidence of the important role of education-based personal networks in the case of regional and national universities; this result supports the interpretation that trust-based relationships such as university-industry relationships, are conditioned by the pre-existence of personal social networks which facilitate interactions between industry researchers over with technological problems, and university researchers engaged in scientific developments. It would be interesting to test whether these personal education networks operate at the international level. Our data are not sufficiently detailed to build a robust indicator, and we do not have detailed information on the foreign universities with whom inventors collaborated (we know only whether they collaborated with European or US universities). Also, in our sample the number of inventors with an international university degree is very small. Therefore, the presence of international education-based network effects remains an open question which should be investigated using data able to measure those effects more precisely; in particular, we need to measure the effect of graduation from a university in a specific location on collaboration with universities in that location (international alumni effect).

The paper provides original evidence on the role played by MNEs in helping local inventors to reach out to knowledge producers (in this case universities) localized in foreign countries. Working for a domestic or foreign-owned MNE increases the probability of collaboration with international universities. Looking in more detail at university locations (Europe vs. the US), we find some evidence supporting the view that only the business networks of foreign MNEs are useful for more distant collaborations i.e. in the US. This result has implications for public policy on the relevance of attracting foreign MNEs to the region to act as bridging organizations able to link regional inventors to distant and advanced knowledge sources.

We found some evidence also of a personal-career network effect; inventors with work experience outside of Piedmont had a higher probability of interacting with international universities compared to regional and national universities. Employing researchers with experience of working outside the home region could become a strategy for national companies (unable to benefit from the MNE effect) to enable links to the international knowledge market.

Finally, in terms of governance of interactions, we highlight the correlation between a personal network based approach (personal contracts) and local interactions, while international university-industry relationships are more often based on institutional contracts. Inventors who source knowledge from a distance need to have the support of institutionalized governance to manage the complexities of cross border relationships. On the basis of these results, we would suggest the need for regional agencies which could help especially small companies to navigate the complexities of institutional interactions at the international level for regions interested in supporting active internationalization of knowledge sourcing,

Taken together, these results suggest two models of interactions with universities. Local relationships are facilitated by inclusion in the same social network e.g. via education-based networks, and are governed by a personal network based system. International relationships are more complex and require more structured support; MNEs and their internal systems for knowledge sharing are facilitators in this case. In the absence of such support relationships form if the inventor has developed specific competences from working outside the region which promote links to organizations that are culturally and geographically distant. Institutionalized governance systems would help to solve problems related to the management of cross border collaborations.

This paper has some limitations typical of survey data based work with relatively small (though representative) numbers of observations. These include the small number of cases of international degree holders and the lack of a specific question on the name of the foreign degree granting institution. This limited the possibility of testing for an international alumni effect. Future work using national data (with regional identification) could address this important issue. In the context of globalized value chains and global knowledge sourcing, better knowledge on the effect of employees with foreign training experience and foreign work experience is crucial to develop and implement policies in this economic area.

References

Abreu, M., Grinevich, V., Hughes, A., Kitson, M., Ternouth, P. (2008). Universities, business and knowledge exchange, London and Cambridge: Council for Industry and Higher Education and Centre for Business Research.

Adams, J.D. (2005). Comparative localization of academic and industrial spillovers. In: Breschi, S.F.M. (Ed.), Clusters, networks and innovation, Oxford: Oxford University Press.

Agrawal, A., Kapur, D., McHale, J. (2008). How do spatial and social proximity influence knowledge flows? Evidence from patent data, *Journal of Urban Economics*, 64(2): 258–269.

Almeida, P., Kogut, B. (1999). Localization of knowledge and the mobility of engineers in regional networks, *Management Science*, 45: 905–917.

Arundel, A., Geuna, A. (2004). Proximity and the use of public science by Innovative European Firms, *Economics of Innovation and New Technology*, 13: 559-580.

Asheim, B.T., Coenen, L. (2006). Contextualizing regional innovation systems in a globalizing learning economy: on knowledge bases and institutional frameworks, *Journal of Technology Transfer*, 31: 163–173.

Asheim, B.T., Isaksen, A. (2002). Regional innovation systems: The integration of local 'sticky' and global 'ubiquitous' knowledge, *The Journal of Technology Transfer*, 27: 77–86.

Audretsch, D.B., Stephan, P. (1996). Company-scientist locational links: the case of biotechnology, *American Economic Review*, 86, 641–652.

Auerswald, P., Branscomb, L., Demos, N., Min, B.K. (2005). Understanding private-sector decision making for early-stage technology development: a "between invention and innovation project", Report No. NIST GCR 02-841A. National Institute of Standards and Technology, Gaithersburg, MD.

Balconi, M., Breschi, S., Lissoni, F. (2004) Networks of Inventors and the Role of Academia: An Exploration of Italian Patent Data, *Research Policy*, 33, 127-45.

Balland, P.A. (2012) Proximity and the evolution of collaboration networks: evidence from research and development projects within the Global Navigation Satellite System (GNSS) industry, *Regional Studies*, 46(6): 741–756.

Barnard, H., Cowan, R., Mueller, M., (2012). Global excellence at the expense of local diffusion, or a bridge between two worlds? Research in science and technology in the developing world. *Research Policy*, 41 (4): 756–769.

Bartlett, C. A., Ghoshal, S. (1988). Organizing for worldwide effectiveness: the transnational solution. *California Management Review*, 31, 54–74.

Beise, M., Stahl, H. (1999). Public research and industrial innovations in Germany, *Research Policy*, 28, 397–422.

Bekkers, R., Bodas Freitas, I. M. (2008) Analyzing preferences for knowledge transfer channels between universities and industry: to what degree do sectors also matter? *Research Policy*, 37: 1837–1853.

Bell, G. G., Zaheer, A. (2007) Geography, networks and knowledge flow, *Organization Science*, 18(6): 955–972.

Bercovitz, J., Feldman, M. (2008). Academic entrepreneurs: organizational change at the individual level, *Organization Science*, 19 (1): 69–89.

Boardman P. G., Ponomariov B. L. (2009). University researchers working with private companies. *Technovation* 29: 142–153.

Bodas Freitas, I.M., Geuna, A., Lawson, C., Rossi F, (2014) 'How do industry inventors collaborate with academic researchers? The choice between shared and unilateral governance forms' in P.P. Patrucco, (ed.) *The Economics of Knowledge*

Generation and Distribution: The Role of Interactions in the System Dynamics of Innovation and Growth, London, Routledge, pp.45-71, 2014.

Bodas Freitas, I., Geuna, A., Rossi, F. (2013a). Collaboration objectives and the location of the university partner: evidence from the Piedmont region in Italy, *Papers in Regional Science*, 93(S1): S203-S226.

Bodas Freitas, I., Geuna, A., Rossi, F. (2013b). Finding the right partners: Institutional and personal modes of governance of university-industry interactions, *Research Policy*, 42(1): 50-62.

Boschma, R. A. (2005). Proximity and innovation: a critical assessment, *Regional Studies*, 39: 61–74.

Bouba-Olga, O., Ferru, M., Pepin, D. (2012). Exploring spatial features of science-industry partnerships: a study on French data. *Papers in Regional Science,* 91(2): 355-375.

Broström, A. (2010).Working with distant researchers—Distance and content in university–industry interaction, *Research Policy*, 39: 1311–1320.

Broström, A., Baltzopoulos, A. (2010) Attractors of talent: Universities, regions, and alumni entrepreneurs, CESIS Working Paper Series in Economics and Institutions of Innovation ; 239.

Busom, I., Fernándes-Ribas, A. (2008). The impact of firm participation in R&D programmes, *Research Policy*, 37: 240–257.

Cantwell , J. and Piscitello, L. (2005). Recent location of foreign-owned research and development activities by large multinational corporations in the European regions: The role of dpillovers and externalities, *Regional Studies*, 39(1): 1-16.

Castellani, D. and Zanfei, A. (2006) *Multinational firms, innovation and productivity*, Cheltenham: Edward Elgar.

Chesbrough, H.W. (2006) Open business models. Harvard Business School Press, Boston, MA.

Cohen, W.M. and Levinthal, D. (1990). Absorptive capacity: a new perspective on learning and innovation, *Administrative Science Quarterly*, 35: 128–152.

Cohen, W.M., Nelson, R.R., Walsh, J. (2002). Links and impacts: the influence of public research on industrial R&D, *Management Science*, 48: 1–23.

Crane, D. (1969). Social structure in a group of scientists: A test of the invisible college hypothesis, *American Sociological Review*, 34: 335-352.

Crescenzi, R., Filippetti, A., Iammarino, S. (2017). Academic inventors: collaboration and proximity with industry, *Journal of Technology Transfer*, DOI 10.1007/s10961-016-9550-z.

D'Este, P., Fontana, R. (2007). What drives the emergence of entrepreneurial academics? A study on collaborative research partnerships in the UK, *Research Evaluation*, 16 (4): 257–270.

D'Este, P., Iammarino, S. (2010). The spatial profile of university-business research partnerships, *Papers in Regional Science*, 89(2): 335-350.

D'Este, P., Patel, P. (2007). University–industry linkages in the UK: what are the factors underlying the variety of interactions with industry? *Research Policy* 36(9):1295-1313.

D'Este, P., Guy, F., Iammarino, S. (2013) Shaping the formation of university-industry research collaborations: what type of proximity does really matter? *Journal of Economic Geography*, 13, 537-558.

Dunning J.H. (1977). Trade, Location of Economic Activity and the MNE: A Search for an Eclectic Approach. In: Ohlin B., Hesselborn PO., Wijkman P.M. (eds) *The International Allocation of Economic Activity*. Palgrave Macmillan, London

Eurostat (2017). Main database, https://ec.europa.eu/eurostat/data/database (accessed March 2019).

Fassio, C., Geuna, A. and Rossi F. (2019). Which governance of university-industry interactions increases the value of industrial inventions? Forthcoming on *Industrial and Corporate Change*.

Figueiredo, P. (2011). The role of dual embeddedness in the innovative performance of MNE subsidiaries: evidence from Brazil. *Journal of Management Studies*, 48, 417–40.

Frame, J.D., Carpenter, M.P. (1979). International research collaboration. *Soc. Stud. Sci.* 9 (4): 481–497.

Fritsch, M. (2001). Co-operation in regional innovation systems. *Regional Studies* 35(4): 297-307.

Fritsch, M., Schwirten, C. (1999). Enterprise-university co-operation and the role of public research institutions in regional innovation systems, *Industry and Innovation*, 6: 69–83.

Giuliani, E., Morrison, A., Pietrobelli, C., Rabellotti, R. (2010). Who are the researchers that are collaborating with industry? An analysis of the wine sectors in Chile, South Africa and Italy, *Research Policy*, 39: 748–761.

Kelchtermans, S., Grabowska, M., Belderbos, R., Leten, B., Riccaboni, M., Jacob, J. (2017). Phone home? Headquarters' involvement in foreign university collaboration, *Academy of Management Proceedings*, 2017, n.1.

Grotz, R., Braun, B. (1997). Territorial or trans-territorial networking: spatial aspects of technology-oriented cooperation within the German mechanical engineering industry, *Regional Studies*, 31: 545–557.

Gulati, R. (1995). Social structure and alliance formation patterns: a longitudinal analysis, *Administrative Science Quarterly*, 40: 619–652.

Hanel, P., St-Pierre, M. (2006). Industry–university collaboration by Canadian manufacturing firms, *Journal of Technology Transfer*, 31(4): 485-499.

Hong, W., Su, Y-S. (2013). The effect of institutional proximity in non-local university–industry collaborations: An analysis based on Chinese patent data, *Research Policy*, 42: 454– 464.

Hughes, A. and Martin, B. (2012). Enhancing impact: the value of public sector R&D. Cambridge, UK: Centre for Business Research and UK_IRC.

ISTAT (2018). I.Stat Database, Istat, Roma.

Jensen, R. J., Szulanski, G. (2004). Stickiness and the adaptation of organizational practices in cross-border knowledge transfers. *Journal of International Business Studies*, 35 (6): 508–523.

Knoben , J., Oelremans, L.A.G. (2006). Proximity and inter-organizational collaboration: a literature review, *International Journal of Management Reviews*, 8: 71–89.

Kotabe, M., Dunlap-Hinkler, D., Parente, R., Mishra, H.A. (2007). Determinants of cross-national knowledge transfer and its effect on firm innovation, *Journal of International Business Studies*, 38(2): 259-282.

Larson, A. (1992). Network dyads in entrepreneurial settings: a study of the governance of exchange relationships, *Administrative Science Quarterly*, 37(1):76–104.

Laursen, K., Reichstein, T., Salter, A. (2011). Exploring the effect of geographical proximity and university quality on university–industry collaboration in the United Kingdom, *Regional Studies*, 45(4): 507-523.

Lennox, C.S., Park, C.W. (2007) Audit Firm Appointments, Audit Firm Alumni, and Audit Committee Independence, *Contemporary Accounting Research*, 24(1): 235-258.

Kelchtermans, S., Grabowska, M., Belderbos, R., Leten, B., Riccaboni, M. and Jacob J. (2017) Phone Home? Headquarters' Involvement in Foreign University Collaboration, *Academy of Management Proceedings*,

Kotabe, M., Dunlap-Hinkler, D., Parente, R. and Mishra H.A. (2007). Determinants of Cross-National Knowledge Transfer and Its Effect on Firm Innovation, *Journal of International Business Studies*, 38: 259-282

Mansfield, E., Lee (1996). The modern university: contributor to industrial innovation and recipient of industrial R&D support, *Research Policy*, 25: 1047–1058.

Meyer, K., Mudambi, R., Narula, R. (2011). Multinational enterprises and local contexts: The opportunities and challenges of multiple embeddedness. *Journal of Management Studies,* 48(2): 235–252.

MIUR (2017) Portale dei dati dell'istruzione superiore, http://ustat.miur.it/ (accessed March 2019).

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: 133-145.

Monjon, S., Waelbroeck, P. (2003). Assessing spillovers from universities to firms: evidence from French firm-level data, *International Journal of Industrial Organization*, 21: 1255–1270.

Montobbio, F., Sterzi, V. (2011). Catching up, spillovers and innovation networks in a Schumpeterian perspective. Springer Berlin Heidelberg, Heidelberg.

Mudambi, R., Navarra, P. (2004). Is knowledge power? Knowledge flows, subsidiary power and rent-seeking within MNCs. *Journal of International Business Studies*, 35 (5): 385–406.

Muscio, A. (2012). University-industry linkages: What are the determinants of distance in collaborations?, *Papers in Regional Science*, 92 (4): 715-740,

Nahapiet, J., Ghosal, S. (1998). Social capital, intellectual capital and the organizational advantage, *Academy of Management Review*, 23(2): 242–266.

Nell, P., Ambos, B. (2013). Parenting advantage in the MNC: An embeddedness perspective on the value added by headquarters. *Strategic Management Journal*, 34(9): 1086–1103.

North, D. C. (1990). Institutions, institutional change and economic performance. Cambridge: Cambridge University Press.

Oettl A. and Agrawal A. (2008). International Labor Mobility and Knowledge Flow Externalities, *Journal of International Business Studies*, 39: 1242-1260

Messeni Petruzzelli, A. (2011). The impact of technological relatedness, prior ties, and geographical distance on university-industry collaborations: a joint patent analysis, *Technovation*, 31:309-319.

Perri, A., Scalera, V.G., Mudambi, R. (2017), What are the most promising conduits for foreign knowledge inflows? innovation networks in the Chinese pharmaceutical industry, *Industrial and Corporate Change*, 26(2): 333–355

Phene, A. and Almeida P. (2008). Innovation in multinational subsidiaries: The role of knowledge assimilation and subsidiary capabilities, *Journal of International Business Studies*, 39:901–919

Ponds, R. (2009). The limits to internationalization of scientific research collaboration, *Journal of Technology Transfer*, 34 (1): 76–94.

Riba-Vilanovam M., Leydesdorff, L. (2001). Why Catalonia cannot be considered a regional innovation system, *Scientometrics*, 50: 215–240.

Rõigas, K. Seppo, M., Varblane, U., Mohnen, P. (2014) Which firms use universities as cooperation partners? The comparative evidence, University of Tartu Working Paper.

Salter, A.J., Martin, B.R. (2001) The economic benefits of publicly funded research: a critical review, *Research Policy*, 30: 509-532.

Schartinger, D., Rammer, C., Fischer, M.M., Fröhlich, J. (2002). Knowledge interactions between universities and industry in Austria: sectoral patterns and determinants, *Research Policy*, 31: 303–328.

Storper, M., Venables, A. (2004) Buzz: face-to-face contact and the urban economy, *Journal of Economic Geography*, 4(4), 351-370.

Suzuki S, Belderbos R, Kwon H, (2017), The location of multinational firms' R&D activities abroad: Host country university research and R&D heterogeneity, *Advances in Strategic Management*, 36:127-162.

Tether, B.S. (2002). Who co-operates for innovation, and why. An empirical analysis, *Research Policy*, 31: 947–967.

Thune, T. (2007). University–industry collaboration: the network embeddedness approach, *Science and Public Policy*, 34(3): 158–168.

Uzzi, B. (1996). The sources and consequences of embeddedness for the economic performance of organizations: the network effect. *American Sociological Review*, 61(4): 674–698.

Uzzi, B. (1997). Social structure and competition in interfirm networks: the paradox of embeddedness, *Administrative Science Quarterly*, 42, 35–67.

Vitali, G., Calabrese, G., Filippo, M. (2011) Rapporto sull'industria in Piemonte. CERIS, Regione Piemonte.

Weterings, A., Ponds, R. (2009): Do regional and non-regional knowledge flows differ? An empirical study on clustered firms in the Dutch life sciences and computing services industry, *Industry and Innovation*, 16:1, 11-31.

Yusuf, S. (2008). Intermediating knowledge exchange between universities and businesses, *Research Policy*, 37: 1167–1174.

Zucker, L.G., Darby, M.R. (2001). Capturing technological opportunity via Japan's star scientists: evidence from Japanese firms' biotech patents and products, *Journal of Technology Transfer*, 26: 37–58.