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'How do firms reach out to foreign universities? Inventors' personal characteristics and the multinational structure of firms'

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A B S T R A C T

We analyze the determinants of firm-based inventors' collaborations with universities abroad, comparing them with collaborations with national universities. We propose a micro-founded theoretical framework that introduces the role of personal linkages and global organizational pipelines as drivers of international academic collaborations, and we empirically investigate collaborations with national and international universities in a sample of inventors in Italy. We find that in general international collaborations depend positively on inventors working for multinational enterprises (MNEs). Instead for collaborations with national universities, the personal local linkages of the inventors play a large role. However, we also find that for collaborations with *very distant* universities abroad, such as US ones, working for an MNE is less crucial and the personal linkages of inventors become more important. In this case being an inventor with a network of foreign colleagues and with greater acquaintance with the norms of open science facilitates the interaction. This applies also to inventors who work for MNEs. The results point to a hybrid model of global linkages in the case of collaborations between firms and universities, in which both the personal international linkages of the inventors and the global organizational pipelines of MNEs play an important role.

1. Introduction

Collaborations between firms and universities represent a relevant driver of technological change and of new knowledge creation. 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 (Mortara & Minshall, 2011; Belderbos et al., 2017), eventually leading to radical innovations and technological breakthroughs (Block & Keller, 2008), or to the shortening of development times for new products (Mansfield, 1991). Evidence shows that firms often collaborate with universities that are closely located (Almeida & Phene, 2004; Cantwell, 2009; Belderbos et al., 2013). This is because of the important roles of trust (Uzzi, 1996) and common practices and norms (Crescenzi et al., 2017), which are facilitated by spatial proximity. However, collaborations between firms and universities have increasingly started to cross national borders. Nowadays international collaborations with universities represent a common practice among firms (Gassmann & Keupp, 2007; Li, 2010), in particular when it comes to large multinational enterprises (MNEs) screening for science-based knowledge (Tijssen, 2009; Castellani et al., 2013; Belderbos et al., 2021).

Yet, there have been very few investigations of the main drivers and factors that facilitate the establishment of international collaborations between firms and universities (Kelchtermans et al., 2017; Belderbos et al., 2021). In particular there is scarce knowledge about the specific role that the individuals that are directly involved in the development of new products and processes, namely the inventors employed by firms, might play in this process. In this paper, we aim to address this gap in knowledge by investigating the factors that allow firm-based inventors to establish collaborations with universities abroad.

The factors that are conductive to the establishment of international connections between organizations have been examined by studies of

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international knowledge linkages and global connectivity (Lorenzen & Mudambi, 2013; Turkina & Van Assche, 2016; Li & Bathelt, 2018). This stream of literature has convincingly shown that international knowledge linkages can be organized in quite different ways, depending on the extent to which the coordination of the interactions is centralized, and on the relative importance of organizations vis a vis individuals in the orchestration of such collaborations (Lorenzen & Mudambi, 2013). In particular, at one extreme of this categorization is the so-called "global pipelines" model, where knowledge flows through the intra-corporate structure of large MNEs, across their networks of subsidiaries (Bathelt et al., 2004). At the other extreme are instead the personal linkages of individuals, who interact based on some common ground that allows them to decrease the transaction costs involved in their interactions. This can be the case of ethnic communities of highly skilled workers scattered across different countries (Saxenian, 1999; Docquier & Rapoport, 2012), or that of scientific communities of individuals working for different public institutions across the world, sharing a common scientific language and a range of scientific interests (Perri et al., 2017).

These different models may also be at play in the context of international collaborations between firms and universities. Such collaborations usually involve, on the one hand, highly-skilled employees (often inventors) working for corporate groups (in most cases large MNEs), and on the other hand university researchers. The inventors working for corporate groups, can be assumed to rely more on the global pipelines model, orchestrated by their firms. The university researchers, instead, usually interact through personal international linkages developed through engagement with other participants in shared communities of practice. International firm-university collaborations are therefore an interesting case in order to understand whether these two types of governance of international linkages can coexist, and how they are managed by firms (Cano-Kollmann et al., 2016). Indeed, firm-based inventors may benefit from the access to intra-corporate channels of screening and searching for knowledge organized at the firm level (Almeida et al., 2002), which may also include international universities. However, when collaborating with university researchers, especially distant ones, inventors may also benefit from having their own personal international linkages, driven by their own personal attributes, which facilitate collaborations with the academic community. Studying the relevance of personal attributes at the inventor level, which may facilitate the establishment of international collaborations with universities, can also shed light on the role of individuals working as boundary spanners within MNEs (Schotter et al., 2017). Indeed recent literature shows the relevance of individual factors in the mobilization of knowledge across the boundaries of MNEs (Tippmann et al., 2014; Mäkelä et al., 2019; Pedersen et al., 2019; Castellani et al., 2022).

We propose a micro-founded theoretical framework that introduces the role of personal and organizational factors as drivers of international collaborations between firms and universities. More specifically we propose that international collaborations will be more likely when firm-based inventors had an international career, when they earned their education abroad and when they have familiarity with the norms of open science, as shown by their publications. We also propose that the global pipelines orchestrated by MNEs play a role: inventors working for MNEs should be more likely to engage in international collaborations with universities. Finally, we suggest that personal characteristics play an important role also among inventors working for MNEs, precisely because also MNEs can benefit from the boundary spanning activities of inventors who have international education and career backgrounds and/or who are better acquainted with academic communities.

We rely upon a mixed method approach that combines an original survey of 915 firm-based inventors (individuals employed by firms who are named as inventors on one or more patents) based in the Italian region of Piedmont, and a set of in-depth interviews with 5 individuals that are part of the same sample. Distinguishing between national (based in the same region or in another region in Italy), and international universities (in Europe or in North America), we analyze to what extent interactions with universities in these different locations are enabled by: (i) the different personal attributes of firm-based inventors, related to the inventors' past education, career, and engagement in scientific research, and (ii) organizational factors related to the inventors' current employment, in particular for those employed by MNEs.

We find that interactions with national universities are facilitated by the personal linkages of the inventors, stemming from their education or career. Instead, interactions with international universities depend crucially on the role of global MNE pipelines. Relevant differences emerge when we distinguish between collaborations with universities in Europe *vis a vis* the United States (US). In the first case it is mainly the global pipeline model that emerges: only working for an MNE matters, while inventors' personal linkages are less relevant. In the case of universities in the US, instead, we find that the inventors' personal international linkages are important: having a network of foreign colleagues and having a relatively high number of publications does matter. Moreover, in this case the global pipeline provided by the MNE only plays a role if the MNE is also North American. The positive impact of personal linkages holds also for the inventors working for MNEs, hence highlighting that even for large international organizations it is crucial to have individuals who, thanks to their personal characteristics, can act as boundary spanners with distant external collaborators.

This paper contributes to the literature in several ways. First, our analysis is relevant for the literature that studies the factors underpinning the development of global innovation networks (Cano-Kollman et al., 2016; Mudambi et al., 2018), focusing in particular on the research-based part of the innovation process, which constitutes the most upstream part of the value chain, and where, according to some evidence, collaborations have a particularly strong impact on innovation (Un & Asakawa, 2015). By considering both the individual attributes of inventors and the features of the organizations where they are employed, the paper highlights the different weight of personal linkages and global organizational pipelines in structuring international knowledge linkages. In this respect the paper contributes to the knowledge connectivity literature and to the recent calls to analyze models of knowledge connectivity, in which both organizational and personal factors play a role (Cano-Kollman et al., 2016, p. 260). In doing so, the study provides some new empirical evidence about the role of boundary spanners in cross-border inter-organizational collaborations, such as the ones with international universities. The international business literature so far has analyzed the role of boundary spanners in global organizations, looking at the role of managers or other skilled employees (Schotter & Beamish, 2011). The role of firm-based inventors as boundary spanners has been highlighted by studies on the international careers of inventors (Castellani et al., 2022), looking specifically at their ability to better integrate the dispersed network of subsidiaries (Marino et al., 2020), i.e. as intra-firm boundary spanners. However, no study has analyzed the specific role of inventors as potential inter-organizational boundary spanners for MNEs. This is particularly important when it comes to international collaborations with universities. As shown by Perri et al. (2017) university researchers' international connections are substantially different from the connections of firm employees, since they tend to rely on personal contacts. Our study shows that inventors that can more easily establish personal contacts with university researchers, are able to play an important role as boundary spanners when global groups need to collaborate with distant universities.

Second, by uncovering the attributes of firm-based inventors that support their engagement with international universities, the paper is contributing to an expanding research stream on the micro-foundations of organizational behavior in international business. As Foss and Pedersen (2019) note, adopting a micro-foundations perspective is generative of theoretical and empirical progress, since it allows to uncover "the basic cogs and wheels producing more aggregate and usually more directly observable [international management] phenomena" (Foss & Pedersen, 2019, p. 1595). Our analysis is well-aligned with this perspective: on the one hand we show that context matters, because the type of organization the inventors works for plays a role in the type of academic collaborations they are able to establish, not only when it comes to MNE versus non-MNEs, but also in terms of the specific type of MNE (foreign-owned versus domestically-owned). On the other hand our results show that the role of individual agency should not be undervalued, since the personal linkages of the inventors are also able to explain the establishment of the most distant international collaborations. Hence, while the structural positions of inventors in their employer organizations act as situational factors (Johns, 2006) which affect their opportunities for engaging in knowledge sharing with distant universities, their individual attributes also play a role in favouring such knowledge sharing actions.

Lastly, our study is one of the first to analyze the drivers of international knowledge sharing between firms and universities specifically, as opposed to international knowledge sharing involving other types of actors. Knowledge sharing in an international context (i.e., cross-border knowledge and intra-MNE knowledge sharing) is a large field of study in IB; however, the focus of the majority of these studies is on knowledge sharing between headquarter and subsidiaries, between subsidiaries, or between partners in strategic alliances, with very limited attention paid to international knowledge sharing involving universities (Ribeiro et al., 2015). The topic has begun to attract some attention, with recent work analyzing the interactions between MNE headquarters and international universities at the organizational level; (Kelchtermans et al., 2017; Belderbos et al., 2021) however, this remains an emerging area of research.

2. Literature review and hypotheses

2.1. The specificities of interactions between firms and distant universities

Much empirical evidence suggests that firms are more likely to initiate collaborations with universities that are geographically close (Belderbos et al., 2013; Crescenzi et al., 2017). Reasons include easier transmission of tacit knowledge (Boschma, 2005; Storper & Venables, 2004), greater trust and easier communication due to common cultural norms (Uzzi, 1996; Li et al., 2010), and policies and funding that promote local cooperation (Hong & Su, 2013). At the same time, there is some evidence of interactions between firms and distant universities. For example, studies of biotechnology and pharmaceutical firms (Gassmann and Keupp, 2010; Tijssen, 2009;) have highlighted their cross-border collaborations with universities. MNEs frequently engage in collaborations with distant universities in order to tap into local scientific networks in the host regions (Castellani et al., 2013; Belderbos et al., 2021)

Engaging with distant universities might generate important benefits for firms, as it can provide them with access to frontier knowledge not available locally (Monjon & Waelbroeck, 2003). Collaborations with distant universities are more likely to focus on basic and cutting-edge research rather than applied research (Frame & Carpenter, 1979; Mansfield & Lee, 1996), on long term, more exploratory R&D projects rather than on projects with a short time to market (Lutchen, 2018; Broström, 2010; Bignami et al., 2020), and to involve top ranked institutions (Mansfield & Lee, 1996; Adams, 2005). Firms that interact with distant universities act as conduits for flows of knowledge into the local economy (Barnard et al., 2012), which can spill over to other local firms (Görg & Strobl, 2005; Ponds, 2009).

Limited research, however, exists on the factors that facilitate collaborations between firms and universities beyond national borders, particularly untangling the roles of personal linkages and global organizational pipelines (Ribeiro et al., 2015). The small body of existing research on international collaborations between firms and universities, positioned mainly within the innovation studies and economic geography literatures, almost exclusively focuses on firm-level characteristics which make it easier for firms to manage such collaborations, in particular the firms' absorptive capacity and its resources (Hong & Su, 2013; Laursen et al., 2011). These studies overlook both the role of industrial inventors' individual attributes that might facilitate the formation of international personal linkages, and the role of organizations' global pipelines. At the same time, studies that contrast the role of personal linkages and global organizational pipelines in the development of international knowledge linkages focus on knowledge sharing between headquarter and subsidiaries, between subsidiaries, or between partners in strategic alliances, rather than between firms and universities (Tippmann et al., 2014; Pedersen et al., 2019). In the following section, we propose several hypotheses concerning specifically the role of the individual attributes of inventors and of the features of the organizations where they are employed, in facilitating the development of linkages with universities beyond national borders.

2.2. Hypotheses

2.2.1. Inventors' individual attributes facilitating the development of personal linkages with international universities

2.2.1.1. International career. We expect that inventors who have experience of working abroad should be more likely to establish collaborations with international universities, than inventors who lack such experience, for at least two main reasons. First, over the course of their careers, individuals accumulate personal contacts that include previous co-workers and employers. The career contacts of an individual who has worked abroad may directly include academics who work at foreign universities, encountered in previous collaborative projects or at academic or industry conferences. Former colleagues abroad may also be able to connect them with academic researchers in their local university. Oettl and Agrawal (2008) show that inventors who move across national borders maintain strong links with researchers in countries where they had previously worked. Internationally mobile inventors indeed can act as bridges between their country of origin and the host country, increasing the amount of international collaborations (Marino et al., 2020). Jonkers and Tissen (2008) find that Chinese researchers who have returned home after a period of work abroad keep collaborating with the institutes in their former host countries. These relationships, sometimes referred to as the 'invisible college' (Crane, 1969), facilitate further collaborations in that locality. Both the presence of direct relationships with academics working at foreign universities and the invisible college effect, increase the probability that inventors who have experience of working abroad will be able to engage in international collaborations with university researchers, compared with individuals without such experience.

Second, the experience of living and working in a different country for an extended period increases an individual's intercultural sensitivity and their ability to work in culturally diverse settings (Li et al., 2012; Heinzmann et al., 2015; Wolff & Borzikowsky, 2018). This in turn can facilitate interactions with people from other cultures, in a range of different contexts including creative collaborations (Chua et al., 2012) and management of teams (Mor et al., 2013; Leung et al., 2014). Evidence suggests that the probability of a knowledge flow between distant inventors increases when these inventors share a common cultural background (Agrawal et al., 2008), and that firm employees and university researchers within joint university-industry laboratories are more likely to collaborate when they are culturally close (Mahdad et al., 2020). Hence, individuals who have experience of working abroad are likely to have developed greater intercultural skills that facilitate their engagement with academics working at universities abroad.

> H1: Having a non-local career increases the individual's likelihood to interact with universities abroad.

2.2.1.2. International education. When faced with problems during their innovation activity, industry staff can benefit also from the network of contacts built during their university education. This network persists after graduation and is available to enable interactions with the academic community in the future. Universities strive to maintain contacts with their alumni in part to obtain future benefits (contract income, donations, prestige). The importance of these relationships for future interactions is confirmed by several studies. It has been shown that entrepreneurs disproportionately localize their startups in the region where they studied (Broström & Baltzopoulos, 2010), and that graduates often rely on connections established during their university days when faced with a problem whose solution requires theoretical or applied academic knowledge (Fassio et al., 2019). While acknowledged in practice, the effect of the networks established during an individual's university education on subsequent university-industry interactions is considered only rarely in the literature (Bekkers & Bodas Freitas, 2008), and perhaps for data reasons it has not been studied quantitatively. Bodas Freitas et al. (2014), using the same dataset analyzed in this paper, provide some preliminary econometric evidence showing that firm-based inventors are more likely to establish personal interactions with academics from their alma mater. In the presence of this effect, firm-based inventors who graduated from a local (regional, national) university will be more likely to interact with a local (regional, national) university, while inventors who graduated from a university abroad will be more likely to engage internationally. The latter effect would be due primarily to the direct personal relationships of the graduate from a university based abroad with academics in that university. It would depend also on the general network of contacts built abroad, which can be exploited to make an initial connection with a distant university. This experience and network increase the graduate's understanding of how the university system works in that country and of the culture of universities there, which facilitate future interactions. Therefore, we hypothesize that:

H2: Having a degree awarded by non-local university increases the individual's likelihood to interact with universities abroad.

2.2.1.3. Familiarity with open science norms. Global linkages are also often facilitated by the existence of epistemic communities, based on personal connections, between individuals that, though working for different organizations, are interested in the same knowledge issues, and which ultimately lead to shared values and work practices (Lissoni, 2001; Cano-Kollmann et al., 2018). The participation of these geographically scattered individuals in the same communities of practice, facilitated by infrastructures such as conferences and journals, and the sharing of similar communication codes and work practices, could substantially compensate for their physical distance.

An important factor that can increase the probability of engagement of firm-based inventors with university researchers is the former's experience of performing scientific research. The goals and incentives of industry and academic research are often very different (Dasgupta & David, 1994): industry aims to develop knowledge that enhances the firm's competitiveness and thus needs to be protected from spilling over, whereas academia aims to expand the stock of knowledge and diffuse new discoveries as widely as possible. Academic research follows the norms of 'open science' according to which reputational rewards accrue to those who publish first, and therefore scientists aim to make their findings public as early as possible (Dasgupta & David, 1994). Individuals who for reasons of personal attitude and educational background are more accustomed to performing scientific research in the open science domain will have greater understanding of academic norms and therefore enjoy greater ability to interact with academics in general, even across geographical distances. In addition, they will have greater opportunities to meet academics by participating in the same global communities of practice, which might involve activities like attending the same scientific conferences, publishing in and reviewing articles for the same academic journals, being members of the same professional societies. This will facilitate the establishment of interactions and can substitute for the lack of geographical proximity (Ponds et al., 2007).

Therefore we hypothesize that:

H3: Personal engagement in scientific research increases the individual's likelihood to interact with universities abroad.

2.2.2. Inventors' reliance on global organizational pipelines facilitating interactions with international universities

2.2.2.1. Working for a MNE. We argue that working for a MNE reduces an individual's organizational distance to academics working in universities abroad, for at least two reasons. First, 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, they have a high level of absorptive capacity. More specifically, MNEs are capable of sourcing knowledge globally and transferring it within their internal organizational (subsidiary) networks (Castellani & Zanfei, 2006; Mudambi & Navarra, 2004; Phene & Almeida, 2008; Ambos & Ambos, 2009). MNEs are known to generate global pipelines (Bathelt et al., 2004) that make it easier to move resources, including knowledge, across geographical space (Mudambi & Navarra, 2004; Kotabe et al., 2007; Phene & Almeida, 2008; Michailova & Mustaffa, 2012; Nell & Ambos, 2013). Hence, employees in the various units (headquarter and subsidiaries) in a MNE are able to easily interact with each other taking advantages of the organizations' global pipelines. Once interactions with colleagues in distant locations are established, these can become indirect vehicles for further interactions with other local organizations, including universities. 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 (Kuemmerle, 1999; Ribeiro et al., 2015; Li, 2010; Jin et al., 2011). This potentially allows all of their subsidiaries to access centers of academic excellence. Each subsidiary can exploit the relationships forged by the MNE's other subsidiaries with their nearby universities.

Second, MNEs are particularly likely to have formal structures in place to organize and manage international projects, and to apply for large-scale public funding to support them. Such international projects often involve universities (Busom & Fernandez Ribas, 2008; Laursen et al., 2011; Rõigas et al., 2014). Participating in joint projects directly reduces the organizational distance between MNE staff and academics working in distant universities.

H4: Working for a firm that is part of a domestic or foreign-owned MNE increases the individual's likelihood to interact with universities abroad

2.2.3. The role of personal relationships for inventors working in MNEs

Even among MNEs the role of personal factors may play an important role. In other words, the hypotheses H1, H2 and H3 (on the importance of personal attributes) and hypothesis H4 (on the importance of global pipelines) should not necessarily been considered as alternative. In most cases working for a MNE allows inventors to rely on the global pipelines that these companies have built over the years, which may also include foreign universities. However, also large MNEs may benefit from having teams of inventors with experience abroad and acquainted with academic knowledge. Indeed, as shown by Perri et al. (2017) academics' and research institutions' international connection depend to a very large extent on personal linkages. Hence sometimes it may be difficult for MNEs to establish new distant collaborations with foreign academics if they lack specific personnel with substantial personal linkages.

According to this argument, the governance of international collaborations between firms and universities would follow a 'hybrid' model: in other words, we would expect that also MNEs may benefit from having inventors with international experience or acquaintance with academic norms, when they need to interact with distant academic institutions. The main difference with respect to domestic firms lies in the fact that for domestic firms personal factors/connections are most likely the *only* channel available to firms, while in the case of MNEs both the global pipelines and the personal factors may play a role. Accordingly, we spell out the final hypothesis:

> H5: The positive effect of having a non-local career and educational background and of personal engagement in scientific research applies also to inventors working for MNEs.

3. Data and methodology

For the empirical analysis, we rely on an original survey of firm-based inventors, aimed specifically at investigating their collaborations with universities (including their geographical dimension), complemented with in-depth interviews with 5 inventors most of whom are part of the same sample.

3.1. The PIEMINV survey

The PIEMINV survey questionnaire[1] was sent to the population of inventors with addresses in the Italian region of Piedmont[2] who had applied for at least one European Patent Office (EPO) patent in the period 1998–2005 (3922 patents and 3027 inventors) and who were employed by a firm. Addresses were collected from EPO patent applications, and updated based on telephone registry information and telephone contact with the firms. After cleaning and confirming the address data, we administered 2916 questionnaires to firm-based inventors by email and surface mail between autumn 2009 and spring 2010. We obtained 938 valid responses (response rate 31%).

The questionnaire was structured in four sections as follows: (i) 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); (ii) role of university knowledge in the development of the inventions; (iii) the inventor's involvement in collaborations with universities; (iv) assessment of the economic impact of university knowledge.

In relation to their involvement in collaborations with universities, inventors were asked information about which universities they engaged with, and how often, allowing for the following possible categories of answers: each of the universities in the region; universities in other Italian regions; universities in other European countries, in the US, or in other countries. The responses to these questions provided crucial information to explore the extent to which inventors interacted with universities in different locations.

We collected information about inventors' patents, such as: 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.[3] These data were available for all the inventors in our sample. 23 inventors who reported to be working for a public institution (university, public research organization, government body) were excluded from the analysis, reducing our observations to 915.

Additional information about the inventors' employers was collected from the CERVED database of Italian firms' accounts, and other public online sources.[4] This information was available for 298 out of 363 firms in the sample (or 738 inventors), excluding many non-public small/micro firms. We collected the number of patents filed by the firms from 1998 to 2005, from the Derwent Innovations Index. The firm information was complemented with a matching methodology that allowed us also to link the companies to the Orbis dataset. This has allowed us also to retrieve information about the Global Ultimate Owner of each firm, the location of the headquarters and the presence of foreign subsidiaries. We also collected information from Scopus about the inventors' publication activity (through a manual work of disambiguation), including all their coauthors and their affiliation at the time of publication. Lastly for a number of inventors who have LinkedIn profiles we were able to find information about their career and education: this allowed us to find additional information about education abroad and job spells outside of Italy.

3.2. Methodology

We investigate what drives firm-based inventors' interactions with universities in different geographical locations, namely national and international universities. The PIEMINV survey asked inventors whether they had interactions with certain universities in Italy and abroad: this information was used to build our dependent variables. These are four ordinal variables indicating inventors' frequency of interactions with the following groups: (1) regional universities (Università di Torino and/or Politecnico di Torino), (2) other Italian universities (3) universities in other European countries, (4) universities in the US. 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), taking 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).[5]

3.2.1. Main equation: independent variables

3.2.1.1. International career and international education of the inventors. To test H1 we built two dummy variables to capture the international reach of the inventor's career. The variable *Foreign co-inventors* measures the number of times that we observe a foreign co-inventor (resident outside of Italy) among the inventor's patent portfolio. We only consider patents applied up to 2003, i.e. at least 5 years before 2008, the year when the survey was conducted. This should allow us to identify foreign personal contacts that the inventors already had before initiating the collaborations that they mentioned in the survey.[6]

The second variable that we use to test H1 captures the embeddedness of the inventor in the region. The variable *Local inventor* is equal to 1 if the inventor has never worked for 6 months or more outside the Piedmont region throughout his or her career: inventors who have worked only in Piedmont can be considered to be strongly embedded.

To test H2, we build three dummy variables to capture the international reach of the inventor's education: *Piedmont Degree* is equal to 1 if the inventor graduated from a university in Piedmont; *Italian Degree* is

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

[2] See Appendix A: The regional context, for a short description of the main characteristics of the Piedmont region.

[3] Classification by macro-technology classes is according to OST-DT7 (OST, 2004).

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

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

[6] In our robustness checks we have tested whether the results also hold when we only consider patents applied up to 10 years before (i.e before 1998).

equal to 1 if the inventor graduated from an Italian university in another region; *International Degree* is equal to 1 if the inventor's highest degree was granted by a foreign university.

3.2.1.2. Familiarity with open science norms. To test H3 we use the information on inventors' publications retrieved from Scopus. We are interested in identifying the inventors that have a high number of publications, thus sharing some understanding of academic norms and enjoying greater familiarity with open science norms. We create a variable, *Top-publications* which is equal to 1 if an inventor published more than 3 papers before 2003 and zero otherwise. We choose the threshold of 3 papers as this represents the 95% percentile of the publication distribution among the sample of inventors, that is, the 5% inventors with the highest propensity to publish. Again, we only use publications before 2003 to make sure that the publications are not the direct outcome of the international collaborations with universities.

3.2.1.3. Working for a domestic or foreign-owned MNE. To test H4, we built three 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 firm with foreign affiliates. The second *Employed by a European MNE* if the inventor's employer is a European (not Italian)-owned MNEs, the third is *Employed by a North American MNE* if the inventor is employed by a North American-owned MNEs. The other inventors are classified as *Employed in domestic firms* with no affiliates abroad: this category will be used as the benchmark category in our estimations.

3.2.2. Main equation: control variables

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

First, we control for individual inventor characteristics such as age (since there might be different propensities to interact with specific universities across generations) and gender. Second we control for the inventor's firm's technology intensity (measured as the firm's absolute number of *granted patents*) and size (*Less than 50 employees* is considered a small firm; *50–250 employees* is a medium sized one; and *More than 250 employees* indicates a large firm). The firm's academic knowledge recognition capabilities are correlated to its level of absorptive capacity (Cohen & Levinthal, 1990; Laursen et al., 2011), and indeed larger firms and those with greater technological intensity, considered as a proxy for absorptive capacity (Tether, 2002; Mohnen & Horeau, 2003) are more likely to interact with universities. These advantages also facilitate more distant collaborations. Studies investigating the characteristics of firms that interact with universities in their own as opposed to another region (e.g. Laursen et al., 2011) show that larger, more technology intensive firms, are more likely to interact with universities outside the region and to have a larger number of interactions; while firms in less developed regions and lacking sufficient absorptive capacity are less able to benefit from international collaborations with universities (Qiu et al., 2017).

We also control for the role of publicly funded research projects. As highlighted by all of our interviewed inventors working for MNEs, it is often the case that collaborations with universities abroad are facilitated by publicly-funded projects that involve the creation of international consortia with companies and universities. These consortia become an important vehicle to establish new collaborations with the partners of the project (which in the case of European Union funded project need to be located in different European countries). The variable *Publicly-funded projects* measures to what extent the inventors considered important institutional agreements between their company and universities that were funded by public funding. The variable is a Likert scale that measures whether inventors did not use these projects (value "0″: 67% of the sample), whether they used them but considered them of little importance (value "1″: 17% of the sample) or whether they used them and considered them important (value "2″: 15% of the sample).

Finally, we control for the technology class in which the inventor patents. The incidence of local and international interactions has been found to differ across sectors and technologies (Abramovsky et al., 2007; Ponds et al., 2007; Crescenzi et al., 2017). Since we are using inventor-level 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*).

3.2.3. Selection equation

The sample of inventors who collaborate with different universities is a nonrandom sample of the respondents of our sample. If there is an omitted variable in our main equation which is correlated with the decision of inventors to collaborate with universities in general and also with some of our main independent variables of interest, estimations of the main equations might be at risk of selection bias (Certo et al., 2016). To avoid this, for each of the main equations measuring the effect of different variables on the probability to interact with universities in different locations we estimate a selection equation (with the same specification for all main equations) which indicates whether inventors interact with a university at all.

This selection equation includes general determinants of firms' collaborations with universities, identified in the literature. We include both firm-level and individual-level variables. Some of these variables are also included in the main specification, as they are relevant both in the decision to collaborate or not with universities in general and in the decision to collaborate with specific universities. This is case of firm size. Firm size has been found to relate positively to the probability to collaborate with a university. This is because, compared to smaller firms, larger firms have more internal resources to collaborate with universities, and are more likely to be aware of university capabilities (Tether, 2002). We use the same firm size variables as in the main equation. Among individual characteristics we include *Age*, present also in the main equation, since there may be differences among generations of inventors in their propensity to collaborate with universities.[7] We also introduce some exclusion restrictions, i.e. variables, at the individual level, that are present only in the selection equation and not in the main equation. These variables are supposed to capture the inventors' absorptive capacity which is likely to increase their ability to interact with university researchers in general. While these variables are likely to influence the decision to collaborate with universities in general, they are not likely to influence the decision to collaborate with a specific university, national or international. We focus on four factors which we expect to increase the probability to collaborate: education, experience of having worked at a university, patent productivity and overall mobility of inventors across employers. The inventor's level of education is measured using a dummy, *Tertiary education*, which is equal to 1 for inventors with a bachelors or masters degree. Having worked in a university is measured with a dummy, *Worked at Uni*, which is equal to 1 if the inventor worked for at least one month at a university during their career. We use the number of patents the inventor applied for in 1998–2005 (*Patents applied for*) to proxy for the inventor's absorptive capacity. Lastly, we measure the mobility of inventors using a dummy variable, *Mobile inventor,* equal to 1 if the inventor has worked for more than 5 organizations overall (only a small share (6%) of our respondents are part of this group). Mobile inventors have been found to be on average more productive (Hoisl, 2009) and to enjoy a larger number of contacts (Miguelez & Moreno, 2013): both of these factors can also

[7] Typically in our sample we find that older inventors are less educated in general, so we could expect a slightly higher propensity to engage with university researchers among younger inventors, who are more likely to have earned a university degree.

Table 1
Interviews details.

Inventor	Company the inventor works for	Position	Collaborations with universities in other European countries	Collaborations with universities in the US
Inventor A	Italian MNE active in Tele-communications	R&D engineer	Frequent	Frequent
Inventor B	Foreign MNE active in Automotive supply	Manager product and technology development	Very Frequent	None
Inventor C	Italian SME active in Technology development in chemical, petrochemical and polymer field.	Owner	Very Frequent	Very Frequent
Inventor D	Italian SME active in the field in scientific instruments and complex systems for advanced research.	Executive director	Frequent	Frequent
Inventor E	Italian MNE active in Tele-communications	R&D group manager	N.A. (Snowball)	N.A. (Snowball)

Table 2
Descriptive statistics.

Variable	Mean	Std. Dev.	Min	Max
Career				
Local inventor	0,708	0,455	0	1
Foreign co-inventors	0,181	1058	0	16
Education				
International degree	0,038	0,191	0	1
Piedmont degree	0,501	0,501	0	1
Italian degree	0,154	0,362	0	1
Familiarity with open science				
Top publications	0,048	0,213	0	1
Working for a MNE				
Employed by a Foreign MNE	0,257	0,437	0	1
Employed by a European MNE	0,143	0,350	0	1
Employed by a North American MNE	0,107	0,310	0	1
Employed by an Italian MNE	0,520	0,500	0	1
Employed by a domestic firm	0,223	0,417	0	1
Individual characteristics				
Public funded projects	0,487	0,751	0	2
Male	0,900	0,300	0	1
Age	47,342	9493	29	77
Tertiary Education/Ph.D	0,720	0,450	0	1
Ph.D	0,040	0,197	0	1
Worked at Uni	0,109	0,312	0	1
Patents applied for 1998–2005	2375	2717	0	24
Mobile inventor	0,067	0,249	0	1
Firm characteristics				
Num of granted patents 1998–2005 (firm)	317,181	576,298	0	4808
Size: <50 employees	0,083	0,276	0	1
Size: 50–250 employees	0,112	0,315	0	1
Size: more than 250 employees	0,739	0,440	0	1
Technological field (OST7)				
Electronics	0,292	0,455	0	1
Instruments	0,128	0,335	0	1
Chemistry and materials	0,069	0,254	0	1
Pharmaceutical -Biotech	0,014	0,119	0	1
Mechanical engineering	0,342	0,475	0	1
Consumer goods (And Others)	0,055	0,228	0	1
Process engineering	0,100	0,300	0	1
Total number of observations				**421**

increase the likelihood to interact with academics.

3.2.4. The model

We are interested in the factors leading an inventor to interact with universities in each of the four locations, and the frequency of those interactions. We include four ordinal dependent variables, one for each type of location identified. Each equation includes the same set of independent and control variables as described in the previous paragraph.

$$INT_i^s = \alpha + \sum_j \beta_j MNE_{ij} + \sum_l \gamma_l CAREER_{il} + + \sum_m \delta_m EDUCATION_{im} + \eta\ PUBLISH_i + \sum_p \varphi_p X_{ip} + \varepsilon_i \quad (1)$$

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). *MNE* measures whether the inventor is employed by an MNE (headquarter or subsidiary of Italian owned-MNE, or Italian subsidiary of foreign-owned MNE). *CAREER* is a set of variables for whether the inventor has a local or international career. *EDUCATION* is a set of variables measuring whether the individual's education is local or international. *PUBLISH* is a variable measuring the individual's prior experience of engagement in science, as proxied by being among the inventors with more publications. We estimate Eq. (1) as four separate ordered probit regressions with sample selection,[8] i.e. including a selection equation in which the dependent variable is equal to 1 for inventors with some kind of collaboration with at least one of the different university types, and zero for inventors with no university collaborations. The independent variables in the selection equation are those indicated in Section 3.2.3.

3.2.5. Interviews

After the implementation of the survey a selected number of individuals were contacted for in-depth interviews for further validation of the model. We identified a small subset of inventors who indicated to have had frequent or very frequent collaborations with international universities. This is because, while we already know from previous literature the context in which local and national collaboration occur, we wanted to gain further insights about international collaborations.

We interviewed two inventors who worked for a MNE and two inventors who worked for a non-MNE domestic firm. Additionally, one of the inventors introduced us to a former manager of hers at the MNE where she worked, who also had extensive experience of international collaborations with universities, so we decided to add the manager to our interviewees. This composition allowed us also to check whether substantial differences in the establishment of collaborations with international universities existed between inventors working for MNEs and for non-MNE domestic firms, and to single out the role of the MNEs. The interviews were conducted in December 2020 and January 2021.[9] Since there are not many inventors in the sample who declared "frequent" or "very frequent" collaborations with international universities (29 and 17 respectively), these interviews, while exploratory in nature, may provide a relatively good account of some of the dynamics occurring within firms in Piedmont that establish international collaborations with universities, (Table 1).

[8] We adopt the Stata command "opsel" (De Luca & Perotti, 2011), which is a command specifically designed for this kind of settings and which jointly estimates -through a maximum-likelihood approach - the selection equation and the main equation.

[9] The inventors were asked questions about their collaborations with distant universities that occurred in the years 2005-2008: therefore these interviews were retrospective accounts of what happened more than 10 years before.

Table 3
Number of inventors employed by foreign MNEs by country of origin of the MNE.

Country of origin of Foreign MNE	Num of employed inventors
Austria	1
Belgium	4
Finland	1
France	6
Germany	7
Ireland	2
Luxembourg	2
Netherlands	6
Portugal	1
Spain	1
Sweden	12
Switzerland	6
UK	12
Total Europe	*61*
US	43
Canada	2
Japan	1
South Korea	1
Total	*108*

4. Results and discussion

4.1. Descriptive statistics

Table 2 presents some descriptive statistics for the sample of inventors used in our analysis. Not all of the 915 respondents to the PIEMINV survey provided information on all the variables used in the current analysis, and it was not possible to retrieve employment information for all of them. The part of the survey that asked about the collaborations with specific universities was answered by 421 inventors; additionally, full information was available for 228 inventors who did not interact with any university during their career, which were only included in the selection equation of our model: this leaves us with a total of 649 inventors included in our sample.[10]

Looking at the 421 inventors that collaborated with any one of the universities (regional, in other Italian regions or international) 70% of them had never worked for 6 months or more outside of the Piedmont region, suggesting a general low level of mobility. On average the inventors have only 0.1 patents with co-inventors abroad: indeed only 7% of inventors have some patents with foreign co-inventors.

About half of the inventors who collaborated with universities graduated 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 4% graduated abroad. This latter finding suggests that, while having studied at a regional or Italian university might affect the probability of collaborating with regional and Italian universities respectively, the limited number of international graduates is not likely to explain the high level of international collaborations.

For what concerns the organizations for which the inventors work, about half (219 in total) are employed by domestic (Italian-owned) MNEs, 30% of inventors work for the headquarters of an Italian MNE, while 22% work for the subsidiary of an Italian MNE with headquarters in other regions of Italy. 26% of the inventors are employed by foreign-owned MNEs (108): of these 61 are European, 45 are North American (two Canadian MNEs, the rest are US MNEs), 1 is Japanese and another one is South Korean. In Table 3 we also show the distribution by countries of inventors employed by foreign-owned MNEs distinguishing between Europe and North America. 22% of the inventors (94 in total) are employed by domestic (non-MNE) firms.

The mean age of inventors who collaborate with universities is 47 years old. Most have a university degree (71%) and 4% have a PhD. About 11% have worked at a university at some point in their career. A large majority (90%) are men, possibly because most inventors in Piedmont are engineers, a field where traditionally the share of women is quite low. In the seven years considered they had on average 2.3 patents filed at the EPO, with more than half of all inventors patenting in mechanical engineering and electronics: this is consistent with the technological specialization of the Piedmont region. Highly mobile inventors with more than 5 previous employers represent a small fraction of the total sample (6.7%), while 33% of inventors worked only for one firm in their entire career (irrespective of age).

Most inventors (74%) work in large firms with more than 250 employees with the remaining 25% distributed fairly equally among small and medium-sized firms. Firms had an average of 317 granted patents in the period 1998–2005. Looking more closely at the distribution of patents (not reported in Table 1) we find that about 25% of inventors were employed by firms with less than 10 registered patents, another 25% worked for firms that registered from 10 to 160 patents, and the remaining half worked for firms that were granted more than 160 patents (up to 4000 patents) in the period. Hence, many inventors work for firms that are quite productive in terms of patent registrations. Due to the high dispersion of this variable in the econometric model we use the log of the number of patents.

Table 4 presents the distribution of our ordinal dependent variables, distinguishing between university locations (regional, other Italian, other Europe/US). As expected, collaborations with regional universities are the most common (364 inventors). Collaborations with other Italian universities are the second most common (246 inventors), while 157 inventors (slightly less than half the number of those that interact with regional universities) reported collaborations with international universities. Among international universities we found collaborations with other European universities to be twice as frequent (146 cases) as US universities (74). Fig. 1 shows the distribution of the frequency of collaborations by university type for inventors declaring some collaboration. We observe a similar pattern of frequency of collaborations among regional, other Italian, and international universities. About 43%−47% of the inventors who collaborate with a specific university do so once every year or two ("rare" collaboration); 26%−28% of inventors collaborate more regularly (once or twice a year – "often"); 15%−19% collaborate "frequently" (3–6 times a year); and 10%−12% collaborate "very frequently" (every month or two). Hence the main difference between regional, national and international collaborations is that overall fewer inventors collaborate with an international university. Among those who do collaborate, the frequency of interactions is not significantly different. This suggests that once the channel of interaction has been established, geographical distance is not a factor inhibiting collaborations with distant researchers.

4.2. Econometric results

Table 5 presents the results of the separate ordered probit estimations of Eq. (1) in relation to the propensity to collaborate frequently with universities in the different locations. Column (3) presents the results for collaborations with international universities, without distinguishing between US and European ones; the results in columns (3a)

[10] We ran a t-test on each of the variables of our models to check whether there are substantial differences between the 649 observations used in our analysis and the 266 inventors who answered the PIEMINV survey for which we lacked some information and that were not included in our sample. For most of the variables we found no significant differences. We found significant differences for the following variables: *Worked at Uni* (lower for those not included), *Employed by an Italian MNE* (lower for those not included), Employed at a *Large firm* (lower for those not included), *Chemistry and materials* (higher for those not included), *Mechanical engineering* (lower for those not included). All in all, this confirms that inventors who worked for small non MNE firms, especially in the chemical sector were more likely to be excluded from our sample, but no major differences emerged between the individual characteristics of the two sets of inventors.

Table 4
Number of inventors who collaborate with universities in different locations.

	Total Answers	No collaboration	Some collaboration	Frequency of collaborations with the university			
				Rarely	Not often	Frequently	Very frequently
Regional or Italian	*421*	*7*	*414*	*170*	*112*	*75*	*57*
	100%	*2%*	*98%*	*41%*	*27%*	*18%*	*14%*
Regional University	411	47	364	170	102	56	36
	100%	*11%*	*89%*	*47%*	*28%*	*15%*	*10%*
Other Italian University	379	133	246	105	63	48	30
	100%	*35%*	*65%*	*43%*	*26%*	*19%*	*12%*
International University	355	198	157	70	41	29	17
	100%	*56%*	*44%*	*45%*	*26%*	*19%*	*11%*
Other European University	350	204	146	66	36	28	16
	100%	*58%*	*42%*	*45%*	*25%*	*19%*	*11%*
US University	347	273	74	36	24	10	4
	100%	*79%*	*21%*	*49%*	*32%*	*13%*	*5%*

Rare = once every two years; Not often = once or twice a year; Frequently = 3 to 6 times a year; Very frequently = once every month or two.

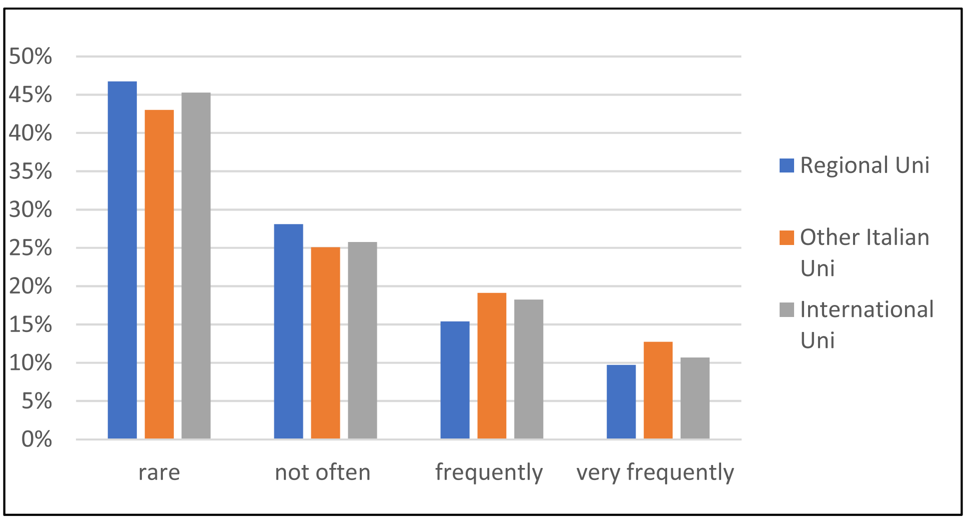

Fig. 1. Frequency of collaborations (%).

and (3b) distinguish between these two. The coefficients indicate the extent to which each variable increases the likelihood that an inventor collaborates frequently with a university in that location. Since selection bias might be an issue, we estimate Eq. (1) including a selection equation that estimates the likelihood of any type of collaboration with a university. The selection equation includes the same independent variables for each estimation. The results of the selection equation show that individual-level and firm-level variables strongly impact the probability of inventors to collaborate with universities. Having a university degree (*Tertiary education*), having been employed at a university during one's own career (*Worked at Uni*) and being a prolific inventor in terms of patents (*Patents applied by inventor*) increase the chances to have some kind of collaboration with universities regardless of their location. Working for a large firm also increases the likelihood of collaborating. We also find a positive but not significant effect of being a mobile inventor and a not significant effect of age. These results are in line with the existing literature: inventors working for larger firms (with higher absorptive capacity) and inventors with higher levels of human capital (as proxied by productivity, tertiary education and experience of work at university) are typically more likely to collaborate with universities.

The results of the main equation show that career and education factors play a role in the establishment of collaborations with universities. The coefficient of the variable *Foreign co-inventors* is only positive and significant in column (3b), which explains the frequency of collaborations with US universities. Hence having more foreign co-inventors increases only the likelihood of collaborating frequently with very distant universities (US). The coefficient of the dummy *Local Inventor* is positive and significantly different from zero for regional and Italian collaborations in columns (1) and (2), while it is negative and significantly different from zero in column (3b). This suggests that being a local inventor who never worked outside of the Piedmont region for more than 6 months increases the likelihood to collaborate with regional and Italian universities, and reduces the likelihood to establish collaborations with distant universities in the US.

Overall, H1 is partially supported: having international contacts is associated with international collaborations, but only very distant ones, with US universities, on the contrary a local career is associated with local interactions.

Having graduated from, respectively, a regional or Italian university increases the likelihood that an inventor will collaborate with a university in the same area, suggesting that direct acquaintance with academics at their alma mater (alumni) and localized personal relationships developed during university education may play a role in subsequent establishment of collaborations with a national university. Having graduated at a university abroad is not correlated to international collaborations, as shown by the non-significant coefficient of *International*

Table 5
Determinants of collaborations with universities, in different locations.

	(1) Regional University	(2) Italian University	(3) International University	(3a) European Universities	(3b) US University
Personal linkages variables					
Inventors' career					
Foreign co-inventors	0.028	0.038	0.044	0.042	0.101***
	(0.044)	(0.043)	(0.034)	(0.034)	(0.032)
Local inventor	0.297**	0.222*	−0.112	−0.097	−0.362**
	(0.126)	(0.121)	(0.116)	(0.118)	(0.149)
Inventors' education					
Piedmont degree	0.408**				
	(0.193)				
Italian degree		0.517***			
		(0.157)			
International degree			−0.031	−0.104	0.341
			(0.367)	(0.296)	(0.409)
Familiarity with open science					
Top publications	0.292	0.092	0.445*	0.436*	0.807***
	(0.320)	(0.334)	(0.234)	(0.239)	(0.276)
Global pipelines variables					
Working for MNEs					
Benchmark: working for domestic companies					
Employed by Italian MNE	0.185	0.199	0.319**	0.327**	0.250
	(0.177)	(0.168)	(0.151)	(0.145)	(0.226)
Employed by a European MNE	0.115	−0.142	0.443**	0.444**	0.263
	(0.210)	(0.201)	(0.176)	(0.180)	(0.245)
Employed by a North American MNE	0.366	0.118	0.459**	0.464**	0.558**
	(0.226)	(0.219)	(0.205)	(0.207)	(0.263)
Control variables					
Individual characteristics					
Male	−0.102	−0.223	−0.249	−0.203	−0.083
	(0.189)	(0.169)	(0.161)	(0.164)	(0.194)
Age	0.001	0.007	−0.000	−0.000	−0.002
	(0.006)	(0.007)	(0.007)	(0.007)	(0.008)
Publicly-funded projects	0.219***	0.194***	0.194***	0.199***	0.150*
	(0.078)	(0.073)	(0.068)	(0.071)	(0.079)
Firm characteristics					
Benchmark: less than 50 emp.					
50–249 employees	0.154	−0.111	−0.306	−0.236	−0.650**
	(0.245)	(0.230)	(0.208)	(0.213)	(0.286)
more than 249 employees	0.124	0.008	−0.024	−0.061	−0.145
	(0.254)	(0.227)	(0.214)	(0.240)	(0.237)
(Log) num of patents (firm)	−0.052	0.011	−0.039	−0.035	−0.065
	(0.040)	(0.044)	(0.039)	(0.041)	(0.047)
Technology dummies	YES	YES	YES	YES	YES
Selection equation					
Age	0.001	0.000	−0.001	−0.002	−0.002
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Tertiary education	0.938***	0.983***	0.948***	0.941***	0.926***
	(0.123)	(0.123)	(0.134)	(0.142)	(0.130)
Worked at uni	0.502**	0.642**	0.821***	0.830***	0.807***
	(0.253)	(0.256)	(0.279)	(0.293)	(0.287)
Patents applied by inventor	0.070***	0.059**	0.048**	0.051**	0.056**
	(0.027)	(0.024)	(0.023)	(0.024)	(0.028)

(*continued on next page*)

Table 5 (*continued*)

	(1) Regional University	(2) Italian University	(3) International University	(3a) European Universities	(3b) US University
Benchmark: less than 50 emp.					
50–249 employees	0.177	0.217	0.172	0.156	0.199
	(0.199)	(0.203)	(0.202)	(0.203)	(0.206)
more than 249 employees	0.284**	0.316**	0.378***	0.357**	0.366**
	(0.140)	(0.144)	(0.146)	(0.147)	(0.147)
very mobile inventor	0.055	0.167	0.250	0.231	0.144
	(0.218)	(0.221)	(0.237)	(0.245)	(0.215)
Constant	−0.593*	−0.669*	−0.651*	−0.592	−0.625*
	(0.345)	(0.349)	(0.373)	(0.376)	(0.369)
Athrho	−0.280	−0.568**	−1.063***	−1.127***	−0.900***
	(0.445)	(0.226)	(0.349)	(0.422)	(0.347)
Observations	636	604	580	575	572
Censored observations	228	228	228	228	228
Uncensored observations	408	376	352	347	344

Result of an ordered probit model estimation with sample selection. Robust standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

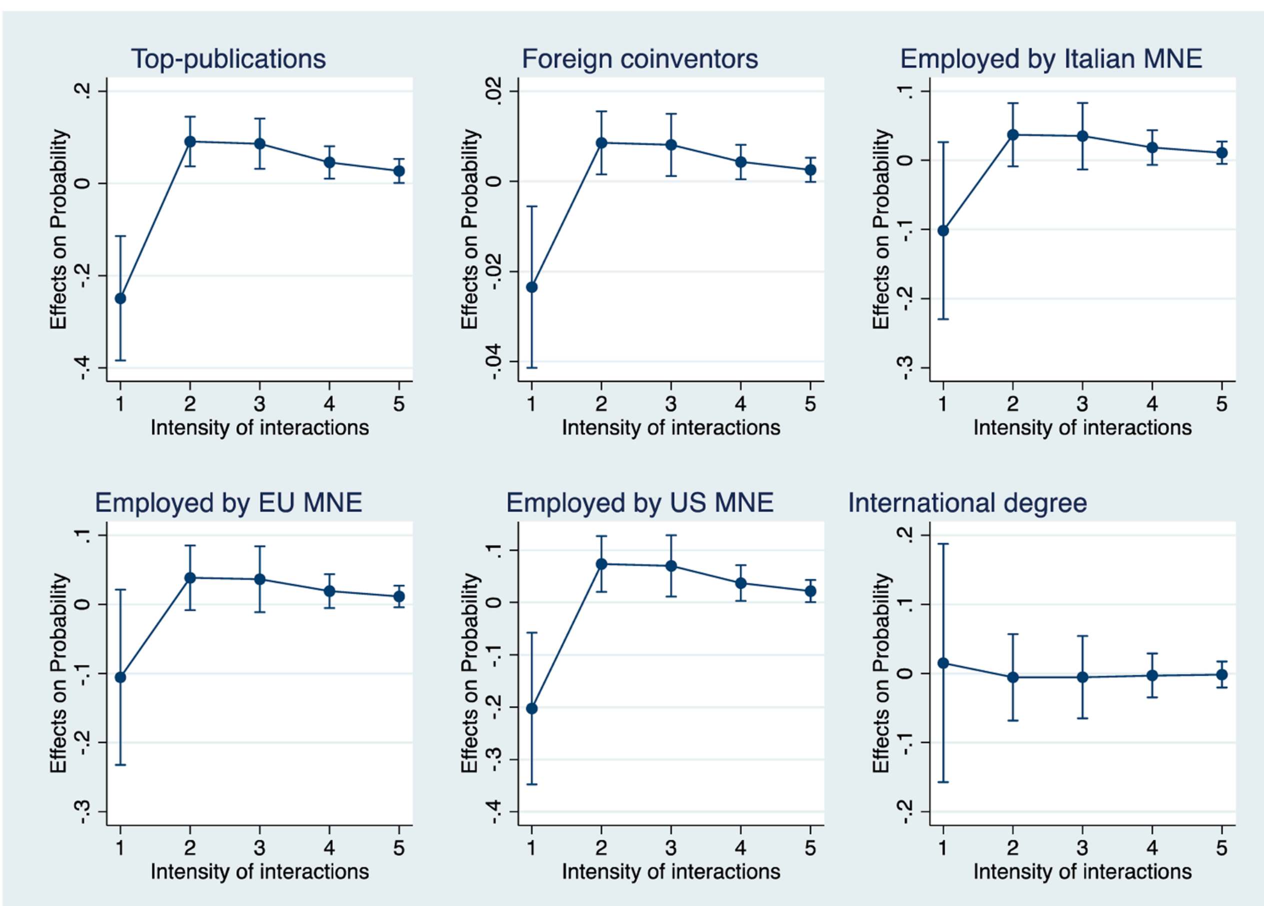

Fig. B4. Marginal effects for intensity of collaborations with US Universities
95% confidence intervals reported.

Table 6
Only international collaborations. Interaction between personal factors and MNE or domestic firms dummy.

	(1) EU Uni	(2) US Uni	(3) EU Uni	(4) US Uni
Interactions between personal linkages and global pipelines variables				
Inventors' career				
Foreign co-inventors * domestic firms	0.285***	0.317***		
	(0.077)	(0.102)		
Foreign co-inventors * MNE	0.009	0.074*		
	(0.040)	(0.039)		
Familiarity with open science				
Top publications *domestic firms			0.434	0.821
			(0.697)	(0.739)
Top publications * MNE			0.437*	0.805***
			(0.254)	(0.284)
Personal linkages variables				
Top publications	0.373	0.773***		
	(0.233)	(0.275)		
Foreign co-inventors			0.042	0.101***
			(0.034)	(0.032)
Local inventor	−0.112	−0.376**	−0.097	−0.362**
	(0.112)	(0.147)	(0.118)	(0.148)
International degree	−0.106	0.332	−0.104	0.340
	(0.291)	(0.405)	(0.296)	(0.408)
Global pipelines variables				
Working for MNEs				
Benchmark: working for domestic firms				
Employed by Italian MNE	0.352**	0.298	0.327**	0.250
	(0.144)	(0.237)	(0.145)	(0.227)
Employed by European MNE	0.496***	0.338	0.444**	0.263
	(0.176)	(0.255)	(0.181)	(0.246)
Employed by North American MNE	0.485**	0.611**	0.464**	0.559**
	(0.211)	(0.272)	(0.206)	(0.262)
Control variables				
Other individual characteristics				
Male	−0.217	−0.102	−0.203	−0.083
	(0.161)	(0.194)	(0.164)	(0.193)
Age	0.002	−0.000	−0.000	−0.002
	(0.007)	(0.008)	(0.007)	(0.008)
Importance of institutional contracts funded by public funds	0.160**	0.120	0.199***	0.150*
	(0.074)	(0.080)	(0.072)	(0.079)
Firm characteristics				
Benchmark: less than 50 employees				
50–249 employees	−0.165	−0.588**	−0.236	−0.649**
	(0.214)	(0.290)	(0.215)	(0.290)
more than 249 employees	−0.023	−0.091	−0.061	−0.145
	(0.241)	(0.242)	(0.238)	(0.236)
(Log) num of patents (firm)	−0.034	−0.066	−0.035	−0.065
	(0.040)	(0.047)	(0.041)	(0.047)
TECH DUMMIES	YES	YES	YES	YES
SELECTION EQUATION	YES	YES	YES	YES
Athrho	−1.247**	−0.912***	−1.126**	−0.901**
	(0.507)	(0.337)	(0.439)	(0.354)
Observations	575	572	575	572
Censored observations	228	228	228	228
Uncensored observations	347	344	347	344

Result of an ordered probit model estimation with sample selection. Robust standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Table 7
Only international collaborations. Interaction between personal factors and typology of MNE.

	(1) EU Uni	(2) US Uni	(3) EU Uni	(4) US Uni
Interactions between personal linkages and global pipelines variables				
Foreign co-inventors* domestic firms	0.285***	0.313***		
	(0.075)	(0.102)		
Foreign co-inventors* Italian MNE	−0.250	−0.461		
	(0.271)	(0.281)		
Foreign co-inventors* European MNE	0.020	0.093***		
	(0.038)	(0.032)		
Foreign co-inventors* North American MNE	−0.094	−0.147		
	(0.179)	(0.258)		
Top publications* domestic firms			−0.006	0.867
			(0.474)	(0.532)
Top publications* Italian MNE			0.236	0.464
			(0.290)	(0.313)
Top publications* European MNE			1.244***	0.970**
			(0.382)	(0.394)
Top publications* North American MNE			0.260	−0.306
			(0.275)	(0.431)
Control variables				
All controls	YES	YES	YES	YES
Technology dummies	YES	YES	YES	YES
Selection equation	YES	YES	YES	YES
athrho	−1.238***	−0.938***	−0.982***	−1.001**
	(0.475)	(0.330)	(0.356)	(0.420)
Observations	575	572	575	572
Censored observations	228	228	228	228
Uncensored observations	347	344	347	344

Result of an ordered probit model estimation with sample selection. Robust standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

degree in columns (3), (3a) and (3b). The variable *International degree* is very weak since we have information on international university degrees for only 16 inventors in our sample, of which 15 graduated from a European university and 1 from a university in another country.[11] Thus, we do not find support for H2.

When it comes to familiarity with open science, we find that the coefficient of the variable *Top publications* is not significantly different from zero for collaborations with national (regional and Italian)

[11] This variable might be able to capture a general propensity to collaborate internationally due to greater cultural proximity to international universities, since institutions and cultures differ greatly across the countries in our sample, but it is less likely to capture social relations, i.e. the development of an international 'invisible college'

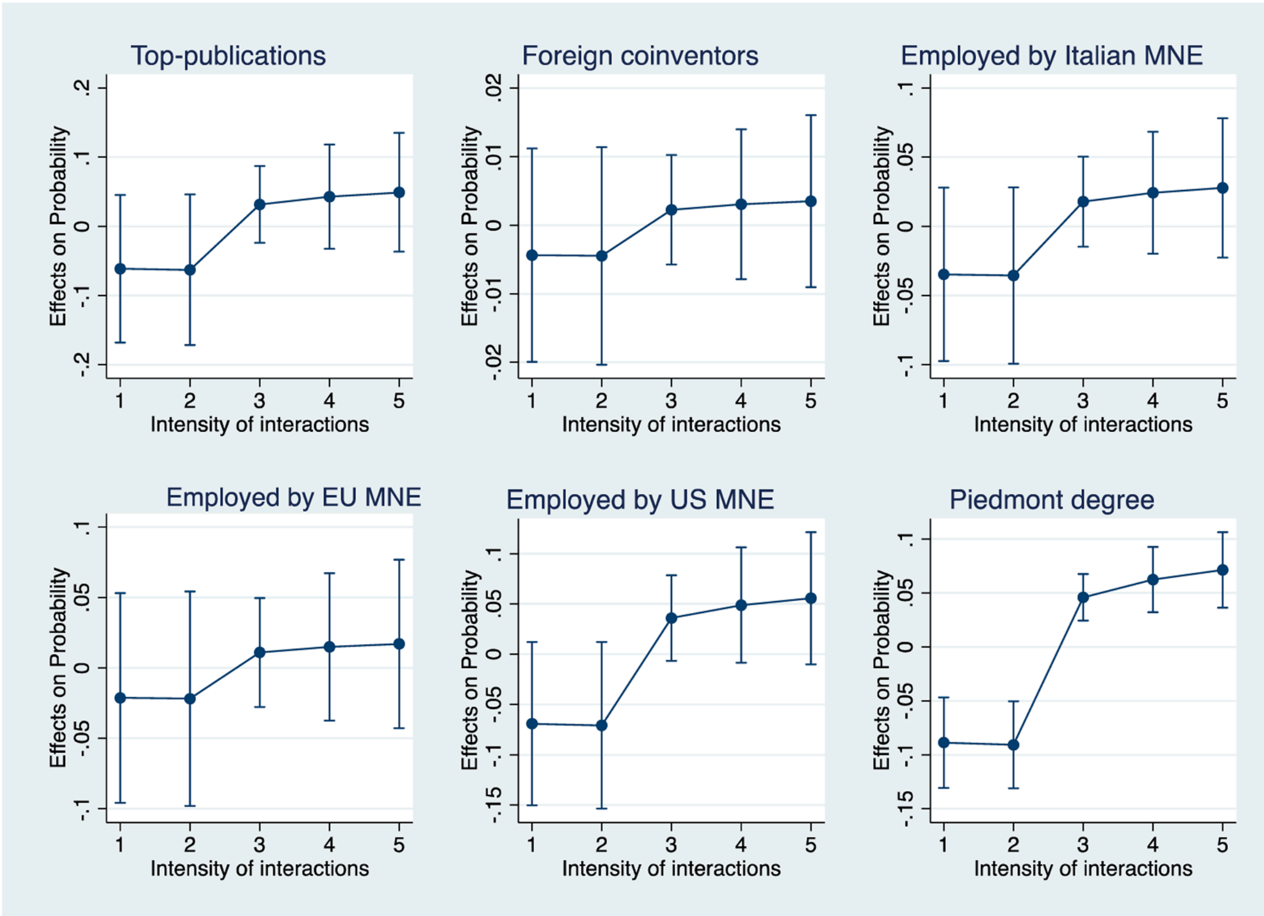

Fig. B1. Marginal effects for intensity of collaborations with regional Universities
95% confidence intervals reported.

universities, while it is positive and significantly different from zero for international universities: the coefficient increases in size and in significance in column (3b), suggesting that being used to the norms of academic work is particularly important for US universities. These results provide overall support for H3.

The results in Table 5 also show the importance of an individual inventor's employment by a MNE (Italian, European or US-owned) in order to bridge the distance with international universities. Being employed by a MNE unambiguously increases the probability of frequent collaborations with foreign universities.

The results also highlight that, while collaborations with European universities are facilitated by all types of MNEs (Italian MNEs, European MNEs and North American MNEs), in the case of collaborations with US universities we only find a positive and significant coefficient for North American MNEs. However, chi square tests indicate that the MNE coefficients are not significantly different from each other. All in all, this provides evidence supporting H4.

In terms of control variables we find that inventors who consider the use of publicly-funded projects as important are generally more likely to collaborate with universities, both national and international ones.

In Appendix B in Figs. B1 to B4 we show the marginal effects of the main variables of interest. In order to further rule out issues of reverse causality, we also test whether our results still hold if the variables *Foreign co-inventors* and *Top publications* are built using only patents applied and publications accepted before 1998 (i.e. 10 years before the survey was run). The results (Table B2 of Appendix B), show that the results of our model are not affected when we use older patents and older publications. Since using only very old patents and publications reduces significantly the number of actual inventors in our sample, we have decided to keep the specification in Table 5 as our preferred one.[12]

4.2.1. International collaborations: the role of personal relationships for inventors working in MNEs

In Table 6 we show the results of an ordered probit model where we interact the main personal level factors with a) a dummy "working for a MNE" and b) a dummy "working for a domestic Italian company" (i.e. a non MNE). In this way we are able to check whether the results that we found for the whole sample of inventors regarding the role of personal factors apply differently to inventors working in domestic firms vis a vis those working for MNEs. In columns (1) and (2) we interact the variable *Foreign co-inventors* with the two dummies. The results indicate that having a high number of foreign co-inventors is especially important for inventors working in domestic companies when it comes to collaboration with both EU and US universities. In the case of inventors working for MNEs we find that the effect is not significant for collaborations with EU universities, but it is instead positive and significant at 10% in the case of collaborations with US universities.

In column (3) and (4) we interact the same two dummies with the variable Top publications. In this case we find that having acquaintance with the academic norms is positive but not significant among domestic inventors, while it is positive and significant among MNE inventors:

[12] In Table B3 we also show the full coefficients of the technology dummies of Table 5. The results of the technology dummies show that there are no relevant and significant differences across the different types of technology when it comes to explain international collaborations with universities abroad.

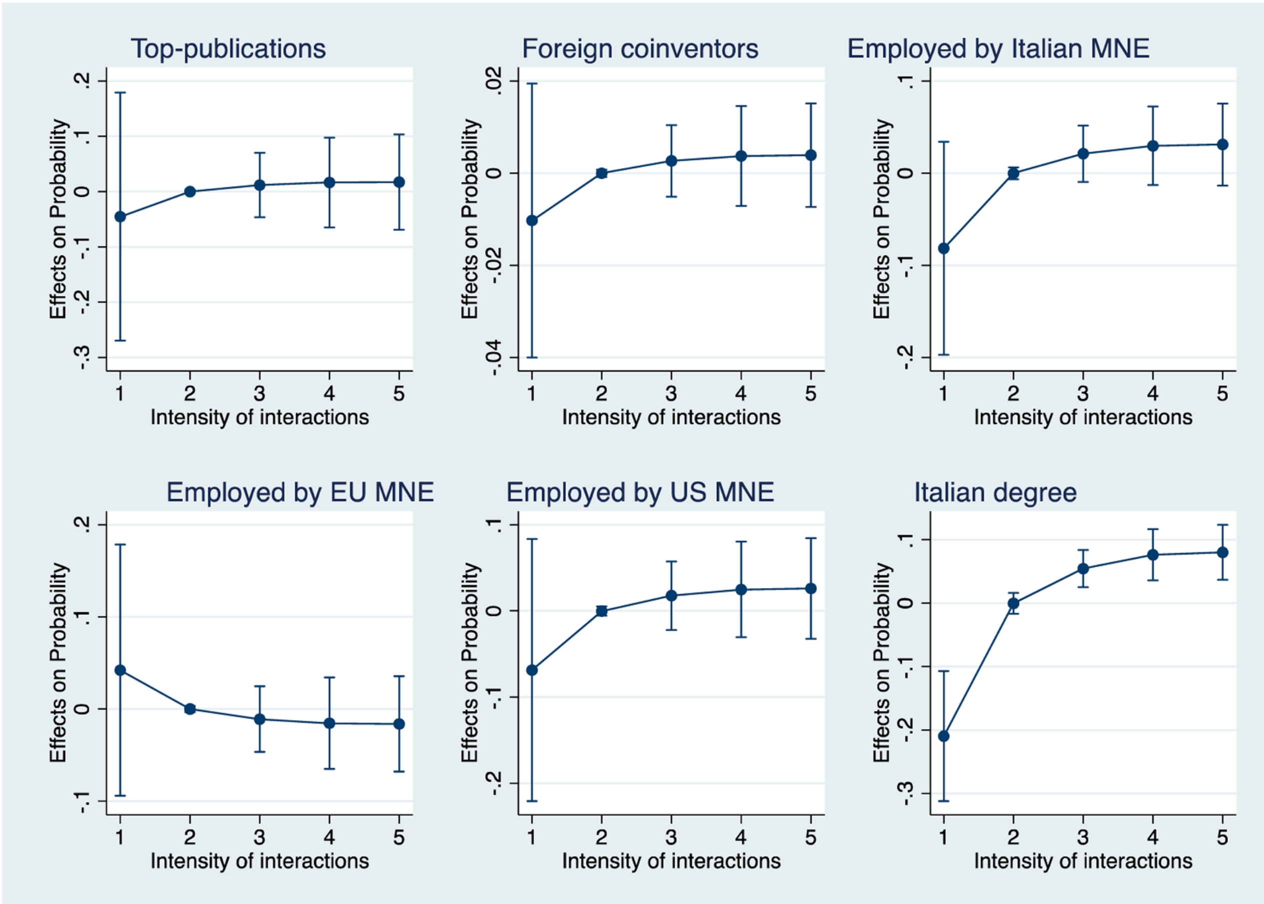

Fig. B2. Marginal effects for intensity of collaborations with Italian Universities
95% confidence intervals reported.

especially when it comes to collaborations with US universities. All these results provide some confirmation about H5 according to which personal attributes are also important for inventors who work in MNEs. Additionally, the results confirm that personal attributes matter for MNE inventors especially for collaborations with US universities.

4.2.1.8. The role of personal linkages and typology of MNEs. In Table 7 we further distinguish our results by typology of MNEs, distinguishing between Italian, European and North American MNEs. The results in column (1) and (2) show that having foreign coinventors is especially important for inventors employed by European MNE and only for what concerns collaborations with US universities. We do not find a positive and significant coefficient for the inventors working in other types of MNEs. In columns (3) and (4) instead we find that having acquaintance with the academic norms, as proxied by academic publications, is especially important for inventors working for European MNEs, both when it comes to collaborations with European and US universities.[13] Again for the other types of MNEs the personal linkages seem less important. An important finding of this latest set of results is that personal linkages seem to be extremely important for European MNEs when it comes to collaborations with US universities. A possible explanation is that European MNEs do not benefit from the so-called global pipelines model for collaborations with US universities, as shown by the non-significant coefficient of the dummy "European MNE" in column 3b of Table 5. Therefore, in this case personal linkages substitute for the lack of organizational structure towards US universities. In the case of North American universities instead the global pipelines effect is there also for collaborations with US universities, therefore the personal linkages of inventors are less crucial in order to collaborate with universities back in the home country of the MNE.

5. Discussion

The econometric analyses provide important evidence about the different role of personal and organizational factors in the establishment of international collaborations between firms and universities.

The role of the inventors' education as a facilitator for the creation of frequent collaborations with universities is strongly supported for collaborations with national universities. Inventors graduating from universities in the region are more likely to collaborate with regional universities and inventors that graduate from universities in other regions in Italy are more likely to collaborate with those Italian universities. This is very much in line with earlier findings on inventors in Piedmont (Bodas Freitas et al., 2014; Fassio et al., 2019)

The picture is different when we look at how the inventors' education affects collaborations with international universities. We do not find a positive and significant effect of having an international degree on

[13] We have to modify slightly the variable Top-publications in order for the model to work. Now the variable indicates if the inventor has published at least 2 publications (instead of 3) before 2003. This allows to slightly increase the total number of inventors who reach this threshold so that when we interact the variable with the dummy for each type of MNE we have enough observations to be able to estimate the coefficients. When we use the variable keeping the old threshold of 3 publications the interaction effect for North American MNEs cannot be estimated for the lack of a sufficiently high number of inventors working for North American MNEs who also have 3 publications before 2003.

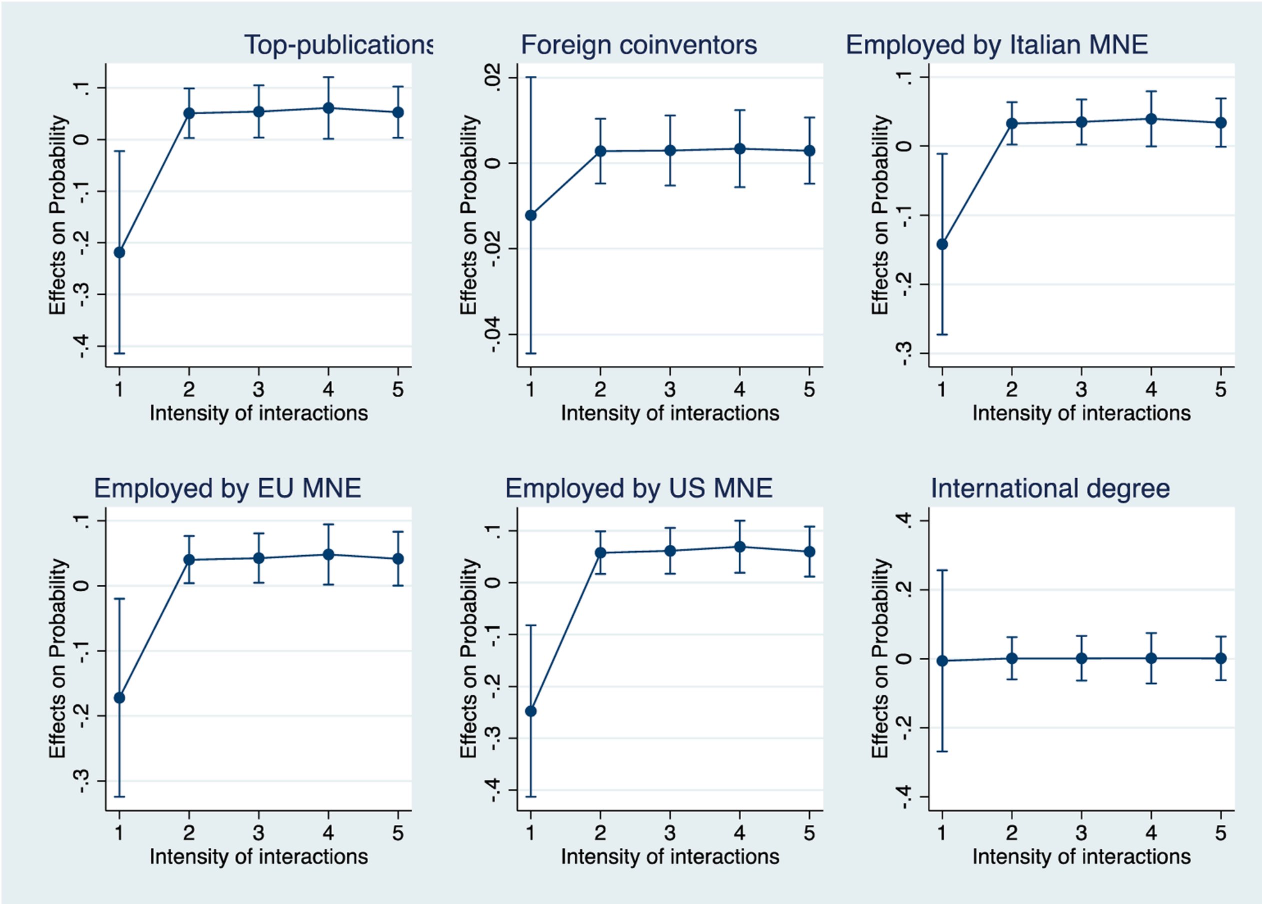

Fig. B3. Marginal effects for intensity of collaborations with European Universities
95% confidence intervals reported.

international collaborations. Also in our interviews being educated abroad was never mentioned as a very important driver of international collaborations. This is however a very context and time specific result, as very few of the inventors in our sample have an international degree, as mentioned by one of our interviewees.

"At that time it was very rare to go abroad for education." (Inventor A)

The inventors' embeddedness in national or international circles of colleagues and collaborators developed throughout their careers plays a role. Our results suggest that inventors with a local career (never worked outside of Piedmont) are more likely to collaborate with national universities. When it comes to international collaborations, having an international pool of colleagues (*co-inventors*) and having worked outside of the region matters, but only for collaborations with universities in the US. Instead, it does not matter for collaborations with European universities. Having international career experiences may allow for the creation of new contacts, as well as boost an individual's intercultural sensitivity and their ability to work in culturally diverse settings (Heinzmann et al., 2015; Wolff & Borzikowsky, 2018).

Also acquaintance with open science norms plays a role in facilitating collaborations with universities abroad: the inventors who publish academic articles are also those that collaborate more frequently with universities abroad, especially with distant ones in the US. Among the inventors working for MNEs that we interviewed, those who had research-oriented (rather than operational) roles indicated that they often established contacts with foreign academics simply after reading their papers and finding them of potential interest. Also participating to international academic conferences is a way to meet university researchers and establish contacts:

"Often these things [international collaborations] grow out of interactions, acquaintances, because you go to a conference and you listen to a presentation of a study that you are interested in or you yourself present a work that generates some interest and then collaborations arise" (Inventor A)

This is in line with Giuri and Mariani (2013), who found that highly educated inventors (to PhD level) are better able to benefit from spillovers from geographically distant partners. Our results further show that when it comes to international collaborations with universities, active publication activity also matters in order to facilitate collaborations across large geographical distances.

Lastly we find that working for a MNE has an important role in increasing the likelihood of collaborations with universities abroad, in line with the global pipelines literature (Lorenzen & Mudambi, 2013). This is also in line with the interviews with inventors working for large MNEs (both Italian and foreign ones). For example, the manager of the subsidiary of a foreign-owned MNE highlighted the role of the firm's main research center in the Netherlands in introducing the inventor to university researchers who were already collaborating with the Dutch research center.

"Cooperation with universities was fundamental. We in our subsidiary did not have this experience, but our Dutch colleagues [working in the main research center of the MNE] had it, so they helped us in what was the first moment for us to switch from in-house problem solving to an approach that involved more basic science, going and picking knowledge right where it was generated." (Inventor B)

Especially the main research centers of the MNE provide an entry point to different university researchers that are located close to the

Table B1
Determinants of probability to collaborate with different types of universities. (PROBIT).

	(1) Regional university	(2) Italian university	(3) International university	(3a) European university	(3b) US university
Personal linkages variables					
Inventors' career					
Foreign co-inventors	0.015	0.014	0.018	0.021	0.036**
	(0.014)	(0.021)	(0.024)	(0.024)	(0.016)
Local inventor	0.077***	−0.019	−0.041	−0.042	−0.097*
	(0.028)	(0.058)	(0.065)	(0.066)	(0.051)
Inventors' education					
Piedmont degree	0.092***				
	(0.031)				
Italian degree		0.242***			
		(0.082)			
International degree			−0.018	−0.001	0.155
			(0.172)	(0.173)	(0.121)
Familiarity with open science					
Top publications	0.011	0.009	0.211	0.173	0.284***
	(0.063)	(0.157)	(0.149)	(0.143)	(0.108)
Global pipelines variables					
Working for a MNE					
Employed by Italian MNE	0.065	0.091	0.101	0.125	0.081
	(0.041)	(0.081)	(0.087)	(0.085)	(0.081)
Employed by European MNE	0.047	−0.075	0.237**	0.221**	0.119
	(0.050)	(0.093)	(0.103)	(0.106)	(0.089)
Employed by North American MNE	0.072	0.002	0.209*	0.245**	0.172*
	(0.051)	(0.099)	(0.112)	(0.111)	(0.093)
Control variables					
Individual characteristics					
Male	0.037	−0.079	−0.131	−0.111	−0.023
	(0.042)	(0.090)	(0.098)	(0.098)	(0.074)
Age	−0.000	0.004	0.001	−0.000	0.000
	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)
Publicly-funded projects	0.004	0.086**	0.120***	0.121***	0.081***
	(0.019)	(0.035)	(0.037)	(0.038)	(0.029)
Firm characteristics					
50–249 employees	−0.004	−0.017	−0.024	0.002	−0.155
	(0.050)	(0.103)	(0.113)	(0.114)	(0.097)
more than 249 employees	0.031	−0.016	0.090	0.046	−0.000
	(0.051)	(0.101)	(0.108)	(0.114)	(0.085)
(Log) num of patents (firm)	−0.012	0.015	−0.017	−0.013	−0.020
	(0.009)	(0.018)	(0.020)	(0.020)	(0.017)
Technology dummies	YES	YES	YES	YES	YES
Selection equation	YES	YES	YES	YES	YES
Rho	0.197	−0.425*	−0.805***	−0.811***	−0.757***
Observations	636	604	580	575	572
Uncensored observations	408	376	352	347	344
Censored observations	228	228	228	228	228

Result of a probit model estimation with selection. Marginal effects reported. Robust standard errors in parentheses.
*** $p<0.01$.
** $p<0.05$.
* $p<0.1$.

subsidiaries of the company.

"We have nowadays a quite precise map of the competences that we need and this is an approach that is nested within the structure of our company, we have the main research center in the Netherlands, we have colleagues in Austria, in Germany in the United States, in India and China. We have a network that allows us to do knowledge scouting with a certain degree of precision. (...) So [whenever I need new knowledge] I would always start by going through the structure of my company and then each of my colleagues can contribute, since it is a network" (Inventor B)

Our results also show that there is not a substantial difference between Italian-owned and foreign-owned MNEs in their ability to provide an infrastructure for their inventors when it comes to collaborations with European universities. On the contrary, collaborations with US universities are more likely to occur among inventors that work for North American-owned MNEs.

We interpret the different role of personal and organizational factors for collaborations with European vis a vis North American universities in terms of the former being easier to reach. In the case of inventors working for MNEs, our interviews suggest that it is often the case that inventors collaborating with European universities are involved in projects led by the MNE, sometimes funded by European public funds, which also involve partners from different European universities, with whom the MNE already had established relationships: the personal background of the inventor does not matter much.

"The majority of international collaborations in the context of EU projects were established with organizations similar to ours in France, Germany or UK. So usually we had a relationship with the national telecom institute (mostly within the context of public funded projects) and then they would put us sometimes in contact with universities in their country with whom they used to collaborate when we had common research interests. (Inventor E)"

Instead, establishing collaborations with US universities is more difficult (due to the greater geographical distance and the lack of a supportive infrastructure of public funds) and requires additional elements that facilitate engagement. These elements could be the global pipelines orchestrated by the MNEs headquartered in North America. As shown by our results especially for inventors working for European MNE

Table B2
Robustness check: only patents and publications before 1998.

	(1) Regional university	(2) Italian university	(3) International university	(4) European university	(5) US university
Personal linkages variables					
Inventors' career					
Foreign co-inventions (before 1998)	−0.131	0.046	0.135	0.111	0.244**
	(0.111)	(0.108)	(0.086)	(0.089)	(0.108)
Local inventor	0.294**	0.219*	−0.105	−0.091	−0.334**
	(0.125)	(0.121)	(0.114)	(0.119)	(0.143)
Inventors' education					
Piedmont degree	0.401**				
	(0.193)				
Italian degree		0.493***			
		(0.159)			
International degree			−0.039	−0.103	0.328
			(0.364)	(0.298)	(0.407)
Familiarity with open science					
top publications (before 1998)	0.072	0.407	0.560**	0.491**	0.716***
	(0.306)	(0.310)	(0.223)	(0.239)	(0.255)
Global pipelines variables					
Working for a MNE					
Employed by Italian MNE	0.194	0.192	0.309**	0.326**	0.259
	(0.177)	(0.166)	(0.141)	(0.145)	(0.199)
Employed by European MNE	0.159	−0.171	0.417**	0.435**	0.314
	(0.210)	(0.198)	(0.167)	(0.178)	(0.231)
Employed by North American MNE	0.379*	0.112	0.438**	0.459**	0.541**
	(0.225)	(0.220)	(0.199)	(0.209)	(0.250)
Control variables					
Individual characteristics					
Male	−0.106	−0.214	−0.239	−0.201	−0.084
	(0.188)	(0.171)	(0.160)	(0.165)	(0.186)
Age	0.003	0.006	−0.002	−0.001	−0.002
	(0.006)	(0.007)	(0.007)	(0.007)	(0.008)
Publicly-funded projects	0.221***	0.190***	0.192***	0.204***	0.158**
	(0.078)	(0.073)	(0.069)	(0.073)	(0.078)
Firm characteristics					
50–249 employees	0.147	−0.117	−0.290	−0.246	−0.673**
	(0.247)	(0.230)	(0.213)	(0.218)	(0.289)
more than 249 employees	0.116	0.035	−0.016	−0.060	−0.194
	(0.252)	(0.227)	(0.217)	(0.246)	(0.231)
(Log) num of patents (firm)	−0.047	0.009	−0.041	−0.034	−0.062
	(0.040)	(0.044)	(0.038)	(0.041)	(0.043)
Technology dummies	YES	YES	YES	YES	YES
Selection equation					
Age	0.001	0.001	−0.001	−0.002	−0.002
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Tertiary education	0.938***	0.987***	0.944***	0.948***	0.922***
	(0.123)	(0.123)	(0.137)	(0.143)	(0.135)
Worked at uni	0.498**	0.628**	0.841***	0.834***	0.823***
	(0.253)	(0.258)	(0.290)	(0.308)	(0.285)
Patents applied by inventor	0.070***	0.059**	0.047**	0.052**	0.053*
	(0.027)	(0.025)	(0.023)	(0.025)	(0.028)
50–249 employees	0.175	0.218	0.160	0.157	0.195
	(0.199)	(0.204)	(0.203)	(0.204)	(0.206)
more than 249 employees	0.284**	0.314**	0.372**	0.350**	0.359**
	(0.140)	(0.145)	(0.146)	(0.148)	(0.147)
very mobile inventor	0.062	0.168	0.261	0.230	0.179
	(0.220)	(0.221)	(0.237)	(0.246)	(0.214)
Constant	−0.593*	−0.676*	−0.657*	−0.608	−0.611
	(0.344)	(0.350)	(0.373)	(0.375)	(0.374)
Athrho	−0.292	−0.539**	−1.093***	−1.095**	−0.999**
	(0.452)	(0.238)	(0.381)	(0.444)	(0.404)
Observations	636	604	580	575	572

the inventor's personal involvement in open science communities, or the inventors' having personal contacts abroad, can partly substitute for the lack of already established global pipelines.

6. Conclusions

This study contributes to the literature that studies global linkages, by analzying the drivers of a specific type of such linkages, international collaborations between firms and universities. We propose that the governance of such linkages can be considered as a hybrid between the global pipelines model and the person-based governance model (Lorenzen & Mudambi, 2013; Cano-Kollman et al., 2016). We focus in particular on the role of the personal characteristics of the inventors involved in these international collaborations and on the international reach of the organizations they work for.

First, our findings show that international collaborations between firms and universities follow a different pattern with respect to the national interactions that the innovation literature has studied so far. National interactions rely a lot on the personal connections of the inventors: local career and local education background play an important

Table B3

Determinants of interaction with universities in different locations (same as Table 5 in the paper, but with the coefficients of the technology dummies).

	(1) Regional University	(2) Italian University	(3) International University	(3a) European Universities	(3b) US University
Personal linkages variables					
Inventors' career					
Foreign co-inventors	0.028	0.038	0.044	0.042	0.101***
	(0.044)	(0.043)	(0.034)	(0.034)	(0.032)
Local inventor	0.297**	0.222*	−0.112	−0.097	−0.362**
	(0.126)	(0.121)	(0.116)	(0.118)	(0.149)
Inventors' education					
Piedmont degree	0.408**				
	(0.193)				
Italian degree		0.517***			
		(0.157)			
International degree			−0.031	−0.104	0.341
			(0.367)	(0.296)	(0.409)
Familiarity with open science					
Top publications	0.292	0.092	0.445*	0.436*	0.807***
	(0.320)	(0.334)	(0.234)	(0.239)	(0.276)
Global pipelines variables					
Working for MNEs					
Baseline: working for domestic companies					
Employed by Italian MNE	0.185	0.199	0.319**	0.327**	0.250
	(0.177)	(0.168)	(0.151)	(0.145)	(0.226)
Employed by a European MNE	0.115	−0.142	0.443**	0.444**	0.263
	(0.210)	(0.201)	(0.176)	(0.180)	(0.245)
Employed by a North American MNE	0.366	0.118	0.459**	0.464**	0.558**
	(0.226)	(0.219)	(0.205)	(0.207)	(0.263)
Control variables					
Individual characteristics					
Male	−0.102	−0.223	−0.249	−0.203	−0.083
	(0.189)	(0.169)	(0.161)	(0.164)	(0.194)
Age	0.001	0.007	−0.000	−0.000	−0.002
	(0.006)	(0.007)	(0.007)	(0.007)	(0.008)
Publicly-funded projects	0.219***	0.194***	0.194***	0.199***	0.150*
	(0.078)	(0.073)	(0.068)	(0.071)	(0.079)
Firm characteristics					
Benchmark: less than 50 emp.					
50–249 employees	0.154	−0.111	−0.306	−0.236	−0.650**
	(0.245)	(0.230)	(0.208)	(0.213)	(0.286)
more than 249 employees	0.124	0.008	−0.024	−0.061	−0.145
	(0.254)	(0.227)	(0.214)	(0.240)	(0.237)
(Log) num of patents (firm)	−0.052	0.011	−0.039	−0.035	−0.065
	(0.040)	(0.044)	(0.039)	(0.041)	(0.047)
Technology dummies					
Benchmark:process engineering					
Electronics	0.487**	0.266	0.036	0.157	0.091
	(0.201)	(0.224)	(0.177)	(0.183)	(0.237)
Instruments	0.700***	0.945***	0.343*	0.455**	0.310
	(0.231)	(0.237)	(0.207)	(0.213)	(0.261)
Chemistry-Materials	0.294	0.650**	0.025	0.166	−0.074
	(0.300)	(0.269)	(0.260)	(0.273)	(0.332)
Pharmaceuticals-Biotechnologies	1.072**	0.822*	−0.393	−0.204	0.081
	(0.513)	(0.455)	(0.374)	(0.371)	(0.460)
Mechanical Engineering	0.393**	0.222	−0.066	0.087	−0.258
	(0.193)	(0.221)	(0.185)	(0.189)	(0.242)
Consumer Goods - Others	0.243	0.273	0.057	0.253	0.152
	(0.281)	(0.324)	(0.255)	(0.260)	(0.340)
Selection equation					
Age	0.001	0.000	−0.001	−0.002	−0.002
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Tertiary education	0.938***	0.983***	0.948***	0.941***	0.926***
	(0.123)	(0.123)	(0.134)	(0.142)	(0.130)
Worked at uni	0.502**	0.642**	0.821***	0.830***	0.807***
	(0.253)	(0.256)	(0.279)	(0.293)	(0.287)
Patents applied by inventor	0.070***	0.059**	0.048**	0.051**	0.056**
	(0.027)	(0.024)	(0.023)	(0.024)	(0.028)
Benchmark: less than 50 emp.					
50–249 employees	0.177	0.217	0.172	0.156	0.199
	(0.199)	(0.203)	(0.202)	(0.203)	(0.206)
more than 249 employees	0.284**	0.316**	0.378***	0.357**	0.366**
	(0.140)	(0.144)	(0.146)	(0.147)	(0.147)
very mobile inventor	0.055	0.167	0.250	0.231	0.144
	(0.218)	(0.221)	(0.237)	(0.245)	(0.215)
Constant	−0.593*	−0.669*	−0.651*	−0.592	−0.625*
	(0.345)	(0.349)	(0.373)	(0.376)	(0.369)

(*continued on next page*)

Table B3 (*continued*)

	(1) Regional University	(2) Italian University	(3) International University	(3a) European Universities	(3b) US University
Athrho	−0.280	−0.568**	−1.063***	−1.127***	−0.900***
	(0.445)	(0.226)	(0.349)	(0.422)	(0.347)
Observations	636	604	582	575	572

Result of an ordered probit model estimation with sample selection. Robust standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Table B4
Description of each variable.

Variable name	Description
Dependent variables	
Regional university	Frequency of interaction with universities in the Piedmont region (University of Torino and Politecnico of Torino
Italian University	Frequency of interaction with universities in all Italian regions, except Piedmont.
International university	Frequency of interaction with universities in Europe or North America.
European university	Frequency of interaction with universities in Europe.
US university	Frequency of interaction with universities in the United States.
Independent variables	
Foreign co-inventors	number of times that we observe a foreign co-inventor, i.e. resident outside of Italy, among the inventor's patent portfolio (only patents applied up to 2003)
Local inventor	dummy variable equal to 1 if the inventor has never worked for 6 months or more outside Piedmont throughout his or her career
Piedmont Degree	dummy variable equal to 1 if the inventor graduated in a university in Piedmont
Italian Degree	dummy variable equal to 1 if the inventor graduated in an Italian university in another region than Piedmont;
International Degree	dummy variable equal to 1 if the inventor graduated in a foreign university.
Top-publications	dummy variable equal to 1 if an inventor published more than 3 papers before 2003 and zero otherwise. The threshold of 3 papers represents the 95% percentile of the publication distribution among the sample of inventors (we only use publications before 2003)
Importance of publicly-funded projects	Importance of institutional agreements between the inventor's company and universities that were funded by public funding. Likert scale that measures whether inventors did not use these projects (value "0″), whether they used them but considered them of little importance (value "1) or whether they used them and considered them important (value "2″).
Employed by an Italian MNE	dummy variable equal to 1 if the inventor is employed by an Italian-owned firm with foreign affiliates.
Employed by a European MNE	dummy variable equal to 1 if the inventor is employed by a European (not Italian)-owned MNE.
Employed by a North American MNE	dummy variable equal to 1 if the inventor is employed by a North American-owned MNE
Age	Age of the inventor
Male	dummy variable equal to 1 if the inventor is a male
1- 49 employees	Firms with less than 50 employees
50–249 employees	Firms with 50 to 249 employees
more than 249 employees	Firms more than 249 employees
(Log) num of patents (firm)	Log of the firm's absolute number of granted patents
Technology dummies	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).

role for establishing links with national universities. On the contrary when it comes to international collaborations the organizational structure of the company inventors work for plays a much more relevant role. Working for a MNE is particularly important for these collaborations, in line with the idea that these companies can leverage their networks of subsidiaries in different parts of the world (Bathelt et al., 2004), allowing for an easier access to contacts with researchers based at universities abroad. Being an inventor with an international education or an international career can still be important, with some important differences according to the location of the international university, but, differently from national interactions, these are not the main facilitating factors.

Secondly, our results also show important differences between the governance of international collaborations, according to the location of the foreign university. Two models emerge: one for collaborations with European universities and one for collaborations with US universities. Collaborations with European universities are very similar to the global pipeline model, where working for a MNE is the crucial factor, regardless of the company's country of origin (either Italian, European or North American). The personal linkages of the inventor are not crucial: also inventors with limited international experience can participate in European-wide collaborations with universities, simply by participating to projects organized by their company, possibly in the context of EU publicly-funded projects. On the contrary, when it comes to collaborations with US universities, working for a MNE is not enough: only working for a North American MNE increases the probability to interact with US universities, highlighting the need for the parent organization to be strongly embedded in the innovation ecosystem of the university with which the collaboration is established. Personal linkages matter here (also for inventors working for MNEs): collaborations with US universities are facilitated by the personal international linkages of the inventors, such as having a pool of foreign co-inventors, and by the acquaintance of inventors with the norms of open science, as proxied by their active publication records.

6.1. Theoretical implications

These findings resonate with the existing literature in international business that studies the nature of global linkages. This literature highlights that global knowledge flows can be orchestrated either through global pipelines -with the central role of MNEs- or through person-based linkages -with the central role of geographically dispersed epistemic communities (Lorenzen & Mudambi, 2013). Our results show that in the case of international collaborations between firms and universities both models are at stake. For collaborations with European universities the global pipelines model can explain a big deal of the interactions observed in our sample, however when it comes to collaborations with more distant US universities also the personal linkages of the inventors play a role. This is in line with our hypotheses that suggest that having an international career allows inventors to benefit from their personal international network, (Marino et al., 2020; Jokers & Tissen, 2008) - the so-called "invisible college" (Crane, 1969) of former colleagues – and possibly also to benefit from a higher degree of intercultural soft skills that also favor international collaborations. This suggests the importance to consider hybrid models of orchestration of global linkages (Cano-Kollmann et al., 2016). This hybrid model can be motivated by the fact that collaborations between firms and universities involve interactions with academic researchers, who rely more on personal connections in their international linkages (Perri et al., 2017). Therefore, the global pipelines model may be less effective for these types of international collaborations, and the role of the personal linkages of the individuals involved acquires greater importance. In this respect our findings provide novel evidence to the literature that highlights the specific role of boundary spanning individuals within MNEs, especially when it comes to establishing collaborations with external actors (Mäkelä et al., 2019; Pedersen et al., 2019). Some individuals are better fit to play this role within their organizations, because of their own personal background in terms of experience and ability to work across boundaries. In our case the personal background of inventors which facilitates their role as boundary spanners has to do with their past experience of co-patenting with foreign colleagues and also with their familiarity with the open science norms, hence within an environment that is markedly different from the more hierarchical and proprietary corporate culture of large corporations. This coexistence of micro (individual) and macro (organizations) drivers of interaction is also in line with the micro-foundation perspective suggested by Foss and Pedersen (2019).

6.2. Public policy implications

Our results have several implications. First, from a public policy perspective, attracting foreign-owned MNEs to a region may be important if these MNEs act as bridging organizations able to link regional inventors working for their subsidiaries to distant and advanced knowledge sources from other academic environments. However, it is important to set the right expectations about what MNEs can actually do: the “pure” global pipeline model in the case of collaborations between firms and universities seem to be working more at a continental level (within Europe), rather than at a true global scale. While European and Italian MNEs are efficient in setting up collaborations with European universities, possibly also through publicly funded projects that facilitate the creation of international consortia with both industry and academic players, the organizational infrastructure provided by Italian or European MNEs may not be enough in order to reach out to US universities. North American MNEs are instead the ones that are more likely to provide this linkage.

6.3. Managerial implications

From a management perspective it is important to acknowledge the role of the individuals involved in international collaborations with universities: MNEs should acknowledge that having individuals with an international career or with greater familiarity with open science norms can increase the chances of setting up successful teams with the aim to set up collaborations with universities abroad, especially with those in different continents, such as in the case of the US. These individuals could act efficiently as boundary spanners capable of building connections with geographically distant academic environments. This implies on the one hand that for MNEs willing to source internationally knowledge from universities it could be important to implement hiring strategies that are aimed at attracting individuals with such characteristics. The importance of familiarity with open science norms for inventors which emerges from our results also suggests that for MNE having individuals with such skills may be particularly beneficial if they hope to start collaborating with distant universities. Even if these individuals may sometimes be considered as slightly distant from the corporate mindset, their value as boundary spanners with foreign universities should be fully appreciated.

6.4. Limitations and further research

This study also has some important limitations which should be addressed by future research. At the international level we only found a significant effect of inventors’ career background, whereas an international education background does not seem to have an effect. However, this should be confirmed by further studies given the shortcomings of our international education variable. Therefore, the presence of international education effects remains an open question, which should be investigated using suitable data; in particular, we need to precisely measure the effect of graduating from a university in a specific location on collaborations with universities in that location (international alumni effect).

The lack of information about the specific universities abroad with which the inventors collaborated also prevents us from investigating subnational dynamics. The international business literature that connects the decisions of MNEs to locate parts of their value chain in specific locations suggests that, especially for the upstream part of the value chain, what matters is not the country level of analysis, but rather the subnational levels (Mudambi et al., 2018). Our results on local interactions, where we differentiate between the regional and Italian level, point to the relevance of such distinction. Future work using data that goes beyond broad geographical areas and identifies specific universities in specific countries could address this important issue. Moreover, having data about specific universities may also provide new insights about the specific type of academic knowledge that companies are looking for when they establish distant collaborations. In the context of globalized value chains and global knowledge sourcing, better understanding of the implications of employing staff with international education experience and international work experience is crucial to develop and implement appropriate policies.

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Appendix A. The regional context

Piedmont is located in the North West of Italy. It has a population of about 4.4 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 firms active in the region in 2017, about 44,000 are in manufacturing. Employment in manufacturing represents about 25% of the total (national average is 21%). High and medium-high technology manufacturing is particularly strong, representing some 12% of total employment.

The region is specialized in automotive components: the home base of Italy's main car producer FCA is in Turin. Among the R&D intensive firms 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 firms active in aeronautics, aerospace and trains manufacturing. In addition to large R&D intensive firms, the regional industrial structure is characterized by many small and medium-sized firms 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 the fourth region in Italy for inward foreign direct investment (FDI). The majority of foreign MNEs (56% of employment) are active in manufacturing, and originate from France, Germany, the US, Switzerland, and the UK. Many of these are active in high and medium-high technology sectors, such as auto propulsion systems, components for machinery, instruments and software, bearing and seal manufacturing, robotics and electrical machinery, automotive components.

Piedmont has the highest value of R&D expenditure as a percentage of regional GDP among the Italian regions (2.2%) (Eurostat, 2017). This is due mostly to the sizeable R&D investments made by a few large Piedmontese firms, particularly FCA and Telecom Italia.

The region has four universities: three public universities (Università di Torino, Politecnico di Torino, Università del Piemonte Orientale "Amedeo Avogadro") and a small private university specialized in food science (Università di Scienze Gastronomiche).[14] Università di Torino and Politecnico are the oldest and largest institutions with student enrollment of respectively 70,500 and 30,800 (MIUR, 2017). Politecnico is specialized in engineering and architecture, while Università di Torino offers undergraduate and postgraduate courses in a wide range of other disciplines

In sum, Piedmont's economy is quite diverse and in many respects is similar to other industrial regions. 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 shares of medium and large firms. Science and technology indicators position the region near the EU-15 average. Piedmont's universities have different and complementary characteristics. This diverse context provides an appropriate setting for an investigation of university-industry interactions.

Appendix B. Robustness checks

Endogeneity

A potential concern with our results is related to the fact that MNE project managers may decide to assign inventors with a particular high number of international contacts to most promising projects or to projects that require international collaborations with universities. This would imply some endogeneity issues in our empirical framework. A tentative way to address this has been to specifically ask to the project managers of Italian and foreign MNEs interviewed whether they assign inventors with larger international connections to those kinds of projects. The common answer was that it only matters to a limited extent: it is more important that the person fits and can contribute with its competences to the development of the specific project.

I don't think it so fundamental: the most important thing is to reach the goal that we aim for. (…) Of course, if among my human resources there is somebody that has a better approach to these kind of relations (international academic relations nba) -with respect to others who are more experimental or more practical- this plays a role, but what matters in general, also in order to get funded by the company, is what we can achieve through that specific project. (Inventor B)

Having a portfolio of contacts did not seem to be relevant also in terms of hiring decisions by the MNEs, at least in the context of Piedmont.

"It never happened to me to see that a multinational would hire somebody because he had a portfolio of international contacts that were such to motivate an hiring also because that would be a position that would require to be put in a relatively high position and this was not so common among firms in Italy. (Inventor E)

While this does not rule out the possibility that this is something that occurs in other contexts, it suggests that in our sample endogeneity issues related to the decision of the MNE to strategically place international inventors in project with higher international scope, may be relatively less of a concern.

Marginal effects and probit

In Figs. B1 to B4 we plot the marginal effects of the main variables of interest on the probability to interact with universities in different locations. This allows us to check both for the actual economic impact of the variables and also to test whether the variables affect the intensity of the collaborations. We find that the effect of the majority of the variables is broadly similar for all types of collaborations (from rare to very frequent). For example, the number of foreign co-inventors positively affects in the same way all types of collaborations with US universities. The only variables that instead increase the intensity of the collaborations are respectively *Piedmont degree* on interactions with regional universities and *Italian degree* on interactions with universities in other Italian regions.

Coupled with the results of Fig. 1, which showed that the frequency of collaborations is similar across types of universities, this suggests that our results should hold also when looking simply at the probability to collaborate with a specific university, regardless of the intensity. To check for this in Table B1 we also perform a probit estimation with sample selection to double check whether the results are in line with those obtained in Table 5 with the ordered probit. The results for international collaborations are in line with the ordered probit results of Table 5: the only difference is the non-significance of the coefficient of Italian MNEs. This suggests that the factors that affect the collaborations with international universities do not have a strong effect on the intensity of such collaborations.

10 years lag for foreign co-inventors

In order to rule out the possibility that the inventor-level variables that measure their circle of international collaborators and their publications activity, are an output of their work for MNEs, in Table B2 we have also lagged the variable *Foreign co-inventors* and used only the co-inventions with foreign colleagues that occurred 10 years before the survey was run, i.e. before 1998. The results are still stable and show that the variable *Foreign co-inventors* is still positive and significant when it comes to collaborations with US universities, while the variable *Top-publisher* is significant for collaborations with both EU universities and US universities.

Tables B3 and B4

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

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