# Academic inventors, allocation of patent rights and knowledge diffusion: Subnetwork structures in university-owned and university-invented patents in two Italian universities

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## Abstract

The role of academics in patenting activity is not limited to patents owned by universities (university-owned patents) as academics often contribute to inventions patented by other organizations (university-invented patents). Moreover, it has been shown that academics play central roles inside the patenting network and that appropriability rules can interfere with the pattern of knowledge diffusion. In this study, we use social network analysis to analyze university-owned and university-invented patents in two Italian universities. We investigate the quality of the ties and the reasons why academics patent with their universities or with external organizations. We identify three subnetwork typologies. Two out of three subnetworks well exemplify the conditions for university ownership and for professor privilege, but the most complex structure, stemming from academic gatekeepers, need more flexible property attribution arrangements. In this contexts, aggressive policies toward university ownership can damage the networks with the highest grade of science-industry cross-fertilisation.

**Key words**: academic patenting; science–industry linkages; social network analysis; brokerage roles.

## 1. Introduction

In recent years, science and innovation policy strategies have been focused on patenting as a means to foster innovation and competitiveness, especially promoting a more active involvement of universities in patenting their scientific results. In the 2000s, the number of patents owned by European universities has grown rapidly. However, a substantial body of literature has shown that university-owned patenting is, at least in Europe, only part of the overall patenting activity of academics, who often cooperate in creating inventions owned by external organizations (Crespi et al. 2010; Lissoni et al. 2009; Thursby et al. 2009; Geuna and Rossi 2011; Lissoni 2012).

The above-mentioned literature argued that the analysis of knowledge exchange between academia and the real world should take into account the whole spectrum of the patenting activity of the academics, looking at patents assigned to the universities (university-owned patents), as well as at those assigned to other organizations (university-invented patents).[1] The literature showed that in Europe, there was no lack of academic patents, only a lack of university-owned patents.

Against this background, the policy objective of increasing the technological transfer from science to the market through stimulus policies that targeted university patenting seems to be, at least partially, misplaced. In fact, a policy initiative should consider the possible crowding-out effects between the two forms of academic patenting (university-owned and university-invented) and explain the reasons for favoring university ownership of the inventions.[2] Moreover, recent studies have shown that new policy initiatives, such as the abolition of the professor's privilege, have had negative effects not only on patenting, but also on the whole set of channels involving university–industry cooperation (Bercovitz and Feldman 2006; Lissoni et al. 2009; Valentin and Jensen 2007; David and Metcalfe 2010) and entrepreneurship (Färnstrand Damsgaard and Thursby 2013; Lindholm Dahlstrand et al. 2016).

In this respect, patent data reporting information on assignees, as well as inventors, can shed some light on an interesting set of university–industry relationships, particularly when analyzed through social network analysis (SNA) to look at a network of collaborations. Many studies have shown the prominent role of networks in the pattern of knowledge creation and diffusion (Zucker et al. 2002;

Breschi and Lissoni 2009) and the role of the academic inventors within it (Breschi and Lissoni 2009; Breschi and Catalini 2010; Lissoni 2010).

However, to the best of our knowledge, the SNA approach has rarely been used to look at the micro-level description of the whole network configuration generated by both kinds of patents around individual universities, possibly connecting it to the different university strategies regarding technological transfer. Capellari and De Stefano (2014) have explored the co-invention networks generated by owed and invented patents of two Italian universities (University of Trieste (UniTS) and University of Udine (UniUD)), both located in a northeastern region of Italy,[3] explicitly taking into account the role of assignees, allowing the identification of a complete set of relationships involved in patenting activity.

In this work, we start from the results of Capellari and De Stefano (2014) and comprehensively analyze the brokerage role played by academics and the subnetwork structures arising around them. The network analysis is then complemented with a set of interviews with academics who play prominent brokerage roles inside these subnetworks. The survey aims to understand the quality of collaboration arising from the identified network ties and some important aspects of academic patenting activity: the reason why academics patent with their own universities or with different organizations and the complementarity of the two forms of patenting, and between patents and other possible channels of cooperation. This remainder of this paper is structured as follows. In Section 2, we look for a comprehensive view of the possible network ties that can be derived from patent data. In Section 3, we briefly present the data and the overall network of the two universities. In Section 4, we describe in detail the three typical subnetwork structures arising from the networks, and in Section 5, we discuss the results of the qualitative analysis on key academic inventors playing brokerage roles in the identified subnetworks structures. We present our conclusions in Section 6.

## 2. Patent data and network construction: Theoretical aspects

Patent data make it possible to jointly consider information on individual inventors and on organizational ownership, allowing us to better understand the role of patents in shaping the patterns of collaboration between science and industry.

Usually, when SNA is applied to the study of co-invention networks, assignees are excluded for two main reasons: first, the heterogeneity of the two kinds of nodes; second, the presence of a hierarchical structure arising from the fact that inventors can be nested into assignees (and into other organizations). In fact, assignees and inventors belong to different levels of analysis because they are usually represented by organizations (ownership level and organization level) and individuals (individual level). However, considering the individual level, ownership level, and organization level together seems particularly important in studying academic patenting because in this way, we introduce information on the relationships among inventors and between inventors and organizations. When assignees are not excluded, the observed networks—directly derived from patent data—are made up of various types of actors (or nodes) and relationships.

Concerning the actors in the network, we can distinguish at least three categories:

- inventors (as individuals)
- assignees (organizations or individuals)
- organizations to which inventors belong (these can be assignees or not)

Only the first two actors are directly observable, whereas the third one depends on the availability of information on individual inventors, which is collected from sources external to the patent data. Notwithstanding, this third actor category is of major importance in the process of knowledge transfer.

As far as relationships are concerned, in such a network, we can *a priori* identify five kinds of links that can convey different levels of knowledge transfer intensity:

- co-invention: inventor–inventor link (I)
- co-assignment: assignee–assignee link (A)
- membership: inventor–assignee or inventor–organization link (M)
- observed cross-level link: inventor–assignee link (OIL)
- unobserved cross-level link: inventor–organization link (UIL)

Co-invention relationships are the typical collaborative ties among inventors, and form the most important knowledge exchange mechanism between intra-level actors (at the individual level). Co-assignee links can typically be considered another intra-level relationship (at the ownership level), and they may convey scant knowledge transfer, being that it is mainly an inter-organizational agreement.

Membership is a form of cross-level linkage that is important for other types of relations that are fundamental in the knowledge transfer process. In particular, we are referring to the relationships among academic and industrial inventors that carry a ‘latent’ or ‘implicit’ relation between each of them and between the organization to which they are affiliated. Such a latent relationship can convey knowledge spillovers and, potentially, gives rise to a variety of forms of cooperation, which is one focus of our analysis. We distinguish between two types of such relationships on the basis of their observability in the data, namely OIL and UIL. We observe OIL by means of the link between individual inventors and assignees, whereas UIL is not observed, because organizations (not assignees) are not included in the patent data.

These cross-level relations are important in understanding knowledge exchange and spillover effects that are mediated by patents because of the different functioning of the two main organizations involved in academic patenting activity: universities and private firms. The former, belonging to the open science environment, are less hierarchical and academic scientists make contact with firm inventors as well as with top managers and headquarters, conveying their research-based output and tacit knowledge at different organizational levels.

Therefore, cross-level relationships are standard and tangible, and their effect on knowledge diffusion processes should not be neglected. Our main assumption is that cross-level relationships are one of the core channels of patent-based knowledge transfer.

## 3. The case study: Context and data

We analyze the academic patents of two Italian universities (UniTS and UniUD), during the period 2000–2010. The two universities share the same institutional context[4] and have some macro-characteristics in common. Specifically, they are of a medium size (both having around 18,000 students and 750 researchers), and they are both generalist universities that include the majority of scientific fields.[5] However, their attitudes toward technological transfer are quite different. UniUD showed an earlier and more definite

**Table 1.** Data on patent ownership, assignees/inventors and the co-invention network from patent data for Universities of Trieste and Udine

| | University | |
|---|---|---|
| Descriptive data | Trieste | Udine |
| Academic patents (total) | 62 | 56 |
| Owned by: | | |
| • Only universities* | 25 | 25 |
| • Only firms and/or research bodies | 29 | 21 |
| • Only group of inventors | 8 | 10 |
| • Co-patented between universities* and firms/PROs | 7 | 3 |
| Academic inventors** | 43 | 44 |
| Assignee (firms, research bodies, PROs) | 26 | 17 |
| **Network data** | | |
| Number of nodes | 171 | 66 |
| Density | 0.036 | 0.038 |
| Number of links | 1024 | 1204 |
| % of multiple links | 7.3 | 7.3 |
| Number of components | 12 | 12 |
| Number of nodes in giant component (% nodes) | 124 (73.4%) | 103 (56.6%) |
| Number of groups of min. size 3 | 41 | 36 |
| Average degree | 12.1 | 13.9 |
| Network centralization | 40.7% | 47.0% |

Source: Capellari and De Stefano (2014)

*Local Universities (Trieste and Udine)

**Ph.D., post-doc and students are excluded.

orientation toward an engagement in this direction, while UniTS engaged later on. Despite the fact that both have taken part in the trend of increased patenting activity that characterized Italian universities during the 2000s, UniUD's patenting began earlier, when the general patenting activity of Italian universities was very low, and shows considerable ability in patent commercialization.[6] Licensing activity and its spin-offs are also significantly increasing at UniTS. On the other hand, UniTS benefits from greater private research funds and has a greater degree of interaction with the private sector via contract research (Benedetti et al. 2012).

We consider all the international patents signed by at least one inventor employed at UniTS or UniUD during the period 2000–2010.[7] We observe a total of 118 academic patents (56 for UniTS and 62 for UniUD), 50 of them are owned by one of the two regional universities and 68 are derived from the collaboration of at least one academic inventor and an external organization. The number of international patents signed by the universities is the same for each of them, so the number of invented patents is greater for UniTS (see Table 1).

Academic inventors are classified by their scientific field, whereas non-academics are grouped according to their affiliation: private firms and public research organizations (PROs). For every assignee, we identified the relevant industry (according to the official Italian Ateco classification) and the localization (regional, national, and international).

The distribution of academics by scientific field highlights a pattern of specialization characterized by the presence of an UniUD-specific scientific field (agricultural and food) and of a higher percentage of researchers in biology and chemistry for UniTS.[8]

Regarding the nature of the patents, both universities have a relatively high number (about 20% of the total) of patents in medical and veterinary science (A61 International Patent Classification (IPC) code). However, for the UniTS, organic chemistry (IPC code C06, 20.6%) and biochemistry (IPC code C12, 8.8%) are the most important patent classes, while in the case of UniUD, a prominent position is taken by manufacturing products, particularly textile laundering (IPC code D06, 19.4%).

The co-invention networks centered on the two universities are slightly different in size (145 inventors and 26 assignees for UniTS, 148 inventors and 18 assignees for UniUD), and the networks exhibit a similar structure: low density, high centralization, and similar average degree (see Table 1). In particular, as expected, the networks are strongly centralized around the two universities, given their role as assignees (or co-assignees) of more than two-thirds of the total number of patents.

Looking at global connectivity with respect to patent ownership, in the case of UniTS, the network generated by university-owned patents represents a large number of multiple ties (i.e. inventors cooperating to realize university-owned, as well as university-invented, patents). Furthermore, the groupings are quite heterogeneous, linking different types of actors (non-academic inventors, companies, and PROs). In the case of UniUD, the university-owned network is almost completely disconnected from the university-invented network: the external components are very large, and few academic inventors are involved in both activities. Apart from these marginal differences, the networks of both universities seem to have similar structures (regarding university-owned and university-invented patents). Therefore, micro-level differences are of greater interest for an in-depth analysis of the subnetwork structure characterizing the two universities.

## 4. Micro-level analysis: Inventor's brokerage roles and subnetwork structures

The analysis of the overall structure of a network allows us to understand the 'model' of the functioning of a given system. However, with many phenomena, the micro-level relationships are those of interest. The interactions among academic inventors and between such inventors and those belonging to various organizations can be appreciated only by discovering local structures, as well as analyzing the individual roles of prominent inventors within the networks.

Lissoni (2010) states that it is of crucial interest:

> ... to measure the extent to which academic inventors stand in between otherwise unrelated co-inventors from university and/or industry.

In order to investigate this factor, he uses a family of sociometric measures derived from an adaptation of Gould and Fernandez's (1989) definitions of brokerage roles to the case of co-invention networks. This allows him to measure the extent to which academic inventors stand between otherwise unrelated co-inventors from academia and/or industry (Lissoni 2010).

Starting from this methodology, we look for the roles that academic inventors can play inside the described networks (both university-owned and university-invented), with a focus on the 'identity' of the inventors. In particular, with respect to Lissoni (2010), we attach a slightly different set of covariates to our inventors, that is, academic inventors (only related to our two

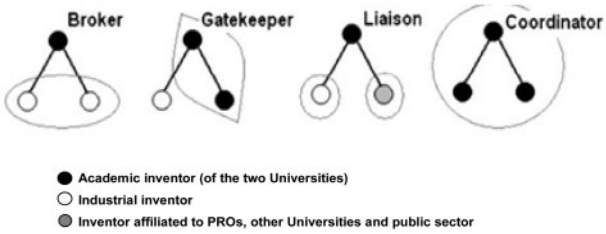


**Figure 1.** Brokerage roles according to a three-group classification of inventors

Highlighted subsets contain inventors belonging to same group (adapted from Lissoni 2010)

Source: Capellari and De Stefano (2014)

universities), industrial inventors, and PROs/other universities' inventors (see Fig. 1).

It should be noted that in this analysis, we exclude the assignees, without losing any relevant information. This choice was made for two main reasons: first, from a methodological point of view, the covariates attached to our inventors already include the affiliation of each inventor (e.g. industrial, PROs), partially accounting for those relationships identified as OIL and UIL; second, from a practical perspective, we cannot include assignees, because in university-owned patent networks, the two universities play an artificially central role by construction, which results in hiding the role of individuals, which is our main interest here. By means of this analysis, we are able to understand the positions of researchers belonging to different organizations in the knowledge flows from academia to the external world (and vice versa).

The brokerage analysis we present below is an in-depth analysis of the betweenness role of individual inventors. Exploiting the individual positions of inventors in the network with respect to the inventors belonging to the different groups (academic, industrial, PROs), we are able to measure four different roles they can play: (itinerant) broker, gatekeeper, liaison, and coordinator. The individual inventor positions with regard to all of these roles are shown in Fig. 1.

We define these roles in detail following de Nooy et al. (2011) and Capellari and De Stefano (2014). The extension to the co-invention networks is pretty straightforward. Two out of four brokerage roles involve mediation between members of a given group. If the mediator is also a member of the group, this is known as the coordinator role. In the second role, two members of a group use a mediator from the outside, who is identified as a broker. The other two brokerage roles describe mediation between members of different groups. In one role, the mediator is a gatekeeper, who regulates the knowledge flow to his group from the outside. Finally, in the second, the liaison is an inventor who mediates between members of different groups but who does not belong to these groups.

Looking at the differences between the two universities, we find that itinerant brokerage roles are more prevalent in the UniUD network, whereas gatekeeping and liaison roles are overrepresented at UniTS. In general, the distribution of brokerage scores is much more concentrated around a few inventors (mainly academic) in the case of UniUD, whereas in the case of UniTS, a slightly higher number of inventors share the same level of importance regarding the various roles. Looking at the scientific sectors, in our case, chemists play gatekeeper and coordinator roles, whereas engineers more often act as itinerant brokers.

Surrounding these different brokerage roles, we detect three different and typical subnetwork structures. These subnetworks arise in different forms, mainly depending on the ownership of the patent and on the university we are considering.

The first subnetwork (type A, defined as 'cooperation with external open science actors') is typical of academics collaborating with scientists belonging to other open science organizations. This structure is made up of homogeneous actors, because they mainly belong to the open science environment, as confirmed by the actor who was interviewed. Occasionally, this subnetwork involves co-patenting. These structures are pretty common and similar across the two universities (although they are more frequent at UniTS) in terms of owned patenting activities. Fig. 2 shows an instance of this subnetwork at UniTS, which is centered on an academic inventor, a star scientist in chemistry, who acts as a gatekeeper, bridging an international university and PROs.

The second typical subnetwork (type B, 'multiple interaction and co-patenting') arises from cooperation between more than one academic scientist and one or more private firms, along with the role of the university as assignee. This kind of subnetwork is often composed of strongly connected nodes in which the ties are activated by inventors or assignees involved in both owned and invented patents. In this instance, the knowledge flows from academia toward private organizations through prominent academic inventors, who often act as gatekeepers. Such a structure represents, in our observed networks, the leading bridging form of interaction between universities and the private sector (occasionally with PROs), involving many cross-level linkages (OIL and UIL). The structure is non-homogeneous, including both industrial and academic inventors, as well as public and private organizations, with more than one academic playing a bridging role.

Fig. 3 shows an example of this type of subnetwork at UniTS in which the co-patenting organizations are a private firm and a prominent Italian PRO. This connection is observed through the membership linkage of IN044, an external inventor belonging to the PRO who acts as an itinerant broker (and also plays a non-negligible role as gatekeeper in the whole network). This inventor plays a very important role, bridging from the inside to the outside. The central academic inventors are three leading chemists. In particular, IN183 and IN212, both having a comparable gatekeeping role, connect actors belonging to different organizations (namely, UniTS with PROs and other external universities).

The third subnetwork (type C), which we define as 'disconnected subnetworks', emerges only with university-invented patents in which individual academics who are employed in the two universities participate. It is characterized by the presence of one (or a few) academic inventors who act as brokers between industrial inventors belonging to different firms or become liaisons when they connect different kind of organizations (e.g. PROs and firms). We show two instances of this subnetwork. In the first example (see Fig. 4(a)), there is only one academic inventor (an engineer), acting as broker, who is connected to an external assignee (locally based multinational firm) and several external co-inventors, otherwise disconnected. The second example (see Fig. 4(b)) represents a case in which the academic (a biologist) plays a liaison role, interacting with private firms and, at the same time, with an external open science organization (a foreign university). These subnetworks seem to represent a typical structure for invented patents, especially in the UniUD network (particularly the second example), where only an academic inventor, who is never involved in owned patenting,

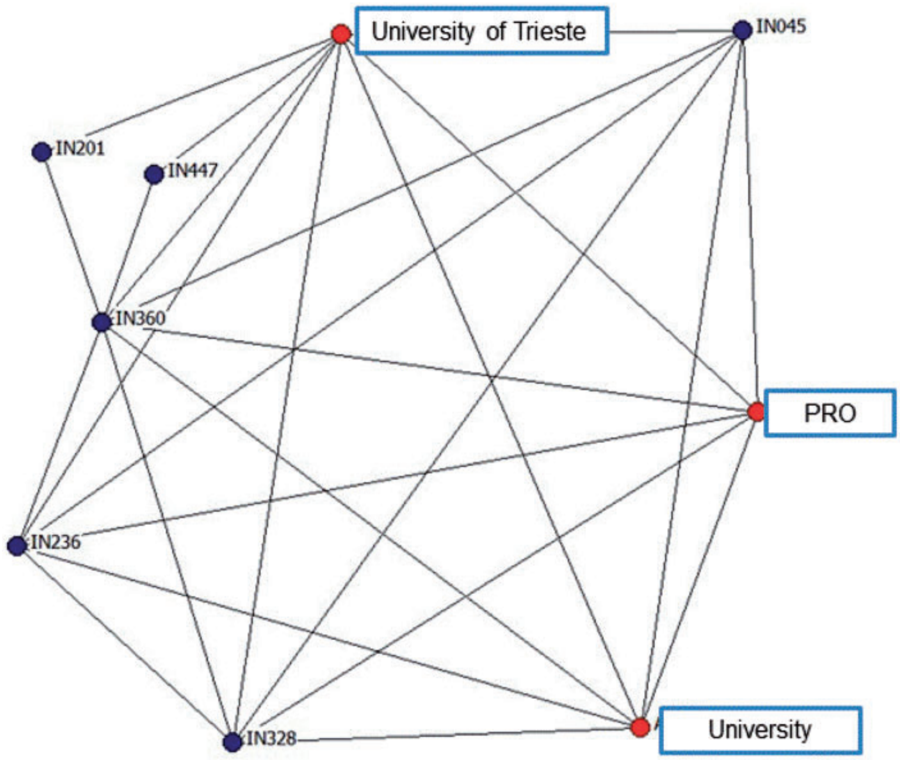


**Figure 2.** Type A. Cooperation with external open science actors

Blue circles represent inventors; red circles represent assignees

Academic inventor IN360 (chemist) is the gatekeeper in this structure

contributes to many patents owned by the same external private assignee or different and heterogeneous private assignees (see Fig. 4).

The subnetwork structures detected seem to adequately represent the possible forms that the cooperation of scientists with external subjects can assume. These structures, as general typologies, are present in both universities. However, their relative importance inside the network and frequency seem to be different: specifically, UniTS is characterized by type B and UniUD by type C subnetworks.[9]

## 5. Qualitative analysis results

The heterogeneity of these subnetworks calls for a qualitative investigation based on two central questions. The former is aimed at verifying the effectiveness of the collaboration links recorded in the patent data, while the latter is used to understand the reason for the different attributions of propriety rights inside the different contexts.

The qualitative analysis was carried out via in-depth interviews with the key actors in the subnetworks that were detected. We interviewed six key actors: one of them is a gatekeeper in university-owned subnetwork type A (see Fig. 1); two are gatekeepers in subnetwork type B (Fig. 2); three are brokers or liaisons in the university-invented network (in particular, in the subnetworks of type C depicted in Fig. 3). The brokers who were interviewed were: chemists (4), a biologist (1) and an engineer (1). Four out of the six are aged under 50 years, while the other two are older (around 60 years old). Four are listed among the top Italian scientists in the scientific performance ranking based on the h-index.[10]

In the first part of the interviews, with the support of a graphical representation of the interviewee's subnetwork, we asked the academic inventors to comment on the quality of their connections (see Section 3). In particular, we investigated the existence and the importance of the cross-links between the academics and external assignees and the extent to which these ties convey factual knowledge flows. We then focused our attention on the existence and quality of a preferential link between academic inventors and assignees, as well as on the hierarchical structure of the collaboration between academics and industrial inventors (when present).

The second part of the interview was devoted to detecting the reasons why inventors patent with their own universities or with external organizations, together with the role of industrial partners, if any, and the possible complementarity or substitutability between owned and invented patents as well as between patents and other channels of cooperation (e.g. different kinds of research contracts). The analysis allows us to reach a set of consistent conclusions related to the three kinds of subnetwork structures identified above.

In the type A subnetwork, patents are derived almost directly from scientific work and represent effective collaboration links among inventors. From the interviews with inventors who play gatekeeper roles, it emerged that:

> ... the patent network represents a subset of wider scientific network of collaboration.

It often acts for:

> ... tracing links created in previous scientific collaborations, especially with doctoral students.

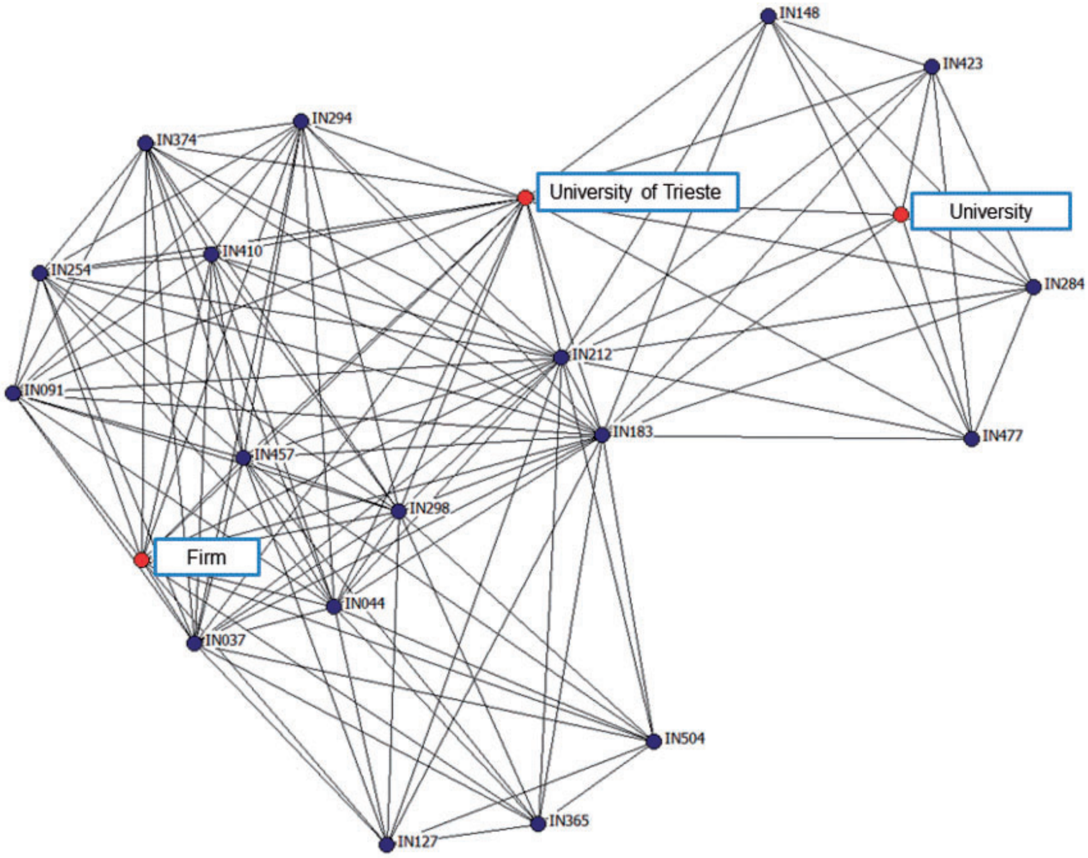


**Figure 3.** Type B. Multiple interactions and co-patenting

Blue circles represent inventors; red circles represent assignees

Academic inventors IN183 (chemist) and IN212 (chemist) play comparable gatekeeping roles, inventor IN044 (PRO inventor) plays an itinerant broker role

Thus, the structure can be considered non-hierarchical (or horizontal) because the role of the organizations to which the scientists belong is considered to be of secondary importance.[11] In this type of subnetwork, inventions arise almost directly from the basic research efforts of the scientist and:

> . . . patenting with [one's] own university is a straightforward way to recognize the economic effort made by the open science organisations [. . .] patents can be thereafter licensed.

Even if this structure is totally rooted in an open science context, the scientist recognizes the possible role of industrial partners when there is a need to develop or to test the inventions through large-scale, complex experiments.

The scientists playing bridging roles inside the type B subnetwork acknowledge the complexity of the links involved in the co-operative activity described in the subnetwork and the importance of the cross-level links mentioned in Section 2. All the inventors who were interviewed recognize that, within patent development:

> . . . centrality indices are good indicators of the relative importance of the actor's contribution.

The links they activate with external (mainly industrial) inventors are mediated by the organizations (firms) to which they belong. Indeed:

> . . . the scientists interact first with the firm headquarters (CEOs).

The industrial inventors named in the patents are not always the industrial researchers who worked on the research project that gave rise to the patent but often 'middle managers or even CEOs'. It also emerges that:

> . . . patents are almost always anticipated by a research contract.

Here, an active contribution from the industrial partners is called for because of the need for laboratories, which are not always available inside Italian universities. Cooperation with firms is also essential for the general academic research from which patentable results can emerge. The decision regarding the optimal choice about a patent's ownership—university or private organization ownership—depends essentially on the 'differences in efficiency of the two kinds of organizations' and on the amount of resources needed to take out and defend the patent.

The type C subnetworks represents the typical structure of the university-invented patents when the 'professor's privilege' is at work. The connection is mainly activated by a single scientist with one (or more) external partners. However, in contrast to the type B subnetwork, these subnetworks are completely disconnected from university-owned patenting activities, and the link with the university is mediated by an academic inventor who did not interact (as far as patents are concerned) with his own university but only interacts with the industrial inventors. Sometimes, the industrial inventors named in the patents are the actual researchers who worked on the

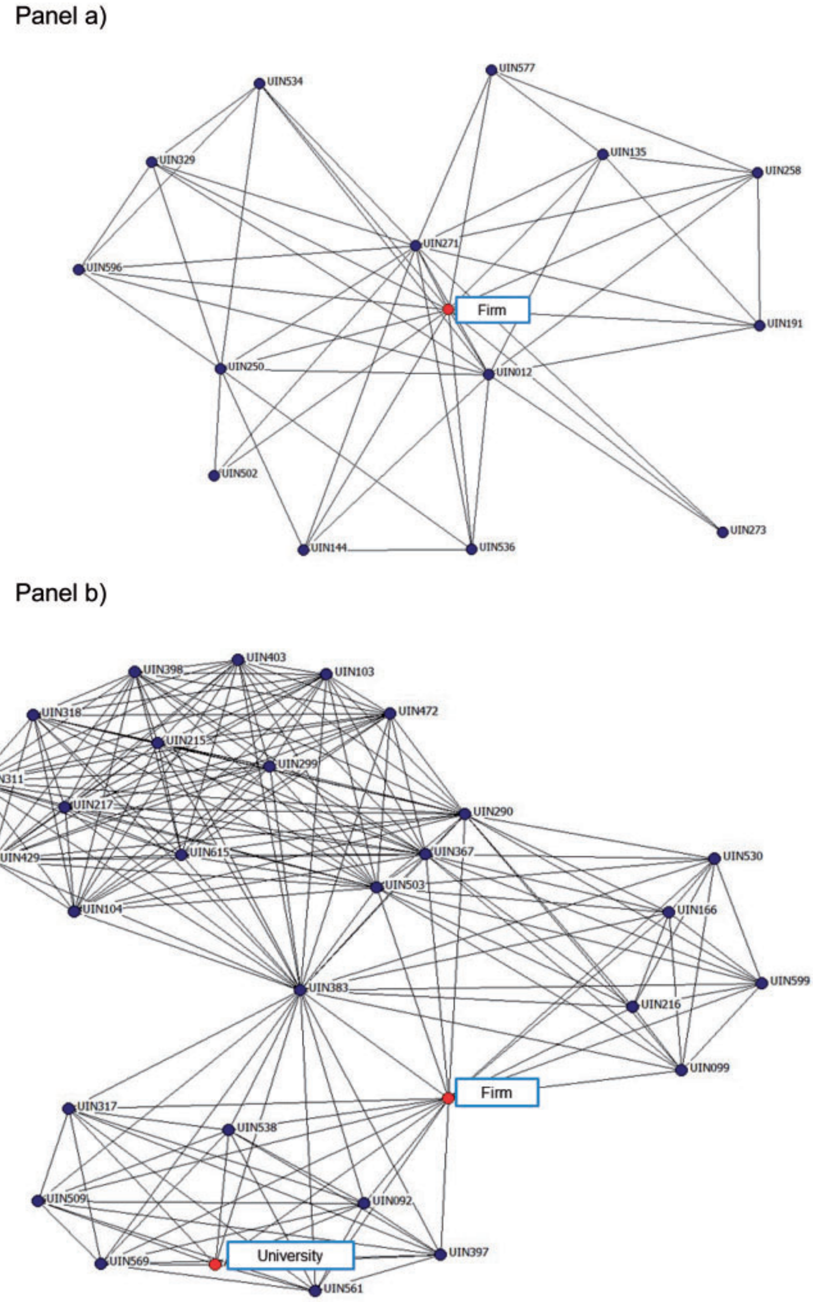


**Figure 4.** Type C. Disconnected subnetworks in university-invented networks

Blue circles represent inventors; red circles represent assignees

(a) inventor UIN271 (engineer) act as broker; (b), inventor UIN383 (biologist) act as a liaison between firms and other universities

invention but they can be middle managers or even CEOs. The role of industrial partners is obviously decisive: patents arise from different degrees of involvement on the part of scientists in the firms' activities (from contract research to the direct responsibility for the management of a sector of the firms' research). From the point of view of ownership:

> . . . there are no reasons why you should patent with your own university, being the results achieved in a context where the resources pertain in large part to the industrial partner.

From the researcher's point of view, cooperation with firms is definitely important in bringing about 'efficiency and the vision'.

At a very general level, we observe that a complementarity between the two forms of patenting may exist. In fact, as far as the type A and type C subnetworks are concerned, the attribution of property rights seems straightforward. A richer and nuanced situation is reported by the scientists belonging to subnetwork type B who refer to a 'relative efficiency' in the patent's management. In this situation, excessive pressure from their own university as organization can damage the multiform set of relationships (between and across the boundaries of the organizations involved) centered on researchers, relationships that can be nurtured only by a significant degree of freedom for the researchers.

## 6. Conclusions

In this paper, we have applied SNA to analyze the co-invention networks generated by academic inventors via patenting activity with their own university and with different organizations, in particular firms and PROs. From a methodological point of view, the network ties were identified using all information retrieved from the patent data of two Italian universities. This choice allowed us to detect three subnetwork typologies (cooperation with external open science actors, multiple interactions and co-patenting, and disconnected subnetworks) that showed the various possible forms of interaction between universities and external partners when we take into account all the possible ownership structures that the patenting activity of academics can take on.

Based on the detection of the brokerage roles and the follow-up qualitative analysis, we showed that direct links between the prominent academic inventors (brokers) and the firms (assignees or not), those we called cross-links, are of great importance in shaping the collaboration structures, and consequently, the knowledge channels from academia to the external world (and vice versa).

In fact, these subnetworks are generated by the meeting of two organizations that differ in their hierarchical structures and in their missions. Open science organizations have been, until now, centered on the researchers (backed by their universities), while the firms are more cohesive and hierarchical. Moreover, from the point of view of the firm, the ultimate aim is profit maximization while from the point of view of the university, the general aim is to maximize the diffusion of knowledge to meet societal needs, subject to the constraint of gaining co-financing for the research effort. This highlights a kind of asymmetry between the networks generated by open science ties, and those generated by cooperation with actors working in the market. The importance of these science–industry cooperation links requires universities to be cautious when exhibiting aggressive attitudes toward the ownership of patents. The dynamics of appropriation can, in fact, damage the cross-fertilisation between the academic and industrial research that occurs when the tacit knowledge of academics is coupled with codified knowledge and the quest for solutions to practical needs.

Furthermore, the qualitative survey points to the importance of the many possible channels of science–industry interaction. In a sense, we can say that the patenting activity of academics with external actors can be damaged not only by an aggressive attitude on the part of universities toward patent assignment rights, but also through the limits imposed on the various forms of cooperation, ranging from research projects to the exchange of researchers.

Finally, it seems worth adding that the comparisons can be enriched by considering the frequency of the identified typologies inside each university. In our case study, we observed that the type C subnetworks are more common at UniUD, whereas the type B subnetworks are more common at UniTS. This fact comes with the stronger push toward technology transfer that UniUD has shown since its foundation. This is a possible case of a university policy affecting the academic inventors' external or internal collaboration network. However, more empirical research is needed to generalise this result, since many other factors can play an important role in this process. Future research will be directed to extending the analysis to a wider cohort of universities, while controlling for these factors. In particular, the characteristics of the relevant scientific areas, those of the brokers, the evolution of the network over time and the features of the geographical area of the localization of the universities will be considered.

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## Notes

1. These two subsets can partially overlap because of the presence of co-assigned patents in which there is at least one university and one other organization. For the sake of completeness, it should be considered that there can be patents that are assigned only to inventors, but in our framework, this case is subsumed within the university-invented patents group.
2. A general framework for the analysis of property rights attribution was developed by Aghion and Tirole (1994) and discussed by Crespi et al. (2010).
3. The two universities are located in the Friuli Venezia Giulia region, which has a population of around 1.2 million inhabitants, and it is one of the most developed and innovative among the Italian regions, ranking eighth in gross domestic product per capita (2013 data).
4. In Italy, the regulatory context changed in a contradictory way during the 2000s. The professor's privilege was introduced in 2001 and only partially reformed in 2004.
5. It should be noted that there is a degree of specialization in food and veterinary science at UniUD and in chemical fields at UniTS.
6. UniUD licensed about 30% of the patents produced. In fact, patenting activity is not far from a budget equilibrium. The entrepreneurial attitude of UniUD is also suggested by its generation of spin-offs. In this respect, UniUD emerges as one of Italy's best performers (Netval 2009).
7. The database was constructed following the methodology adopted in the literature (also reported by Lissoni et al. 2009).
8. If we weight these numbers on the average number of researchers employed in the period 2000–2010 in each of the two universities, we find that the percentage of academic inventors varies from 5% (UniTS) to 7% (UniUD). If we consider only those researchers in scientific areas, the percentage almost doubles, a value that is significantly higher than that reported by Lissoni (2012) on the basis of more general data.
9. In general, UniUD is characterized by a smaller degree of overall collaboration.

10. See <http://www.topitalianscientists.org> accessed 8 July 2016.
11. It is interesting to note that the link is often mediated by well-established, previous, professor–student relationships.

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