

Makers and clusters. Knowledge leaks in open innovation networks

Jessica D. Giusti, Fernando G. Alberti, Federica Belfanti*

Institute for Entrepreneurship and Competitiveness, LIUC Università Cattaneo, Corso Matteotti 22, 21053 Castellanza (VA), Italy



ARTICLE INFO

Article history:

Received 29 March 2018

Accepted 4 April 2018

Available online 25 April 2018

JEL classification:

O3

Keywords:

Open innovation
Maker Movement
Knowledge leak
Cluster
SNA
Multiplexity

ABSTRACT

This paper aims at investigating the role of makers in open innovation networks by focusing on whether and how knowledge leaks occur in open innovation networks with makers. In the last years, makers have been widely recognized as conducive to innovation and growth in different fields through a novel and open approach. However, little is known about the role played by makers and, more specifically, about the flow of unintended knowledge – i.e. knowledge leaks. Data have been collected by iteratively deploying a snowball sampling technique in an Italian high-tech cluster with a dense and heterogeneous ecosystem of makers. Data analysis relied on social network analysis method and techniques. Findings shed light on a totally unexplored phenomenon and suggest intriguing implications both for theory and practice on whether and how knowledge is exchanged in innovation networks and how knowledge leaks occur.

© 2018 Journal of Innovation & Knowledge. Published by Elsevier España, S.L.U. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Introduction

It is widely acknowledged that the Maker Movement is having far reaching effects on business, economy, even our everyday way of life (Make, 2013). The growth of the Maker Movement and the rapid changes in the ecosystem of business and platforms supporting Makers is already attracting interest from entities as diverse as the White House and the Chinese government (Lindtner, 2015) to major multinational corporations (Deloitte, 2014).

Makers have been widely recognized by media (NCDMM, 2016) as well as in literature as conducive to innovation and growth. In fact, one of the main implications for the Maker Movement is that they are advancing innovation in several fields through a novel and open approach. Thus, what are the implications of the Maker Movement for innovation? Aldrich (2014) suggested a number of implications. First, user driven innovation, like the one promoted by makers, is often a major source of product improvements, as well as totally new products, in established industries (Von Hippel, 2005). Next, the tools (such as rapid prototyping tools: 3D printers, laser cutters, form boxes, etc.) available in spaces and laboratories (Stacey, 2014) where makers work enable users to quickly and cheaply experiment with variations on their designs (Hatch, 2013). Further, the Maker Movement is grounded in an ideology

promoting cooperation and sharing (Pieri & Domeniconi, 2016), according to the paradigm of collaborative and open innovation.

Open innovation is defined as “the use of purposive inflows and outflows of knowledge to accelerate internal innovation and to expand the markets for external use of innovation” (Chesbrough, 2003). Adopting open innovation approaches implies redefining the firm’s boundaries, allowing knowledge to become an exchangeable good (Chesbrough, 2003). The assumption for pursuing open innovation with a variety of partners (e.g. users, suppliers, universities, research centres, individual experts/scientists and even makers) is that they are conducive to several potential benefits (e.g. reducing time to market, cost and risk reduction, improving access to specific expertise; West, Salter, Vanhaverbeke, & Chesbrough, 2014).

Previous works on the Maker Movement and culture do stress their capacity of open and collaborative innovation through networking (e.g. Aldrich, 2014; Browder, Aldrich, & Bradley, 2017; Van Holm, 2015; Von Busch, 2013). Openness, peering and sharing are integral parts of the Maker Movement. Inter-organizational networking for innovation is a distinctive trait of any community of makers (e.g. Aldrich, 2014; Browder et al., 2017; Van Holm, 2015; Von Busch, 2013), but scholars in open innovation networks argue that a strength in the most competitive networks is the exchange of a large quantity and quality of different types of knowledge (Alberti & Pizzurno, 2015). The general understanding in literature (Alberti & Pizzurno, 2017) is that different types of knowledge exchanges are required for innovation and that multiplexity of knowledge exchanges – i.e. the concurrent and not-intended exchange of

* Corresponding author.

E-mail address: fbelfanti@liuc.it (F. Belfanti).

different types of knowledge at the same time – is dramatically crucial in open innovation networks, where, despite the setting is open, the intent is to govern which actor is bringing in/out a specific knowledge contribution for the sake of innovation.

However, so far research has failed to identify reliable signals of makers' innovation practices and approaches (Tanenbaum, Williams, Desjardins, & Tanenbaum, 2013). To this regard and in the interest of the present paper, little is known about the role played by makers in open innovation networks and on how do they exchange knowledge for innovation.

The topic is extremely relevant since the Maker Movement can be surely conceptualized as a knowledge-building community (Howard, Gerosa, Mejuto, & Giannella, 2014), where innovation is put forward by sharing knowledge. Further, it is even more crucial when open innovation networks are not set among peers, but – as in the case of makers – among them and for instance large firms or institutions, where on both sides we expect to have more unintended knowledge flows. Such knowledge 'leaks' that – according to Alberti and Pizzurno (2017) – are defined as 'an involuntary and sometimes unconscious exchange of types of knowledge other than the one meant for exchange in open innovation networks' are totally unexplored in relation to makers' innovation practices. Hence, our research focus for this paper is 'whether and how knowledge leaks occur in open innovation networks with makers'.

The study is based on data collected in an Italian high-tech cluster, located near Milano, in Northern Italy, where the cluster ecosystem comprises also an active and dense community of makers as well as fab labs (literally, fabrication laboratories) and makerspaces.

Data collection relied on a snowball sampling technique. By iteratively applying this procedure we interviewed 53 cluster actors and collected relational data concerning the flows of knowledge in innovation networks.

Data analysis relied on Social Network Analysis techniques and software.

Our paper sheds light on an almost unexplored phenomenon, theorizing on the role of makers in open innovation networks and suggesting intriguing implications both for theory and managers.

The paper proceeds as follows. We begin by reviewing the literature on open innovation and makers, and then we focus on knowledge exchanges in innovation networks. This is followed by a methodological section, where the research design of the study is illustrated. Next, we present and discuss our findings. We conclude providing final reflections and contributions as well as limitations.

Theoretical background

Makers and open innovation networks

In today's business environment, firms keep searching for new and effective innovation models, of which the so-called 'open innovation' approach seems to be largely spread (Alberti, Giusti, Papa, & Pizzurno, 2014; Alberti & Pizzurno, 2013).

While a large part of the available literature has concentrated the attention on large innovators (Van de Vrande, de Jong, Vanhaverbeke, & de Rochemont, 2009), academic interest in this topic has now shifted on other kinds of innovators and makers actually do qualify for playing a crucial role in open innovation networks.

In *Makers: The New Industrial Revolution*, Chris Anderson (2012), the former editor-in-chief of Wired, describes how open-source design and 3D printing "bring manufacturing to the desktop". Much of this activity has been fuelled by a new generation of hardcore makers, who have come together under the banner of the "Maker Movement". The Maker Movement, whose journey "from the margins to the mainstream" was chronicled in

the March 2011 Wired cover story, is deeply committed to local, collaborative, community-based invention; makers network to share tools, technologies, and ideas through online communities but also through physical spaces. The MIT pioneered this field setting up a Center for Bits and Atoms (<http://cba.mit.edu/>) and a fab lab (<http://fab.cba.mit.edu/>) that aim at an interdisciplinary spreading of material open production in a wide range of academic and economic fields (Thompson, 2005).

As Maker communities spring up around the globe, a variety of physical and virtual platforms to serve them have emerged – from platforms that inspire and teach, to those that provide access to tools and mentorship, to those that connect individuals with financing and customers (Deloitte, 2014; Gershenfeld & Euchner, 2015). Several concepts compete for understanding the makers communities: knowledge networks, knowledge communities, communities of interest, communities of practice, etc. (e.g. Brown & Duguid, 1991; Lave & Wenger, 1991). These resemble both virtual platforms like Instructables, Makerspace.com, etc. as well as locally based communities of makers either temporary (e.g. Bay Area Maker Fairs), in the form of temporary clusters (Belussi, Sedita, & Omizolo, 2008; Maskell, Bathelt, & Malmberg, 2004), or stable (e.g. Central Florida makers community), with related and supporting industries and institutions in the form of clusters (Lazzeretti, Boix, & Capone, 2010; Porter, 2008), where knowledge is co-constructed and shared, through joint problem-solving. A preliminary review of the literature, drawing on previous studies on the clustering of creative industries – like the Makers Movement – suggests that several factors are at play to explain why collaborative knowledge networks or communities of practice might cluster (e.g. Lazzeretti et al., 2010).

On a physical level, the rise of the maker culture is closely associated with the rise of a totally new entrepreneurial ecosystem (Mortara & Parisot, 2016) made of hackerspaces, fab labs, makerspaces, tech-shops, co-working spaces, crowdfunding platforms, related and supporting industries (first of all laser-cut and 3D printers makers and consultants, but not only; dedicated vocational training and education, academic and corporate research, etc.), local and international associations, clubs and institutions.

On a virtual level, sharing and cooperation in the Maker Movement is also facilitated by Internet-based platforms (Chesbrough, 2003). Internet-based sharing, marketing, distribution, and crowd funding (such as platforms like Kickstarter, Indiegogo, and Funded-ByMe) have given makers access to resources hitherto unavailable through traditional physical platforms (Mollick, 2014).

The makers' culture is experimental and open (Shah, 2005). Collaboration and sharing are so essential to the Makers Movement that a survey titled Maker Market Study (Make, 2013) which examined the extent of makers' sharing and collaboration reported that 59% of all respondents either said "other use what they make" (41%) or they "make things with others" (50%). Collaborations and interactions are the backbone of the maker culture (Von Busch, 2013). The maker culture is thus less of a do-it-yourself (DIY) and more a do-it-together culture, merging collaborative play and interactions, often for the sake of shared curiosity.

Knowledge exchanges in open innovation networks

Recent studies (see Alberti & Pizzurno, 2015 for a comprehensive review) on open innovation have shown that successful innovation does not depend exclusively on technological knowledge but rather on a heterogeneous recombination of a broader set of knowledge types (Boschma & Ter Wal, 2007; Rodan & Galunic, 2004). Knowledge is a broad concept, encompassing various types (Amin & Cohendet, 2004; Simonin, 1999) such as technological knowledge (i.e. product and process development knowledge), market knowledge (i.e. organized and structured information about the markets),

and managerial knowledge (i.e. competencies to make managerial and organizational processes more efficient and effective), as well as industry-specific knowledge (i.e. idiosyncratic competencies that strictly refer to a specific sector), financial knowledge (i.e. access to finance and competencies on how to deal with financial players) and institutional knowledge (i.e. translation of historical data, traditions, values and norms).

Knowledge exchange can offer a series of benefits, such as reducing time to market, cost and risk reduction, improving access to specific expertise, etc.

The combination of the aforementioned streams of literature in open innovation – (i) open innovation and makers and (ii) open innovation and knowledge exchanges – suggest that the research gap in literature is twofold.

When studying knowledge flows and exchanges in innovation networks, some authors (Alberti & Pizzurno, 2015) have suggested to dig more in their multiplexity (Gimeno & Woo, 1996), i.e. the concurrent and not-intended exchange of different forms of knowledge (i.e. market, managerial and technological knowledge) at the same time. The idea is that different types of knowledge may be embedded one in the other or that the exchange of one type of knowledge may deliberately or unconsciously imply the exchange of other types of knowledge. The multiplexity in knowledge exchange is dramatically crucial in open innovation networks, where, despite the setting is open, the intent is to govern which actor is bringing in/out a specific knowledge contribution for the sake of innovation.

Hence, our research question is the following.

RQ: Whether and how knowledge leaks occur in open innovation networks with makers?

Makers in the Green and High-tech Cluster of Brianza

The Green and Hi-tech Cluster of Brianza is a technological-driven cluster located in Northern Italy, between the Province of Milano and Monza-Brianza.

The two main fields of the technological specialization of the cluster are ICT, including microelectronics telecommunications and software, and Energy, with a focus on sustainable sources.

In the late 1950s, many large high-tech electronics corporations (e.g. IBM, ST Microelectronics, Siemens and Cisco) chose to settle in this area mostly attracted by the strategic position of the location. The energy specialization of the cluster followed the liberalization of the energy market in the 1990s and the establishment of two large companies, Philips and Edison. Over the years, several small and medium enterprises (SMEs) were founded in proximity to these larger firms and many spin-offs were launched. Thanks to the extraordinary level of productivity and innovation achieved in those years, the area became known as the “Italian Silicon Valley”.

Among several types of collaborations, those based on innovation are well diffused in the area, due to its technological complexity. The presence of several excellent research poles such as, for example, the Polytechnics of Milan and the University of Milano-Bicocca provided a fundamental support in sustaining and promoting the R&D activity of the local actors. A key role in promoting innovation, is also played by the local vocational centres, in particular technical institutes, training the future generation of highly skilled workers. In order to ensure the dissemination and sharing of knowledge and information and to bolster the internal collaboration, in 2008 the Green and Hi-tech Cluster established a cluster organization.

The evolution of cluster collaborations pushed firms to move from pure internal network relationships towards open innovation practices with the community of makers, as well as fab labs and makerspaces, comprising the cluster ecosystem.

In recent years, the Maker Movement of Brianza has been very intense and heterogeneous. Several initiatives have been launched with different kind of physical platforms, and with various technological application and field specializations. There are: fab labs and multi-factory spaces, such as IDEAS and Made in MAGE; co-working spaces, such as Bigmagma and MonzaHub; maker spaces, such as Monzamakers, a start-up specialized in 3D printing. A great support to the Maker Movement is also provided through different kind of initiatives, such as local contests among technical institutes.

Large corporations, SMEs and the entire maker community, collaborate together for innovation in a complex relational network and several other organizations like research centres and universities, take part to open innovation networks too, exchanging multiple types of knowledge.

Method

Research design

To answer our research question, the research design of this study relies on Social Network Analysis (SNA) methods and techniques. SNA has been increasingly used in management science and business studies (Borgatti, Mehra, Brass, & Labianca, 2009) and – more specifically – to investigate open innovation networks and knowledge exchanges (Alberti & Pizzurno, 2015; Cantner, Meder, & Ter Wal, 2010; Giuliani & Bell, 2005; Pe'er & Keil, 2013; Sammarra & Biggiaro, 2008).

SNA data collection and analysis allowed us to elaborate a preliminary discussion on the practices of open innovation and the specific role of makers. First, we disentangled the role of makers in open innovation networks vis-à-vis the three types of knowledge considered in this study, i.e. market, managerial and technological knowledge. Second, we tested whether knowledge flows were affected by multiplexity – i.e. the concurrent flow of multiple types of knowledge, even unconsciously. Finally, SNA techniques allowed us to confirm the occurrence of ‘knowledge leaks’ in open innovation networks with makers.

Data collection

We followed previous studies applying SNA to the study of innovation networks (e.g. Alberti & Pizzurno, 2017) and we employed a *snowball sampling* technique to collect data (Frank, 2005). We started our sampling from a list of makers made available by a makerspace operating in the selected cluster, namely Monzamakers. Players in the initial sample were then asked to nominate other players involved in their practices of open innovation with firms. And we re-iterated the process until when makers, fab labs and firms named as being part of open innovation practices were always the same. The final sample is the one reported in Table 1.

Interviews were based on a structured questionnaire and data collected have been turned to anonymous to protect sensitive data, considering unintended drawbacks and implications of disclosing innovation practices. Data collection on the cluster and the community of makers in the cluster relied on secondary data made available both from the cluster organization and the main fab labs/makerspaces in the area.

Data collection allowed the construction of four different networks. First, interviewees were asked to list all other actors with whom they engaged in open innovation practices in the previous year. Each one of the actors mentioned during interviews was then complemented with data on their location and their profile. Finally, we asked to evaluate each collaboration in terms of market, technological and managerial knowledge received and transferred (see Table 2).

Table 1
Empirical sample (bold and in brackets is the number of interviewees).

	Identified	
Players	78	(53)
Makers	17	(17)
Firms	40	(28)
Research organizations	8	(6)
Fablabs and Makerspaces	13	(2)
Other Italian players	30	
Italian makers cited	10	
Italian firms cited	4	
Italian research organizations cited	16	
Italian fablabs and makerspaces cited	0	
International organizations cited	39	
International makers cited	26	
International firms cited	2	
International research organizations cited	7	
International fablabs and makerspaces cited	4	
Total actors	147	

Giuliani and Bell (2005), who use the cognitive position of players combined with their degree of openness, distinguished among gatekeepers (i.e. players with a central position in the network in terms of knowledge transfer to other proximate players and strongly connected with external sources); mutual exchangers (i.e. players that have a balanced source/absorber position); external stars (i.e. players that have established strong linkages with external sources, but have limited links with local knowledge system); isolated actors (i.e. players that are poorly linked in general). Accordingly, we measured the cognitive position of each player as well as its degree of openness, to define four types of actors. The cognitive position was obtained by calculating the ratio between the in-degree and out-degree for each actor in all the three knowledge networks considered. The degree of openness was instead measured calculating the proportion of the knowledge exchanged at the local level with respect to the total knowledge one particular actor exchanges. This value was then subtracted from 1. We, then, defined four types of roles played by actors in the knowledge system: (a) gatekeepers (cognitive position with an in/out degree centrality <1 and an external openness above the average); (b) mutual exchangers (cognitive position with in/out degree centrality about 1 and their external openness is on average); (c) external stars (cognitive position with an in/out degree centrality >1, but also a very high external openness); (d) isolated firms (cognitive position with an in degree centrality as well as an out degree centrality of about 0 and external openness above the average).

Finally, we discriminated by four types of cluster actors in our study: firms (either small-sized or large corporations), makers, research organizations (research centres, laboratories and universities) and fab labs or makerspaces.

Data analysis

For network data analysis, we relied on SNA techniques and we used UCINET 6 (Borgatti, Everett, & Freeman, 2002) as a software package.

First, we constructed the entire open innovation network (binary, symmetric and not oriented) and the three knowledge networks – technological, managerial and market knowledge (val-

ued, symmetric and oriented) and we described them in terms of isolates, average degree (out/in) and components. Then, we focused solely on players involved in either technological or market or managerial knowledge exchanges in open innovation networks.

To answer our research question, we then applied Giuliani and Bell (2005) typology to dig into the role of makers in open innovation networks and then – following Fonti (2002) – we checked for multiplexity in knowledge flows, to explore knowledge leaks in open innovation networks with makers.

Findings and discussion

In line with the purpose of the present paper – i.e. to understand whether and how knowledge leaks occur in open innovation networks with makers – we relied on the research design illustrated above.

Before focusing our data analysis on the above-mentioned research question, through SNA we constructed and explored the entire open innovation network and checked for how the three types of knowledge considered in this study are exchanged. Then, we proceeded step-wise and first we disentangled the role of makers in open innovation networks vis-à-vis the three types of knowledge considered in this study, i.e. market, managerial and technological knowledge. Second, we checked for multiplexity in knowledge exchanges, i.e. the concurrent exchange of technological and/or market and/or managerial knowledge to check for knowledge leaks.

Features of the open innovation network

First, we analysed the overall network emerging from the answers obtained from the interviewed organizations. The open innovation network obtained is reported in Fig. 1, while the exchange of technological, market and managerial knowledge in the cluster in Figs. 2–4 respectively. Actors are distinguished by type: smallest black nodes represent makers, other black nodes (depending on their size) represent small-sized firms (medium node) or large corporations (large node) respectively; research organizations are in white and fab labs and makerspaces in grey.

Consistently with previous literature (Giuliani, 2007a, 2007b; Sammarra & Biggiero, 2008) our preliminary investigation of open

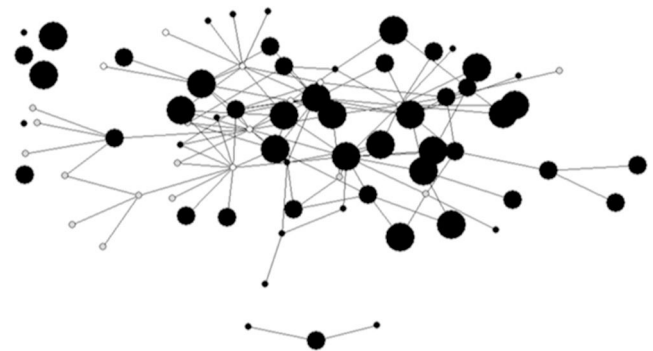


Fig. 1. The entire open innovation network.

Table 2
The structural variables: open innovation and knowledge exchange networks.

	Collaborative network		Knowledge exchange networks		
			Managerial	Market	Technological
Direction of ties	Not oriented		Oriented	Oriented	Oriented
Value of ties	0–1		0–3	0–3	0–3
Graph	Binary, symmetric		Valued, asymmetric	Valued, asymmetric	Valued, asymmetric

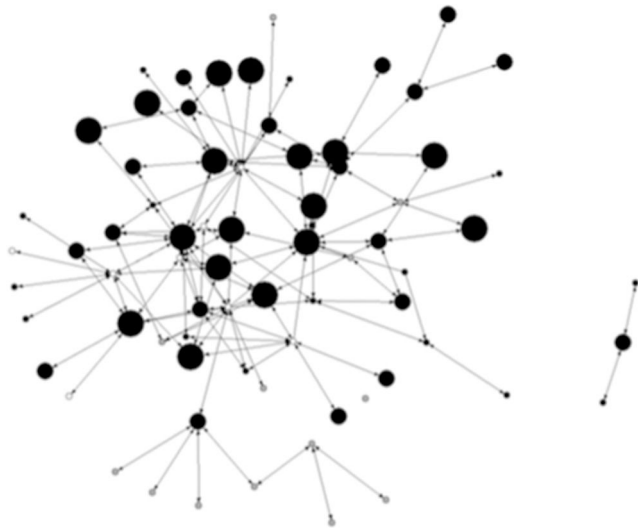


Fig. 2. Technological knowledge exchanges.

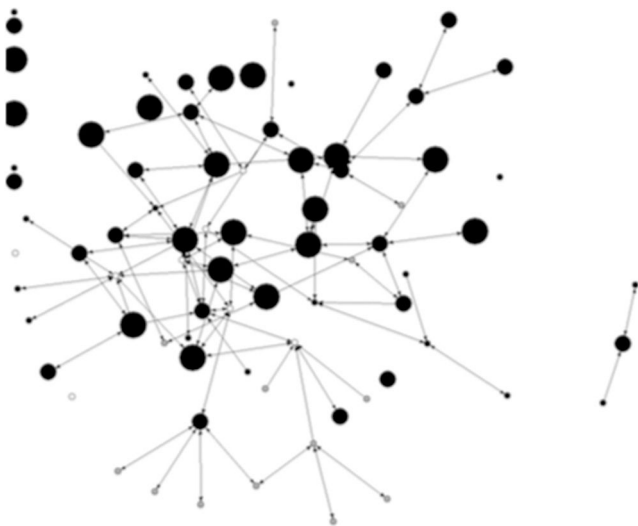


Fig. 3. Market knowledge exchanges in the cluster.

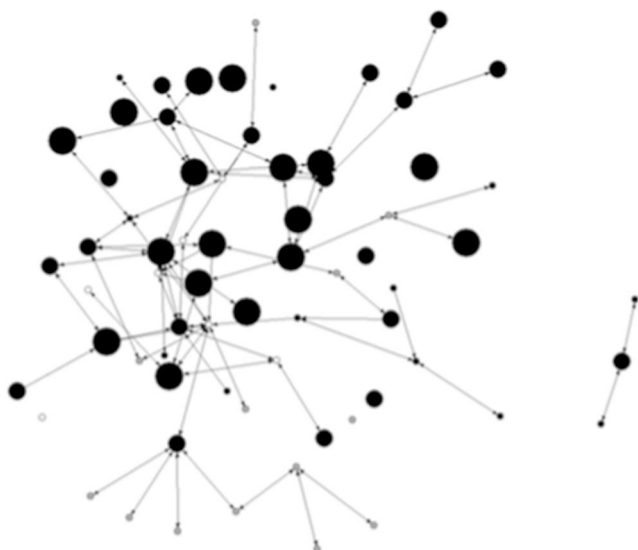


Fig. 4. Managerial knowledge exchanges in the cluster.

innovation networks confirms that the three types of knowledge considered are unevenly exchanged. The exchange of technological knowledge seems to be open to most of the actors, whilst the exchange of market and managerial knowledge appears as more selective. As reported in the paper by [Alberti and Pizzurno \(2015\)](#), different types of actors have also different roles in open innovation networks, especially with reference to the three types of knowledge considered in this study.

[Table 3](#) confirms what emerges from visual representations. The technological knowledge network involves the vast majority of the actors and firms exchange more technological knowledge than other types. The average degree of the technological knowledge network is indeed significantly higher than in the other two cases. This aspect is also reflected in the number of components, that shows how market and managerial knowledge networks are much more fragmented.

The role of makers in open innovation networks

With the specific aim to disentangle the role of makers in open innovation networks vis-à-vis the three types of knowledge considered, we deepened our understanding of the different knowledge brokerage roles played by makers and firms (either large corporations or small-sized firms) applying the typology suggested above.

[Fig. 5](#) positions actors in the managerial knowledge network. Using [Giuliani and Bell's taxonomy \(2005\)](#) there are several gatekeepers (low in/out-degree ratio and high openness) who are mainly large corporations and some small-sized firm with connections outside the local context, who absorb inputs from the global industry and then transfer them locally. There are also some mutual exchangers and a few external stars which are actors with several international connections. They are often makers that are very specialized on specific technological applications or fields. Finally, there are just a few isolated firms.

With regard to market knowledge networks ([Fig. 6](#)), there is a relative presence of gatekeepers. It seems therefore that only a limited number of actors have access to global market knowledge networks, while the others are absolutely excluded from a direct access to it. Interestingly, the vast majority of these organizations are makers that tap into global networks of peers with the same interests, expertise and focus. There is also a significant number of mutual exchangers, i.e. firms that have a balanced source/absorber position.

For technological knowledge exchanges, there is a more heterogeneous and not so clear situation. A variety of roles are present ([Fig. 7](#)), for example some makers seem to be acting as external stars while just a few perform the role of gatekeepers. The large corporations are positioned more in the role of absorber or mutual exchanger, consistently with their role in the supply chain where they act as integrators of sub-components and organizers of the supply chain.

In conclusion, our first analysis revealed that in open innovation networks, whilst in managerial knowledge exchanges large corporations and some small-sized firms act as gatekeepers and makers as external stars, in market knowledge makers are gatekeepers and bring in the knowledge they access from global niche markets. This also happens in technological knowledge exchanges where large corporations absorb and makers act as gatekeepers. Such a composite situation, suggested us that while when firms engage in open innovation practices they do absorb from makers market and technological knowledge, it is makers who benefit from larger firms when it comes to managerial knowledge. This implies – as already suggested in literature ([Alberti & Pizzurno, 2015](#)) – that knowledge flows are affected by multiplexity.

Table 3
Collaboration and knowledge networks.

	Collaboration network	Knowledge networks		
		Technological	Managerial	Market
Total players	147	147	147	147
Isolates	5	8	45	30
Active players	142	139	102	117
<i>Local players</i>	73	72	59	66
Makers	17	17	10	11
Firms	40	40	31	36
Research organizations	8	8	6	6
Fablabs and Makerspaces	13	12	12	13
<i>Other Italian players</i>	30	30	19	22
Makers	10	10	7	8
Firms	4	4	2	3
Research organizations	16	16	10	11
Fablabs and Makerspaces	–	–	–	–
<i>International players</i>	39	37	24	29
Makers	26	25	13	19
Firms	2	1	2	2
Research organizations	7	7	6	6
Fablabs and Makerspaces	4	3	3	2
Average degree (out/in)	2.79 (3.37)	2.58 (3.06/3.17)	1.54 (2.15/2.14)	1.82 (2.27/2.45)
Strong components	n.a.	18	55	48
Weak components	8	11	48	33

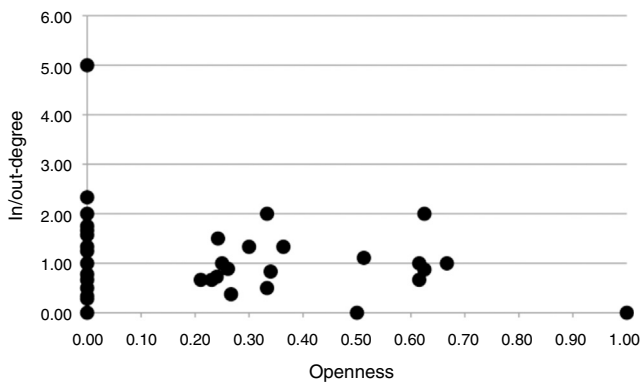


Fig. 5. Firms' roles in managerial knowledge exchanges.

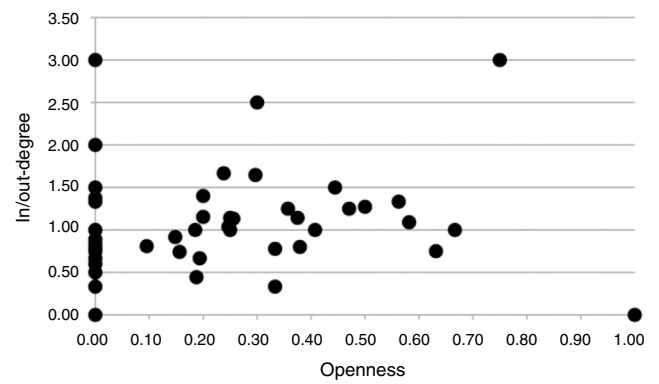


Fig. 7. Firms' roles in technological knowledge exchanges.

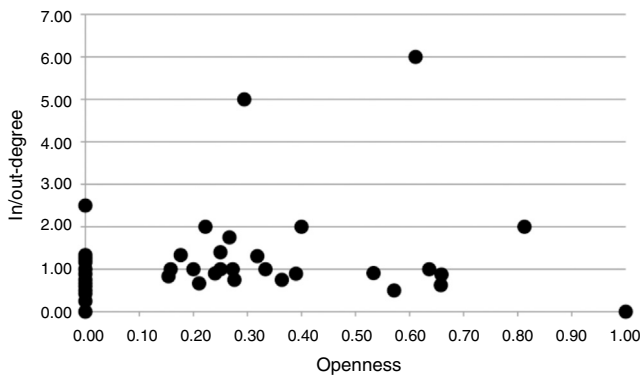


Fig. 6. Firms' roles in market knowledge exchanges.

Multiplexity in knowledge exchanges

Hence, we checked for multiplexity in knowledge exchanges, exploring how the different knowledge networks are interrelated. At first, we performed a correlation analysis of the different knowledge networks. We employed a Quadratic Assignment Procedure (QAP), a test based on the repetition of a permutation for an arbitrarily large number of times (De Lange, Agneessens, & Waeye, 2004; Kilduff & Krackhardt, 1994). Results of the correlation test

are presented in Table 4. All the results, obtained running 10,000 permutations, are significant ($p < 0.001$) and show a very strong correlation among the three types of knowledge exchanges.

Next, we conducted a more fine-grained analysis of the simultaneous exchange of different types of knowledge through a multiplexity analysis (Fonti, 2002). Table 5 presents some basic information about the knowledge networks resulting from the combination of the exchange of technological and/or market and/or managerial knowledge. The test shows how different combinations are less likely to occur than others and involve fewer players. Moreover, the exchange of managerial and market knowledge takes place less frequently than other exchanges and when it happens, it is always associated with the exchange of technological knowledge as well. In both cases, the number of isolates is higher than in other knowledge combinations. This can be the consequence of the fact that not all players are involved in the simultaneous exchange of multiple knowledge as well as to the specific nature of some organizations or to their limited absorptive capacity, which represents a threshold to the knowledge they can receive from partners. Hence, actors are often engaged in simultaneous exchanges of knowledge.

In conclusion, we verified whether some simultaneous knowledge exchanges are more likely to happen than others. We applied a bootstrap technique suggested by Snijders and Borgatti (1999) to compare the densities of the different networks and understand

Table 4
Differences in knowledge exchange in innovation networks.

	Technological knowledge	Market knowledge	Managerial knowledge
Technological knowledge	1		
Market knowledge	0.7098	1	
Managerial knowledge	0.7038	0.6945	1

Table 5
Properties of multiple knowledge exchange networks.

	Density	Isolates
Technology + market knowledge	0.0256	15 (19.2%)
Technology + managerial knowledge	0.0220	20 (25.6%)
Managerial + market knowledge	0.0186	24 (30.8%)
Technology + managerial + market knowledge	0.0186	24 (30.8%)

whether such differences are the result of pure random chance or not. The results of this test are presented in Table 6.

Interestingly, the difference in density takes a meaningful and significant value only when comparing one network including the exchange of technological knowledge with a network not including it. Again, the relevance of the exchange of technological knowledge emerges, suggesting that technological knowledge exchanges may imply even the unintended exchange of either market or managerial knowledge, configuring what in literature is referred to as a ‘knowledge leak’ (Alberti & Pizzurno, 2017). Furthermore, the exchange of the three types of knowledge at the same time is constantly less frequent than other multiple exchanges, confirming the selective nature of knowledge flows.

Conclusions

Research contributions

This study is positioned in one of the hotspots of research on innovation, where open innovation studies (West et al., 2014), account for knowledge exchanges (e.g. Alberti & Pizzurno, 2017) in the field of makers (e.g. Aldrich, 2014; Browder et al., 2017; Van Holm, 2015, 2017; Von Busch, 2013), through the lenses of SNA (Ter Wal & Boschma, 2009).

First of all, our findings confirm multiplexity and heteromorphism in knowledge exchanges (e.g. Biggiero & Sammarra, 2010; Boschma, 2005). Open innovation networks are the result of the exchange of multiple types of knowledge by a variety of actors that play heterogeneous roles vis-à-vis different types of knowledge.

Second, the present study sheds light on a totally unexplored phenomenon, that is the phenomenon of open innovation and makers, focusing on knowledge leaks. Makers are eager to absorb knowledge from other players, when they engage in open innovation practices. Makers engaging in open innovation networks may

Table 6
Comparing densities between multiple knowledge exchanges of knowledge.

	Technological + market knowledge	Technological + managerial knowledge	Managerial + market knowledge	Technological + managerial + market knowledge
	Difference	Difference	Difference	Difference
Technological + market knowledge (Density: 0.0256)				
Technological + managerial knowledge (Density: 0.0220)	0.0037 (p = 0.1381)			
Managerial + market knowledge (Density: 0.0186)	0.0070 (p = 0.0041)	0.0033 (p = 0.0244)		
Technological + managerial + market knowledge (Density: 0.0152)	0.0070 (p = 0.0031)	0.0033 (p = 0.0209)	0 (p = 1)	

largely benefit from absorbing several types of knowledge either on technology dynamics and applications, market scenarios and evolutions or managerial practices and requirements. This is confirmed by our empirical evidence, according to which makers act as external stars, i.e. not sharing their specialized technological expertise but absorbing general technological knowledge from the cluster ecosystem (Alberti, Sciascia, Tripodi, & Visconti, 2011) and, given the evidence that technological knowledge is inextricably linked to market and managerial ones, by multiplexity effect, open innovation networks become a gateway to several knowledge leaks that makers absorb. Conversely, our work sheds light on the fact that makers convey knowledge flows to larger and consolidated firms. Our evidence confirms the general understanding that makers may be a rich source of knowledge leaks. Typically, makers operate in global niches, where dedicated technological knowledge is inextricably linked to a certain kind of market knowledge. Given their credo and their immaturity in managerial processes and in open innovation practices and their eagerness in collaborating with key players in the field, for innovation-specific matters, they might pay less attention in engaging in open innovation networks and succumb to knowledge leaks to the benefit of their partners who can access through them particular knowledge.

The exploration of open innovation practices with makers allowed us to understand, consistently with previous studies (Alberti & Pizzurno, 2017), how one type of knowledge – in our case, the technological one – may be conducive of other types of knowledge, qualifying as a platform or a language that drives market and managerial knowledge leaks.

Policy and managerial implications

Our results have practical implications both for policy makers and for managers. First of all, our research confirms how open innovation often originates from a combination of different knowledge types acquired through the collaboration with heterogeneous players, makers included. Hence, managers may design open innovation strategies balancing their portfolio of collaborations to maximize the absorption of relevant knowledge and makers may consider engaging in open innovation practices to accelerate knowledge absorption and eventually launch a start-up. Nevertheless, our study warns managers against the risk of knowledge leaks, especially in those cases where the eagerness or the prestige to take

part to some open innovation networks may hamper them to protect or to control over knowledge leaks. This opens up for possible interventions for policy makers too. First of all, policy makers may consider incorporating the concept of knowledge leaks in their campaign in favour of open innovation. Second, our study may help policy makers in designing programmes for knowledge transfer partnerships between firms and makers in a more conscious way, especially warning new to business players, like makers, about possible leaks, despite their culture of openness. Finally, there is also the need of developing professional figures like consultants, maybe operating in fab labs, co-working spaces or makerspaces that can mentor and advise makers on how to get engaged in open innovation networks and, hence, find their specific role in the cluster.

Limitations and future research

The present paper has some limitations that open avenues for future research. Given the explorative nature of this paper that looks at a totally unfamiliar phenomenon, there is abundant room to go in-depth in the refinement of the concept of knowledge leak, even operationalizing it for future tests. Future studies on this line, may even consider developing a specific set of SNA measures for the specific analysis of knowledge leaks to complement the ones on multiplexity. Future studies may continue to explore the phenomenon through in-depth case studies on both sides.

Despite these limitations, our data illuminate several aspects of whether and how knowledge leaks occur in open innovation networks with makers, opening up intriguing aspects that have been overlooked by extant literature and triggering several lines of further research on the topic.

References

- Alberti, F. G., Giusti, J. D., Papa, F., & Pizzurno, E. (2014). Competitiveness policies for medical tourism clusters: Government initiatives in Thailand. *International Journal of Economic Policy in Emerging Economies*, 7(3), 281–309.
- Alberti, F. G., & Pizzurno, E. (2013). Technology, innovation and performance in family firms. *International Journal of Entrepreneurship and Innovation Management*, 17(1–3), 142–161.
- Alberti, F. G., & Pizzurno, E. (2015). Knowledge exchanges in innovation networks: Evidences from an Italian aerospace cluster. *Competitiveness Review*, 25(3), 258–287.
- Alberti, F. G., & Pizzurno, E. (2017). Oops I did it again! Knowledge leaks with start-ups in open innovation networks. *European Journal of Innovation Management*, 20(1), 50–79.
- Alberti, F. G., Sciascia, S., Tripodi, C., & Visconti, F. (2011). The entrepreneurial growth of firms located in clusters. A cross-case study. *International Journal of Technology Management*, 54(1), 53–79.
- Aldrich, H. E. (2014). The democratization of entrepreneurship? Hackers, makerspaces, and crowdfunding. Presented at the Annual meeting of the academy of management, Philadelphia, PA.
- Amin, A., & Cohendet, P. (2004). *Architectures of knowledge: Firms, capabilities and communities*. Oxford: Oxford University Press.
- Anderson, C. (2012). *Makers: The new industrial revolution*. New York, NY: Crown Business.
- Belussi, F., Sedita, S. R., & Omizzolo, M. (2008). The trade fair as a temporary cluster: A relational platform and knowledge filter for firms. First results of an exploratory study. In *4th international conference of the academy of wine business research Siena*
- Biggiaro, L., & Sammarra, A. (2010). Does geographical proximity enhance knowledge exchange? The case of the aerospace industrial cluster of centre Italy. *International Journal of Technology Transfer and Commercialisation*, 9(4), 283–305.
- Borgatti, S. P., Everett, M. G., & Freeman, L. C. (2002). *Ucinet for windows: Software for social network analysis*. Harvard, MA: Analytic Technologies.
- Borgatti, S. P., Mehra, A., Brass, D. J., & Labianca, G. (2009). Network analysis in the social sciences. *Science*, 323(5916), 892–895.
- Boschma, R. A. (2005). Proximity and innovation: A critical assessment. *Regional Studies*, 39(1), 61–74.
- Boschma, R. A., & Ter Wal, A. L. J. (2007). Knowledge networks and innovative performance in an industrial district: The case of a footwear district in the south of Italy. *Industry and Innovation*, 14(2), 177–199.
- Browder, R. E., Aldrich, H. E., & Bradley, S. W. (2017). *Entrepreneurship research, Makers, and the Maker Movement*. mimeo.
- Brown, J. S., & Duguid, P. (1991). Organizational learning and communities of-practice: Toward a unified view of working, learning, and innovation. *Organization Science*, 2(1), 40–57.
- Cantner, U., Meder, A., & Ter Wal, A. L. J. (2010). Innovator networks and regional knowledge base. *Technovation*, 30(9–10), 496–507.
- Chesbrough, H. W. (2003). The era of open innovation. *Sloan Management Review*, 44(3), 35–41.
- De Lange, D., Agneessens, F., & Waeye, H. (2004). Asking social network questions: A quality assessment of different measures. *Metodoloski Zvezki*, 1(2), 351–378.
- Deloitte. (2014). *Impact of the Maker Movement*. MakerMedia.
- Fonti, F. (2002). *One relationship is not enough: An initial view of multiplex embeddedness* (Thesis). University of Illinois at Urbana-Champaign.
- Frank, O. (2005). Network sampling and model fitting. In P. J. Carrington, J. Scott, & S. Wasserman (Eds.), *Models and methods in social network analysis* (pp. 31–56). New York: Cambridge University Press.
- Gershenfeld, N., & Euchner, J. (2015). Atoms and bits: Rethinking manufacturing. *Research Technology Management*, 58(5), 16–21.
- Gimeno, J., & Woo, C. Y. (1996). Economic multiplexity: The structural embeddedness of cooperation in multiple relations of interdependence. In J. A. C. Baum, & J. E. Dutton (Eds.), *Advances in strategic management – The embeddedness of strategy* (pp. 323–361). Greenwich, CT: JAI Press.
- Giuliani, E. (2007a). Cluster absorptive capacity: Why do some clusters forge ahead and others lag behind? *European Urban and Regional Studies*, 12(3), 269–288.
- Giuliani, E. (2007b). The selective nature of knowledge networks in clusters: Evidence from the wine industry. *Journal of Economic Geography*, 7(2), 139–168.
- Giuliani, E., & Bell, M. (2005). The micro-determinants of meso-level learning and innovation: Evidence from a Chilean wine cluster. *Research Policy*, 34(1), 47–68.
- Hatch, M. (2013). *The Maker Movement manifesto: Rules for innovation in the new world of crafters, hackers and tinkerers*. New York: McGraw-Hill.
- Howard, C., Gerosa, A., Mejuto, M., & Giannella, G. (2014). The maker movement: A new avenue for competition in the EU. *European View*, 13(2), 333–340.
- Kilduff, M., & Krackhardt, D. (1994). Bringing the individual back in: A structural analysis of the internal market for reputation in organizations. *Academy of Management Journal*, 37(1), 87–106.
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. UK: Cambridge University Press.
- Lazzeretti, L., Boix, R., & Capone, F. (2010). Reasons for clustering of creative industries in Italy and Spain. *European Planning Studies*, 20(8), 1243–1262.
- Lindtner, S. (2015). Hacking with Chinese characteristics: The promises of the maker movement against China's manufacturing culture. *Science, Technology, & Human Values*, 40(5), 854–879.
- Make. (2013). *Maker market study: An in-depth profile of makers at the forefront of hardware innovation*. Makezine.
- Maskell, P., Bathelt, H., & Malmberg, A. (2004). *Temporary clusters and knowledge creation: The effects of international trade fairs, conventions and other professional gatherings*. Spaces 2004-04. Marburg: University of Marburg.
- Mollick, E. (2014). The dynamics of crowdfunding: An exploratory study. *Journal of Business Venturing*, 29(1), 1–16.
- Mortara, L., & Parisot, N. G. (2016). Through entrepreneurs' eyes: The Fab-spaces constellation. *International Journal of Production Research*, 54(23), 7158–7180.
- NCDMM. (2016). *America makes*. National Center for Defense Manufacturing and Machining. Retrieved from <https://www.americamakes.us/membership/why-america-makes>
- Pe'er, A., & Keil, T. (2013). Are all startups affected similarly by clusters? Agglomeration, competition, firm heterogeneity, and survival. *Journal of Business Venturing*, 28(3), 354–372.
- Pieri, J., & Domeniconi, J. (2016). *Makers who made it: 100 stories of starting a business (The Grommet eBook)*. Retrieved from <https://www.thegrommet.com/press/makers-who-made-it-ebook/>
- Porter, M. E. (2008). *On competition*. Boston: Harvard Business School Press.
- Rodan, S., & Galunic, D. (2004). More than network structure: How knowledge heterogeneity influences managerial performance and innovativeness. *Strategic Management Journal*, 25(6), 541–562.
- Sammarra, A., & Biggiaro, L. (2008). Heterogeneity and specificity of inter-firm knowledge flows in innovation networks. *Journal of Management Studies*, 45(4), 800–829.
- Shah, S. (2005). Open beyond software. In C. DiBona, D. Cooper, & M. Stone (Eds.), *Open sources 2.0*. Sebastopol: O'Reilly Media.
- Simonin, B. L. (1999). Transfer of marketing know-how in international strategic alliances: An empirical investigation of the role and antecedents of knowledge ambiguity. *Journal of International Business Studies*, 30(3), 463–490.
- Snijders, T. A. B., & Borgatti, S. P. (1999). Non-parametric standard errors and tests for network statistics. *Connections*, 22(2), 161–170.
- Stacey, M. (2014). The FAB LAB Network: A global platform for digital invention, education and entrepreneurship. *Innovations: Technology, Governance, Globalization*, 9(1–2), 221–238.
- Tanenbaum, J. G., Williams, A. M., Desjardins, A., & Tanenbaum, K. (2013). Democratizing technology: Pleasure, utility and expressiveness in DIY and maker practice. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 2603–2612). ACM.
- Ter Wal, A. L. J., & Boschma, R. A. (2009). Applying social network analysis in economic geography: Framing some key analytic issues. *The Annals of Regional Science*, 43(3), 739–756.
- Thompson, C. (2005). Dream Factory: From design to delivery, custom manufacturing is coming soon to a desktop near you. Inside the “fab lab” revolution. *WIRED-SAN FRANCISCO*, 13(9), 128–133.

- Van de Vrande, V., de Jong, J. P. J., Vanhaverbeke, W., & de Rochemont, M. (2009). Open innovation in SMEs: Trends, motives and management challenges. *Technovation*, 29(6–7), 423–437.
- Van Holm, E. J. (2015). Makerspaces and contributions to entrepreneurship. *Procedia-Social and Behavioral Sciences*, 135, 24–31.
- Von Busch, O. (2013). Molecular management: Protocols in the maker culture. *Creative Industries Journal*, 5(1–2), 55–68.
- Von Hippel, E. (2005). *Democratizing innovation*. Cambridge, MA: MIT Press.
- West, J., Salter, A., Vanhaverbeke, W., & Chesbrough, H. (2014). Open innovation: The next decade. *Research Policy*, 43(5), 805–811.