COMPETING WITH NETWORKS: A CASE STUDY ON THE 3D PRINTER

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Abstract

This paper aims at describing how firms can engage intermediaries to benefit from the surrounding network in order to increase competitiveness. Competitiveness is intended as delivering superior quality products, beating the competitors and making a surplus. Firms are involved in changing environments, and they need to react by acting on their design and innovation processes. Recent literature has argued that it can be achieved by involving the users in the innovative processes, such as communities for new product development, open source communities, suggesting their involvement as a consequence of the changes in business ecosystems. The paper will analyse, with an in-depth case study, the changes in the competitive environment in technology intense sector, 3D printers. The sector was chosen because users are demonstrated with faster and more effective ways to exchange knowledge and with increased possibilities to access communities respect to the past. The paper discusses how the presence of strong networks allowed the development and maintenance of a competitive technology, by studying: 1) how the community starts, 2) why users join the community and 3) how firms can be competitive by adopting a network approach. The particularity of the 3D printing communities is the consistent presence of diversified users, including initiators, sponsors, entrepreneurs and technology experts. Explaining and building different interactions are one of the possible explanations why the process that such an innovation was adopted, adapted to local needs and became competitive.

Introduction

This paper aims at describing how firms can engage intermediaries in order to increase competitiveness. Competitiveness is intended as delivering superior quality products, beating competitors and obtaining a surplus (Porter, 1985). Firms are involved in changing environments (Siggelkow, 2001), which they handle through changes to their design, innovation strategies, distribution systems and organizational processes (Nadler and Tushman, 1997), in order to remain competitive and create value. Extant research has argued that competitiveness can be achieved by involving users in the innovative processes (Von Hippel, 1986). Specifically, it can be achieved by involving communities for new product development (Lilien et al., 2003), open – source software development (Bagozzi and Dholakia, 2006; Von Krogh and Von Hippel, 2003) and highly technological products (Jeppesen and Frederiksen, 2006), showing the importance of users as contributors to the innovative process, and suggesting their involvement as a consequence of the changes in business ecosystems (Iansiti and Levien, 2004).

This paper aims at answering the research question: is the users’ network around a firm and a source of competitiveness? Which factors and network actors actually lead to a firm’s competitiveness?

We start from extant studies explaining that changes in the competitive environment have provided users with faster and more effective ways to exchange knowledge and with increased possibilities to access communities respect to the past (Jeppesen and Frederiksen, 2006). Researchers in innovation field have also highlighted that the diversification of users constituting communities has increased, requiring companies to adopt various strategies for exploiting the knowledge that they exchange (Porter and Donthu, 2008). Leveraging on this knowledge is crucial for enhancing competitiveness. However, the full understanding of the
drivers leading to be competitive leveraging on users’ communities is still missing and it is difficult to understand how companies can leverage on users’ knowledge to stay competitive.

In this paper, we devote further attention to the topic, in order to draw overarching conclusions on how companies enhance innovation leveraging on users’ interactions (David and Shapiro, 2008) and therefore increase their competitiveness. We aim at providing an understanding of the topic, by analysing with an historical case study looking at (1) how the community starts, (2) why users join the community and (3) how firms can be competitive by adopting a network approach. The community that constitutes our empirical setting is the 3D printing. The 3D printing communities involve users belonging to different groups, including initiators, sponsors, entrepreneurs and technology experts; this multifaceted portfolio of users calls companies for considering several aspects when exploring the reason of the success of the network around the innovation.

By leveraging on the multi-dimensional connectedness of the 3D printing community, we looked at the different interactions, trying to understand how to explain the process that such an innovation was adopted, adapted to local needs and became competitive. The paper proceeds as follow: after an introduction, the method for collecting the data and constructing the case study is presented, following by the description of the case study and the analysis with the findings. The paper concludes with a discussion, conclusion, direction for future research and managerial implications.

Method

Given the incompleteness of the framework on the interaction among different characteristics of communities’ users and on how companies leverage on them to increase competitiveness, we opted for the development of a case study (Yin, 2013).

The ration for adopting the case study was: ‘When the main research questions are ‘how’ and ‘why’ questions; when a researcher has little or no control over the behavioral events; and, when the focus of study is a contemporary (as opposed to entirely historical) phenomenon’ (Yin, 2013, p. 4). The case study method appeared to suit the intentions of analyzing the evolution of 3D printing. The role of observant researchers was taken to not interfere with the context. The 3D printing technology is a recent innovation, a contemporary phenomenon, as it started in the 80s and only in recent years it has been spreading all around the world; therefore, an exploratory approach was considered appropriate for this study.

The 3D printing community was explored by leveraging on qualitative interviews and ethnographic observations. The research team collected 19 semi-structured in depth interviews (lasting between 40 and 60 minutes each) involving different stakeholders within the 3D printing community: directors, founders and members of worldwide Fab Labs network, members of online communities, engineers, entrepreneurs, companies’ owners, and university professors have been interviewed. Furthermore, the team collected ethnographic observations of 8 different Fab Labs1 in two different countries (Italy and Spain), and conducted a Netnography (Kozinets, 2002) of 5 online international 3D printing communities. These data were complemented with online and offline archival data (i.e. newspaper and magazine articles, seminars, webinars, interviews available on the Internet, blogs, and video recordings). The data were analyzed through a qualitative thematic approach (Gioia and Pitre, 1990). After a first phase of open coding, the key actors in the 3D community were identified. In a second step, the key motivations reproduced by actors in

1 A Fab Lab (abbreviation for fabrication laboratory) is a laboratory equipped for the development of digital fabrication.
participating in the community were highlighted and, thirdly, the characteristics of these actors were mapped.

The 3D printers for industries: a historical perspective

This section has the purpose to present the maps representing the evolution of the three actor-networks, or sets of actor-networks, that have determined the development of the 3D printing technology. This first unit of analysis investigates 3D printing as an innovation, from its invention, through its transformation and diffusion in the market. In particular, we will study how the relationships between human and non-human actors have changed, modifying the configuration of the network. In order to accomplish this, we have identified the spokespersons, the mediators and which the intermediaries of this technology in every phase, and we’ll examine the actions they have taken and see how these affected the enlargement of the network. Next, we presents the translations and qualification-requalification processes have taken place, either successfully or unsuccessfully, leading to the enrollment of new actors, to changes in the relationships or to the activation of new actors.

The life of 3D printers can be divided into three periods, each one of them representing a moment of the qualification-requalification dynamics that changed the value associated to the technology, and widened the network responsible for the diffusion of this technology. These three phases correspond to time frames in which the network, meaning the actors and the relationships among them, was stabilized for a certain period. Each actor-network is composed of heterogeneous elements, and it is made of both human and non-human actors. For each of this period, companies leveraged on users in different ways in order to enhance competitiveness, as it will be explained in the following paragraphs.

The first period represents the creation and launch on the market of the first 3D printing technologies. In the beginning, 3D printers were expensive and difficult to use, but they were suitable for industries that needed a cheap and fast way for prototyping. The second period starts with the RepRap Project, set up in 2005, which reconfigured the network as it made available open source printers to a wide audience of technology enthusiasts. Lastly, the third period is characterized by a reconfiguration and an even greater widening of the network, as 3D printers, now cheap and easy to use, are destined to regular people attracted by the ‘fun’ and ‘entrepreneurialism’ aspects of the technology.


3D printing has its roots in inkjet printing, meaning the commonly used 2D printer that prints data on paper. The beginning of 3D printing, in fact, can be traced back to 1984 when, instead of using ink, Charles Hull replaced it with material. Charles Hull is the inventor of the technology and the spokesperson of the network in this first phase. He has been speaking on behalf of the technology with his articles and experiments and through 3D Systems, the company he founded to sell 3D printers. As Lipsons stated in the interview: “At that time Charles Hull was dominating the scene, since he invented the 3D printing technology and he basically started distributing it”.
Beside Hull, the other actors that developed this technology are: Scott Crump and his wife Lisa who invented the Fused Deposition Modeling (FDM), Paul Williams and Professor Eli Sachs who developed the 3DP technology, Object Geometries who launched on the market the PolyJet printers, and Carl Deckard and Joe Beaman who invented the SLS machine at the University of Texas. Starting from these inventions, many companies were created, some of them by the inventors themselves such as Stratasys (founded by Scott Crump) and 3D Systems (founded by Charles Hull). Stratasys and 3D Systems were among the most important companies of this network that were selling 3D printers to the industries, and they were considered as mediators since they were helping the diffusion of the technology by allowing other entities to know and use the machines. Those sectors that employed the 3D printers for producing prototypes or end parts (such as aerospace sector, locomotive sector, et cetera) were also acting as mediators.

Hod Lipson referred in the interview to “Charles Hull, Joe Beaman, Carl Deckard, and Scott Crump” as “the pioneers of applications”, as much as those concerned with “the medical application, hearing aids, teeth orthodontic braces, these have all contributed to make the technology take off”.

3D printing in this first stage of its evolution was not accessible to everyone since the machines were very expensive, of big dimensions and difficult to use. As Hod Lipson, Professor at Cornell University, remarked in the interview:

“It was expensive. And because it was expensive it was never accessible to ordinary people”.

The customer market for these 3D printers was represented by the industrial sector, where the technology was used for rapid prototyping. As Lipson confirmed:
“Most of the industries used them to prototype”. Industries, in fact, enrolled in the network in this first phase because they found in 3D printers a faster and cheaper way to make prototypes. Before the 3D printing technology was invented, industries could not prototype as often because they could only use injection-molding processes that involved an investment of thousands of dollars to create the initial mold. Therefore, they often relied on pictures, CAD models, or hand-carved models (expensive and slow to make) in the product development phase (Lipson & Kurman, 2013).

When the network came into being, industries enrolled in it as mediators and started using 3D printers to prototype in a cheaper, faster and more efficient way. As Hod Lipson said in the interview, when he saw for the first time a 3D printer at his university he thought: “It immediately looked like all conventional manufacturing was obsolete”. Neil Gershenfeld can be considered as the spokesperson for the 3D printing technology in this phase. Professor and the Director of the Centre for Bits and Atoms at MIT and ‘in 1998, Gershenfeld started teaching a class at MIT called ‘How to Make (Almost) Anything’ as a way to introduce technical students to the expensive, industrial-size machines’ used for prototyping (Dunn, 2005). Enrico Bassi said in the interview, when asked who was representative of 3D printing at the time: “Neil Gershenfeld. He started everything”. Tomas Díez answered as well to the same question in the following way: “Neil Gershenfeld for sure”.

As spokesperson, Gershenfeld spoke on behalf of the technology at MIT University or in his books, such as the one titled When Things Start To Think (Gershenfeld, 2000), and he helped to define and enlarge the network. He has been teaching to students at MIT about these new technologies, attempting to ‘interesse’ (interessement) them and enrolling them in the network. By founding the first Fab Lab at MIT, and successively one in Boston in 2003, he assigned new roles to the actors by involving them in the project, attracting them to the labs where they could try out the technology, giving suggestions to those who wanted to open new Fab Labs around the world, et cetera. As Gershenfeld stated: ‘I know how to do the technology, these labs are teaching me what it’s good for’ (Dunn, 2005).

In the first period, the value construction of 3D printers is stabilized by qualities like “cheap and fast prototyping”, “industrial applications”, “very expensive (not for everyone)”, and “difficult to use”.

The desire for 3D printing technologies can be traced back to the so-called ‘Replicator’ in the American science fiction series Star Trek. The show was aired for the first time in the 1960s, but it was set in a future in which humans have colonized other planets and keep exploring the cosmos on spacecrafts. The Replicator is a machine installed on the starship, and it is able to create objects. The explanation given on the show regarding how the machine works is that it is ‘rearranging subatomic particles, which are abundant everywhere in the universe, to form molecules and arrange those molecules to form the object’. The machine could make for instance: objects, food, and drinks (‘Replicator (Star Trek)’ n.d.). The Star Trek Replicator machine acts as a framing device in this phase, since actors in the 3D printing network, for instance, often refer to a quote by the fictional Star Trek character Captain Picard that used to give the following instructions to the Replicator: ‘Tea. Earl Grey. Hot.’ The machine, which looked like a large microwave, was then making out of thin air a cup of hot tea ready to consume. With this in mind, Chris Anderson starts the chapter ‘The Tools of Transformation’ in his book entitled Makers with the sentence ‘Tea. Earl Grey. Hot.’ (Anderson, 2012, p. 81). In addition, an article appeared on The Boston Globe reports:
Ultimately, Gershenfeld wants to build a machine that can make any machine - one that can "print" 3-D objects that include all the circuitry and mechanisms they need to move around, heat up, make noise, connect to the Internet, or do whatever it is they're designed to do. [...] Think of the "replicators" on Star Trek’ (Dunn, 2005).

Enrico Bassi, Director of Fab Lab Torino, was most certainly referring to the Replicator in Start Trek as well when he said in the interview, affirming that the 3D printing was quite similar to those science fiction machines that are able to make everything.

In this early stage of the technology, 3D printing techniques have been patented, and therefore they can only be used and fostered by the people who invented them, unless they decided to sell the rights to a company as for example MIT did, licensing the technology to Z Corporation and many others (Three Dimentional Printing MIT, 1989). Patents are acting as mediators within the network, and more specifically as adversaries, since they are used to protect 3D printing innovations and therefore slow down the diffusion of the innovation. Andre Melò, who is opening a Fab Lab in Bologna, and defined himself as “pro open source”, argued in the interview that: “Patents slow down innovation”.

Using the frame proposed by Chalmers Thomas et al. (2013), we saw that at this stage the community was very difficult to access given the high costs of technology. Hence, the community was gathering in few dispersed sites both independent and interconnected. Given the complexity of access, spokespersons and entrepreneurs have a strong role in shaping the community. They are the ones that have the resources in order to allow the innovation to develop and that allow more actors to enter in the network. Furthermore, the community has a low marketplace orientation. There are strong ideologies around the technology, and the development of the technology for the market is not considered as a primary focus.

Companies are excluded at this stage of development. They do not take part to the development of the technology and of the community. This is a big shortcoming in their strategy since it impacts negatively their competiveness at a later stage.

Period 2: 2005-2009: Open source and Makers
In 2005 the network welcomed a new important actor, who acted as spokesperson, and who changed the meanings associated to 3D printing. His name is Adrian Bowyer and he is a Professor at the University of Bath, where he set up the RepRap Project (which stands for Replicating Rapid Prototyper). Adrian Bowyer was considered as the spokesperson who greatly helped the diffusion of the 3D printing technology.

Jose Perez de Lama, Director of Fab Lab Sevilla, said in the interview: “Adrian Bowyer, the inventor and implementer of RepRap has been very important”, and M.C. said: “The main actor is Adrian Bowyer”.

Bowyer’s intention was to sell a desktop 3D printer that was cheap, as the price dropped from $10,000 (Lipson & Kurman, 2013) to around $600; easy to use; that could be self-replicated; and, that could be shared in open source. In the interview with Adrian Bowyer, he said that his first opinion of 3D printers was in fact very interesting, but too expensive. Hod Lipson said in the interview that:

“The RepRap Project made printers available to a larger number of people, as it was more accessible since the price was lower and […] easier to use. Moreover, even if people could buy the expensive ones, they could not tinker with them because it was very very closed”.

To sum up, in the second period, the value construction of 3D printers was stabilized by qualities like: “open source”, “cheap”, “accessible”, “collaboration”, “developing technology”, and “democratization of innovation”.

In the interview with Adrian Bowyer, he told us the sequence of events that brought him to create the RepRap Project:
“Around 2000 Bath University got a large capital grant and, at my suggestion, bought two 3D printing machines. This was the first time that I actually had machines to play with, and I found it a most liberating technology. After playing with the machines bought in 2000 mentioned above for a while, I realized in February 2004 that for the first time we had a manufacturing technology that stood a good chance of being able to self-replicate”.

As spokesperson, Adrian Bowyer has carried out a translation that started with elaborating a program to have 3D printers at a cheaper price, that are easy to use, and that are shared in open source. Many people got involved in the RepRap community online, in the Project itself, and started to innovate around the RepRap printers (Darwin, Mendel, and Huxley) and to share the results online. As Jose Perez de Lama, Director of Fab Lab Sevilla, stated in the interview, there has been an online community development of this idea that was really astonishing. The communities around 3D printers enroll therefore in the network in this phase, as mediators. The role of communities was of major importance in this second phase, as these attracted, enrolled and mobilized numerous actors, from all around the world. In the interview, the creator of the RepRap Project himself said that the main characteristics of the first RepRap were that

“it should be good enough to self-replicate, but no better. From that point on, Darwinian evolution could be relied upon to improve it”.

The materials used with the open source printers were mainly ABS plastic and PLA plastic, enabling the users to print with materials that were cheap, resistant, light, safe, even though this meant offering a limited range of choice. The materials determined then which type of object the users were able to print.

This RepRap project opened up the 3D printing technology to a wider market of technology enthusiasts and gave people a new tool for personal fabrication. As Gershenfeld described it, it occurred a

‘shift from large-scale, expensive machine tools to personal fabrication as analogous to the evolution that began forty years ago from room-sized mainframes to personal computers’ (Dunn, 2005).

Adrian Bowyer with his decision to share his 3D printing technology in open source reconfigured the relationships within the network and greatly promoted the diffusion of 3D printers, as Lipson remarked in the interview

“most of the money is in the industrial 3D printers, but most of the awareness comes from the actual open source ones”.

Open source acted as a mediator as it distinguished these 3D printers, with all its qualities that make them accessible to a wider market, to the ones destined to industrial use. Supporters of open source became Obligatory Points of Passage, since without this premise communities would have not flourished, the network would have been smaller and with a slower rate of diffusion. If Bowyer had decided to patent his 3D printing technology, its development would have been lengthy and more difficult as it was for many other
technologies that in human history were patented. Adrian Bowyer mentions an example of this phenomenon:

‘James Watt patented various vital aspects of the steam engine. Yet, you look at steam engine development and nothing happened for 20 years during the life of Watt’s patent. When the patents lapsed, there was a great flaring of steam engine innovation and then the industrial revolution. It’s in the nature of patents that they give monopoly to whoever holds them for 20 years’ (Lipson & Kurman, 2013, p. 235).

The technology was therefore now attracting a wider audience of people who started collaborating in the project and shared with others their experiences and innovations. As the founder of the 3D printers producing company Kentstrapper, Lorenzo Cantini, said in the interview:

“[open source] is a do ut des phenomenon. Open source does not mean to give things for free, instead it means that people share information and collaborate to innovate”.

In other words, these actors were mostly technology enthusiasts who enrolled in the network wearing two roles at the same time: as customers who bought (or built by themselves) 3D printers, and researchers who helped to further develop the technology. One can argue that people from all around the world interested in 3D printing have become part of the RepRap R&D department, as Juan Esteban Paz said in the interview: “Open source is the best way so that people all around the world can learn and develop a lot of things”. In the words of Bowyer:

‘Any development or improvement of RepRap design, software, or electronics arises out of its users own initiatives. There is no central institution giving directions: users themselves invest time and thought in the evolutionary process of RepRap design. If they inspire other users they can all team up and combine their efforts’ (Lipson & Kurman, 2013, p. 233).

For instance, Alessandro Ranellucci, a member of the RepRap community, felt the need for a simpler version of software that could “slice” in layers a 3D model in order to send the information to the 3D printer and therefore invented Slic3r, which is now one of the most used “slicing” software. As Enrico Bassi said in the interview:

“Lots of people are doing a lot everywhere. Here in Italy there is Alessandro Ranellucci, who is 28 years old, and he is an architect and software designer. […] He decided to do something he needed […] and created Slic3r that now is one of the most common software to work with 3D printers. He is a very passionate guy that no one knows, but in the RepRap community he is a kind of hero. Because he is the one who started a lot of improvements in the 3D printing community”.

In the words of Ranellucci:

“It was clear to me that if you need something in the open-source world, you only can start doing it yourself and sharing it with other people in order to meet the needs of other people. When I started printing, the technology was at its very beginning. So, the results were not satisfying for me. […] It was very, very complicated to operate a 3D printer and to prepare prints. It was a cumbersome way of working with printers. So, I decided to start writing the software side of 3D printing from scratch. And, the initial results of my efforts
were much appreciated in the community, so people started saying, "Hey, go on. Please continue. We are enjoying your results." So this is how I started”.

RepRap community participants and users of RepRap printers were empowered by the technology and became part of the production process as well, as they were able to print replacement parts of the 3D printer by themselves. The motto of Bowyer, as M.C. reported in the interview was “Wealth without money”, which is in contrast with the previous network where the companies producing 3D printers were mostly interested in making profits and in legally protecting their innovations. Bowyer, instead, decided to share his innovations, as the Creative Commons states on the website about the RepRap: ‘The schematics are released under the GNU GPL copyleft license. This means that anyone can copy and improve the project as long as they share alike their modifications, just as one must with GPL’ed free and open source software’ (Creative Commons, 2001).

Open source licenses, like GNU in this case, were enrolled in the network as mediators and have contributed to the diffusion of 3D printing, by providing meanings of “sharing” and “collaborating” to the technology,

Another mediator of the network and pro open source actor was Hod Lipson, who created a similar project to the RepRap one, at Cornell University and he called it Fab@Home (Fab @ Home, 2006). This project was in open source as well and aimed at rendering more accessible the 3D printing technology. He had a similar mission to Bowyer’s one to, create this low cost, open source 3D printer that anybody could build and play around with it, and experiment with it.

Several universities (University of Bath, MIT, Cornell University, University of Texas) were enrolled in the network as intermediaries because they have been transporting the meaning related to 3D printing, through the divulgation of the technology with seminars, courses, lectures, et cetera, but they acted as carriers, and therefore were not involved in any transformation.

Hod Lipson identified during the interview two main factors that brought 3D printers from being confined to the industrial sector to serve a wider audience: first, improvements in the technology: the technology became much better, to the point that you can make not only prototypes but actual end parts, and, second, the creation of open source 3D printers projects, such as the RepRap which was the most popular, and the Fab@Home

The Fab@Home which came out from our work here. These were the two first open source printers.

As Lipson remarked, the RepRap project had a bigger impact regarding the dissemination of the technology:

“Adrian Bowyer really pushed the idea of self-replication, that the machine can make most of its parts. And I think his vision paid off, and his printers proliferated very quickly. Our emphasis with the Fab@Home was the ability to make, to work, with multiple materials”.

These two similar projects, both based on producing open source and easy to use 3D printers, had very different results, due to the different identities that the actors associated with the innovation. Bowyer defined the identity of its innovation as self-replicating, and was more successful, while Lipson focused on the printing with different materials identity and attracted a lower number of actors. Chris Anderson, writer of Makers, was also considering
the RepRap as the most important open source project for 3D printers, and saw Bowyer’s project as a ‘key milestone’ of the Maker Movement (Anderson, 2012).

Another mediator stimulating the promulgation of the 3D printing technology was the Maker Movement, an evolution of the Do-It-Yourself trend (Anderson, 2012, p. 21).

3D printers became the leading technology of what has been called the ‘Maker Movement’, or as Hod Lipson stated in the interview.

Andrea Melò, who is opening a Fab Lab in Bologna, recognized that 3D printing is the leader of the Maker movement, although this movement is not only made of 3D printers, there are also other machines and technologies, such as other CNC machines and laser cutters.

Chris Anderson, in his book Makers, traced back the emergence of the Maker Movement to the launch of the MAKE Magazine in 2005 (Anderson, 2012), since this magazine was responsible for creating the culture of the Movement. In 2005, Dale Dougherty and Tim O’Reilly founded MAKE Magazine, a magazine available in printed or online version that invited ‘everyone to become a maker, and integrate creative goals with technical skills’ (Maker Media, 2005).

Sprung from the Maker Movement, the MAKE Magazine, along with its founders, were mediators that strengthened the meanings of the Movement. We are going to treat the Maker Movement as a black box, interested in the input and output of it, but we are not going to investigate its content.

Dale Dougherty stated also that the Maker Movement is spurred by the introduction of new technologies such as 3D printing and the Arduino microcontroller which represent ‘new opportunities created by faster prototyping and fabrication tools as well as easier sourcing of parts and direct distribution of physical products online’ (Dougherty, 2013).

Massimo Banzi was also a mediator in the network in this second phase, as he strengthened the meanings associated with the 3D printers and that derive from the Maker Movement and the open source mentality, since his company, Arduino, has been producing electronics in open source for DIY activities. The RepRap project was compared to the Arduino one by the Director of Fab Lab Sevilla, and Bowyer’s initiative was very closely connected to the previous experience of the free software communities, and the Arduino community.

According to Ian Cole on his blog called Raising Geeks:

‘Makers have been on the margins for a long time – but what caused this move from the margins to the mainstream? Many factors have contributed, from technological progress, cost reductions in electronics manufacturing on a small scale’.

3D printing and related technologies have been instrumental in the rise of the Maker Movement, a more empowered version of the DIY one.

Makers met both online, in communities such as Adafruit or Fabber Italia; and, offline at the Maker Faire that was organized every few months in a different city (in New York, Bay Area, UK…). In fact, another actor that had a great impact on the diffusion of the Maker Movement: the community itself. This community celebrates learning, and freely shares ideas (Cole, 2011).
The online communities are composed of different actors, human (such as architects, designers, researchers, engineers, et cetera) and non-human (virtual websites, platforms, et cetera), but we are interested in investigating the inputs and outputs of the communities rather than their composition.

People from all around the world, and from every kind of background, started to gather online mostly around the RepRap Project and, in lower density also around the Fab@Home Project during this second phase. The Fab@Home community was not a tight-knit community as it is the RepRap.

One of the founders of Fab Lab Brazil explained why the RepRap is the most important community online:

“Rep Rap is the most important community, it is: horizontal, open and democratic. Openness is the most important way to construct and involve a community”.

Chris Anderson saw the RepRap community as acting worldwide, while other smaller communities originated from it are demanded to act locally:

“There is a need for communities in each country but also some acting worldwide. Like the RepRap communities that is know worldwide but then also has smaller communities in each country”.

In this phase, communities were mainly concerned with developing and studying the 3D printing technology itself. Discussions, updates, questions, all centered around the RepRap project and 3D printers. Most part participants were favoring technical questions and discussions. People seem to be more interested in the development of the 3D printer rather than showing to the community their designs or final outputs. Hod Lipson argued that the open source community for 3D printing took off and they were good at exploring the use of new materials and all the food printing for instance happened in open sourcing, as it is not something that companies work with. Bio-printing also started with the open source ones.

The RepRap community was very much technical. The value that the open source type of community provided to its participants is expressed in the point of view of Alessandro Ranellucci, the creator of Slic3r software:

“Community is a precious help. When I started, I could have chosen the opposite way... the opposite strategy...the traditional software development strategy, which is to close the source, and keep it for yourself and sell licenses for your software. This is how most software works. But, I thought that I wouldn’t have been able to use all the goodness that comes from the community... I mean, hundreds of people cooperating on a daily basis with you for free. And, sending the results of their tests... My email... my mailbox gets tens of emails each day with pictures of prints and ideas and feedback. This is test... testing activity. If you are to develop a software in a company, this would be a cost, but is for free for me. Because [...] people provide feedback”.

Some limits of these communities in developing 3D printing technologies existed, though, such as metal printing that are not explored at all by the communities, because more focused on safe and inexpensive technologies.
Massimo Menichinelli at Fab Lab Helsinki saw a specific role for online communities and said in the interview that online communities are more active in designing and developing machines, as opposed to the role of the Fab Labs that have a more educational role. Fab Labs had more a role of testing and educating people in using these machines. Neil Gershenfeld was not the spokesperson anymore in this phase, but he remained in the network as a mediator. His role has changed and now he is mostly associated to Fab Labs. These are mediators that offer offline places for gatherings, workshops and events, where people learn how to use 3D printers thanks to the help of experts and through experimenting with the technology.

The first Fab Labs, the one at MIT and the one in Boston, enrolled in the network in the previous phase, but now that the network is enlarging, Fab Labs are becoming a worldwide phenomenon as Tomas Díez from Fab Lab Barcelona said in the interview:

“Our Fab Lab is actually a part of a worldwide network of Fab Labs”

The role of each Fab Lab is two-folded: to educate, and to draw together 3D printers and people. In the interview, Hod Lipson declared: The Fab Lab is mostly about education”, and Tomas Díez suggested that Fab Labs are there mainly being educational. Kentstrapper founder, Lorenzo Cantini, said in the interview:

“FabLabs have the role to put in contact 3D printers and people”,

and Nuria Robles, from FabLab León, used similar words, suggesting that the role of Fab Labs was to offer a point where all community members can gather. It connects different disciplines and consequently generates synergies between them. Andrea Melò emphasized the power of the Fab Lab to help the diffusion of the 3D printing technologies, as they put in contact people with 3D printers, and vice versa the buzz around 3D printers brings people to Fab Labs.

The network was also composed also of many journalists and writers that act as framing devices, since they have contributed to interpret and define the innovation, as its qualities are related to the DIY culture and the Maker Movement, the open source philosophy. Among these journalists we can name a few that were mentioned in the interviews: Riccardo Luna (journalist, first Editor-in-Chief of Wired Magazine Italia), Jeremy Rifkin (economist and writer of The Third Industrial Revolution), Eric von Hippel (Professor of Technological Innovation in the MIT Sloan School of Management, writer of Democratizing Innovation 2005).

To sum up, in this second stage the access of the community is wider. The lower cost of the technology and the democratization of the resources allow more actors to access the community. They participate actively to the development of the technology and to promotion the innovation. The ‘space’ as an actor has key role in this stage since it allows the community to gather together and boosts the innovation process.

The marketplace orientation of the community is still low and the ideology around the innovation becomes stronger thanks the leadership role of the spokespersons. However, the low marketplace orientation impacts the interests of companies in appropriating this technology or being part of the community. In fact, companies do not play a pivotal role at
this stage and they are not able to leverage on the community in order to increase their competitiveness.


The network is once again reconfigured as a qualification process in under way from 2009 to the present. This time the spokespersons are two: Bre Pettis and Chris Anderson. Pettis is one of the founders and CEO of MakerBot Industries, a 3D printers producing company based in Brooklyn, NY. While, Anderson is the writer of Makers and an entrepreneur who started a company called 3D Robotics that uses 3D printers to create customized drones. The owner of E-Gadget, a Torino-based shop that sells 3D printers, mentioned “Bre Pettis, the one from MakerBot” as main actor in the interview. Chris Anderson was mentioned also several times during the interviews, including Tomas Díez and Juan Esteban Paz.

Both spokespersons have been very active in the qualification process, as they are attracting (interessement) new actors and enrolling them in the network. Bre Pettis has been speaking on behalf of 3D printers through his company and the products he sells, attaching the values of “fun” and “easy-to-use” to the technology. Chris Anderson has been translating the meanings associated with 3D printers through his books, speeches and his career path, since he decided to resign from his position of Editor-in Chief at Wired Magazine U.S. to become a full time entrepreneur. The meaning that Anderson is bringing to 3D printers is, in fact, of the entrepreneurial kind. To sum up, during this third period the value construction of 3D printers is stabilized by qualities like “fun”, “cool”, “easy-to-use technology”, “for everyone”, “entrepreneurialism”, and “key to the next industrial revolution”. 
The framing devices in this phase are the following: the book *Makers* that is on the next industrial revolution and it was written by Chris Anderson in 2012, journalists and writers, magazines such as Wired Magazine, and offline events such as the Maker Faire. These framing devices help attach the above-mentioned qualities to the innovation.

The following mediators are still present from the previous period and they have not changed their roles within the network: the Maker Movement, Adrian Bowyer, the RepRap Project, Massimo Banzi, Dale Dougherty, Tim O’Reilly, and the MAKE Magazine.

Among the mediators that are still present from the previous network and have changed their roles, there are: the Fab Labs that have increased in number, raw materials (PLA plastic, ABS plastic are still the most used, but researchers are tinkering with new materials that may be available soon, like nylon), and online communities around 3D printers that have increased and became more specialized (Thingiverse, Shapeways, 3D printing Google+...).

In 2009, MakerBot Industries, an open-source hardware Brooklyn based company, starts to sell consumer-friendly 3D printers. Bre Pettis, Zach Smith and Adam Mayer, founders of the MakerBot project, find the initial investments on Kickstarter. The technology used by MakerBot to produce their 3D printers is derived from the two open source projects we mentioned before: the RepRap and the Fab@Home. As the founder of Fab@Home and Professor at Cornell University, Hod Lipson, said in the interview: “I think these two open source printers definitely gave rise to the MakerBot printers, which have elements of both these two kinds of printers”.

Bre Pettis is very active as spokesperson, he has a Twitter page and he has a website in which he keeps a blog to promote MakerBot products, but also 3D printing in general. He gives speeches at conferences, universities, and events around the world. In the website it is written:

‘We are leading the next industrial revolution to empower creative explorers to make anything. MakerBot is setting the standard in desktop 3D printing. We’re changing the face of personal manufacturing and changing the way the world thinks about THINGS’ (Pettis, 2009).

As spokesperson of 3D printers, Pettis started a qualification process to attach new meanings to the 3D printers that now are: “fun” and “for everyone”. As Hod Lipson stated in this book *Fabricated*, ‘Bre Pettis [...] is a marketing mastermind who has skillfully shaped the company’s image and appeal’ (Lipson & Kurman, 2013, p. 52-53). Lipson remarked during the interview that MakerBot does not have a role in the technology development, but more in terms of reachability and making it accessible, making it fun, making it interesting to lots of people, founding the right balance of functionality and accessibility. He fosters the problem that it is more about finding the balance between quality and accessibility. The spokespersons in the previous network were able to find that sweet spot, the very basic open source system was maybe too difficult for people to use, the [industrial scale] systems were very good but too expensive, making MakerBot an indispensable player in the history of this technology.

Lorenzo Cantini from Kentstrapper also appointed the company as the main representative of the technology, sustaining that it was the main actor for what concerns 3D printers. And the Brooklyn based company was able to make the technology “fun”, as Enrico Bassi said in the interview: “It sounds fun” and “it is a tool, a pretty cool tool. Fun”. Chris Anderson refers to MakerBot products as ‘thrillingly cool’ (Anderson, 2012, p. 93). Hod Lipson agreed in his book *Fabricated*: ‘MakerBot’s ability [is] to transform a relatively dry
additive manufacturing machine into a sociable, creative playful endeavor (Lipson & Kurman, 2013). Lastly, Giovanni Calà, who recently bought a 3D printer, explained he bought it because it was fun, and it was able to make his own objects from my ideas easily, stable and cheaply.

Among the new mediators enrolled in the network there are the following: the two models of MakerBot printers (Replicator 2, Replicator 2X, that interestingly enough took the name from the Star Trek Replicator machine) that with their qualities (cheap, easy-to-use, aesthetically attractive) are attracting and activating other actors.

In 2012, MakerBot became for some actors a betrayer in the network, when CEO Bre Pettis stated on the company website that ‘for the Replicator 2, we will not share the way the physical machine is designed or our GUI’, which means that the company is not completely open source anymore (Pettis, 2012). Following to this statement there has been a lot of controversy. During the ethnography at the Fab Lab Torino, two of the experts working there mentioned MakerBot with a mocking attitude. When one person said that the Politecnico of Torino was going to buy two 3D printers from the company, another replied: “What will they do with a Replicator? It is also “closed” now!”. The first confirmed: “Eh, yeah. I know!”

One of the co-founder of MakerBot, Zach Smith, decided to exit the company following the decision of partly ‘closing’ the technology, and he became a hero in the open source community. As the Director of Fab Lab Torino, Enrico Bassi, said that Zach Smith which was one of the guys from MakerBot, the one that left after MakerBot became closed-sourced and he became the hero of the community, MakerBot became a betrayer for the open source community, because it changed an essential feature of the technology and was seen as an act of treason. But at this point the audience of MakerBot was mainly composed not by those that are familiar with the technology, but by all the other people that want a tool that is very simple to use and that guarantees them to have a fun experience and know little about the open source controversy. Bre Pettis has contributed to make the technology popular thanks to the translation process he put in place. Articles about 3D printing are increasing on every kind of media, from newspapers, to television programs, on the Internet, et cetera. Alessandro Ranellucci remarked: “Recently, in last year or so, or maybe a little more than a year, also in the magazines and the TV and the other mass media...[you find people talking about 3D printers]”. Enrico Bassi added: “3D printing [...] is becoming in some way quite popular as it is becoming a cool thing. People are talking about it more and more on television [and] there is a music video with 3D printers” (ndr. Will.i.am ft. Britney Spears “Scream & Shout”).

Chris Anderson sustained that he saw a 3D printer in real life for the first time in 2008, but it took him one more year of research and experimentation to realize that

“we were on the verge of a new industrial revolution”.

With the book Makers (2012), Anderson wants to be an inspiration for people, to convince them to embrace this new technology, since he is suggesting the readers to start entrepreneurial projects based on the use of 3D printers. What he calls the “next industrial revolution” is, in fact, centered around 3D printing, seen as:

‘An emblem of the democratization of technology [...] In other words, the industrial tools are given to regular people. This was true for the computer and then for the Web, for instance. [...] Whenever a tool becomes democratized, it means that it has social not just
technological forces. [...] A particular set of tools, I mean wider than with other technologies, is that these bring a revolution as they give people access to manufacturing’ (Anderson, 2012, p. 18)

Chris Anderson, as spokesperson in the network, is translating the values associated with 3D printers and these can be identified with entrepreneurialism and with seeing the technology as key to the next industrial revolution. As an example of this entrepreneurial spirit, we can take the example of Giovanni Calà, an engineer who has recently bought a 3D printer saying that he thought it was fun, but also, when asked what are his projects in the future he said:

“Now I will make some prototypes from my ideas. And then I will set up a website to offer a service of prototyping to other people”.

This network has been affected by the economic crisis that started in 2007 and that represents an actor as well, since the employment situation in developed countries has consequently transformed and the unemployment rate has greatly increased. This situation was reflected on an emerging need to find new ways to create jobs. An article appeared on The Economist in 2012, reported that:

‘A 2009 study found that over half of Fortune 500 companies got their start during a downturn or a bear market. A recession, it seems, may not be an entirely bad time to start a company’ and that ‘recessions may also spur the creation of new businesses’ (‘Downturn, start up’, 2012).

In addition, the Telegraph revealed in 2010, that more than 200,000 new businesses opened in the six months that followed the recession – the highest for more than a decade’ (Hurley, 2010). Moreover, as the founder of Kentrapper, a company based in Italy that produces and sells 3D printers, suggested in the interview: “3D printing can create interesting new job opportunities”. In 2009 Kickstarter was launched, which is a website where people can raise funds for their projects and start-ups. Kickstarter has then enrolled in the network as mediator as well, as Chris Anderson said in the interview because a lot of actors are putting their projects on Kickstarter. In this phase, collaboration becomes more and more important also with FabLab, as Dale Dougherty stated that he sees in the Maker Movement an “increasing participation of all kinds of people in interconnected communities with shared common goals. Online communities shifted their function, though, as Hod Lipson stated in the interview:

“We may be beyond that community. So, the role of that community may have sort of subsided. [...] So we may be now moving ahead and just building a 3D printer is not exciting anymore. Now we’ll have room for different communities: communities of designers or of people interested in food printing, or in bio-printing”.

As opposed, or in addition, to participating in technical communities, such as the RepRap that is more concerned with the development of technologies, now new communities arise that are more focused on what one can do with 3D printers. Depending on the need of the actor approaching the network, he or she will participate in a specific community, and
some of these new needs are captured for instance by online communities such as Thingiverse or Shapeways. On the Shapeways online community, the main objective of the participants is to have post their own designs, exchange ideas and help each other out for what concerns the designing and the 3D printing of objects. Similarly, on Thingiverse, members use the community as a window, to demonstrate their abilities in creating 3D objects and models, and at the same time they like to share these designs freely with other people. Other members can, in fact, download and print the designs as they are, or they can remix them to improve them or customize them.

The offline versions of communities have changed as well lately. Fab Labs are spreading more and more, and therefore a greater number of actors are enrolling in the network. Most of them are acting as mediators, such as Enrico Bassi who is the Director of Fab Lab Torino, Tomas Diez who is the Director of Fab Lab Barcelona, alongside all the other Fab Lab Directors from all over the world. Similarly to what is happening for online spaces, that are more and more specialized, also for offline gatherings there is an emergence of new makerspaces (or hackerspaces) that are adopting different and specific characterizations. For instance, the TechLab in Chieri, in the words of one of its founds Paolo Cavagnolo, is different from the Fab Lab role, as it is seen more as a space where to craft things or adjust things. Another example is the L.U.N.A. Lab in Bologna, which, as Andrea Melò defined it, is a private school, quite expensive, and its purpose is to teach people how to use 3D printing and related technologies to produce design pieces, such as furniture and jewelry, to put up for sale in the L.U.N.A. shop. The positions regarding the legal protection for 3D printing technologies vary from one actor to the other: industrial 3D printers producing companies are for patenting every single innovation they do in their R&D department because they are afraid of the competition, while, participants in the RepRap community are pro open source and the open source community position is that one person cannot change the world, but many people together can. Many people stand in between these two extreme visions and they would prefer to find a middle way solution. Hod Lipson, for instance, who founded the project Fab@Home to share the 3D printing technology in open source, remarked that there are also advantages in patents as:

“The reason why we have two or three 3D printing technologies is because of patents, because companies could not infringe on each other’s patent so every company had to come up with a new way to 3D print, and this is for metal printing. Printing plastic is open, so there are hundreds of companies that are selling machines that print plastic the exact same way, like MakerBot. Some things are good to open source for their accessibility, some innovations happen thanks to open sourcing, but not all. It is not that simple. There is a balance that should be reached”.

Alessandro Ranellucci analogously declares in the interview that he is not “against patents” even though he developed and shared his project for Slic3r completely in open source. But he also said that the problem is that “ there are many old patents that have not expired yet” and these limits the innovation possibilities around 3D printers. Moreover, he added:

“Big companies like Stratasys are patenting things right now […] there are many other interesting technologies like powders, resins, lasers, all these things are being
protected by patents. And not just old patents... new patents... so this is a problem. When it comes to selling printers or developing a software like Slic3r, things become [...] complicated because big companies are big, and we are individuals with no lawyers and no funding to defend ourselves”.

Interestingly, many of the interviewees felt that the community is an asset against intellectual property violation. Ranellucci sustains that his strength is the community, or as Paolo Cavagnolo said using the example of Arduino

“There may be other products that work as good, or better than Arduino. But Arduino has a competitive advantage: its community”.

The balance that Hod Lipson mentioned can be therefore reached with a new mediators that enrolls in the network in this phase: the Creative Commons (Creative Commons, 2001).

The Creative Commons is a non profit organization that offers six types of copyright licenses that are made from the following four different types of attributes: Attribution (permitting others to distribute or build upon the work, as long as they credit the author for the original creation), No Derivative Works (the work cannot be modified), Non Commercial (it is not permitted to use the work for commercial purposes), and Share Alike (the work can be modified but it must be shared with the same conditions chosen by the original author). The six licenses available are the following: Attribution, Attribution-No Derivative Works, Attribution-Non Commercial-ShareAlike, Attribution-ShareAlike, Attribution-Non Commercial, Attribution-Non Commercial-No Derivative Work.

As M.C. suggested that instead of using patents, companies and people should use licenses from the Creative Commons.

Companies that are using 3D printers for prototyping in their R&D, or for letting their consumers customize the products, such as Lego or General Electric, are also actors enrolled in the network. Bassi argued that companies are quite slow to change. Companies are interested in understanding better how to innovate, but at the same time they are slow and usually focuses on making profits. Chris Anderson has outlined some suggestions for companies in the interview:

“I’d say there should be a 3D printer on every employees’ desktop in order for them to try out their ideas. And this would encourage innovation. Then they can change their relationship with their customers to involve them in the production process, the way many big companies are doing”.

Moreover, Anderson added that companies should adopt the strategy of combining the tool internally with employees, and externally with the customers. As the founder of Fab Lab Brazil also stated that the users are changing, the world is much more connected and the innovative people don’t want to work in a traditional company.

Alessandro Ranellucci lists some of the major advantages for companies that embrace an open innovation approach:

“Who release back their designs to the community under an open license, for example... they benefit from good visibility... from help from the community. It's basically free
advertising... free marketing. So, there is a business advantage in doing so. And they also can have their product improved. And also, their customers are more open towards any defects of their product. Because when you buy something and you know that it is open, you actually complain less than if you buy a closed product that you assume works out of the box”.

A handful of companies that have been successful with an open source model exist. Enrico Bassi takes the examples of Arduino, that produces electronics, and Ultimaker, that produces 3D printers:

Nuria Robles from FabLab León takes as well the Arduino example, looking at open-source is an opportunity, not a threat, Paolo Cavagnolo agrees on the Arduino example but he says that for the most part, within for-profit companies open source is still seen with mistrust.

The founder of Fab Lab Brazil criticized companies because in her opinion they:

“Buy the newest and most expensive technology but continue working with old business models. The open innovation is the way that companies can change to the old paradigm to the new and be connected and interact with a really collaborative world. If they don’t understand that, they could suffer some problems”.

She also believes, though, that it is possible to change this situation by embracing open innovation.

Massimo Menichinelli of Fab Lab Helsinki thinks that open source is becoming more popular.

Other mediators that enrolled in the network in this third period are the following ones: other companies besides MakerBot that are producing 3D printers (such as Kentstrapper, WASP, Ultimaker, 3D Systems, Stratasys, Solidoodle…); 3D design software (Google SketchUp, Autodesk 123D, TinkerCAD, AutoCAD, Solidworks); and, other machines involved in the Maker movement (laser cutter, 3D scanner, CNC machine)

The intermediaries are growing in number, and are the following: stores that are selling 3D printers (MakerBot store in New York, E-Gadget in Torino) which are only physical space where the printers can be bought, schools and universities that are hosting seminars or courses about 3D printing that have merely a divulging role, as well as Andrea Gebhardt has a divulging role (German professor and writer of articles and books).

The actors that might threaten the network of 3D printing are: prices, materials and the user-friendliness of the software, IP. The qualities that are reinforcing the network are collaboration, sociality, usefulness and passion.

Enrico Bassi believes there is a desire for collaboration, and says that the Fab Lab in Torino for instance is a “space where people can share their ideas all together, share knowledge, work together, learn new things, learn new technologies, [and] developing projects”. In the interview with M.C., an online communities participant himself, he stated: “People in communities love collaboration”. The interview with Fab Lab Brazil revealed that:

“Communities let people discover what they can do, empower them. Alone, we have less power. The online collaborative platforms are much more powerful to construct important things in a short time and spending less money. I think people collaborate because they see the benefits of that. Because is nice to help and be helped. But, especially because they see that their works go further”.
The Boston Globe also noticed that there was a collaborative motivation in people that participate in communities like the Fab Lab:

‘[...] the lab in Norway -- where farmers and engineers are collaborating to build a wireless radio network to track sheep and reindeer -- built an antenna and posted photos and instructions on the Web for the others to see’ (Dunn, 2005)

While carrying out the observations both at Fab Lab Torino and at Fab Lab Barcelona, we detected that there was a collaborative environment, with the more expert people teaching and helping out the others to realize their projects

Lipson gives more emphasis to the social value, saying:

“I think the social aspect is very important: talking with a community of like-minded people. And often people interested in technical issues are sort of isolated and this is a way for them to connect. The physical hackerspaces are like going to a club or a gym where you meet people and talk about common interests”.

Enrico Bassi also recognized the importance of sociality in these communities, when he said, regarding to the people that participate in Fab Labs, that some are retired and they have time to spend here, they like to meet other people.

The third value is passion, which is a word that appeared a lot in the interviews we carried out. Andrea Melò clearly stated that “passion” is the one and most important motivation for people to participate in online communities. Enrico Bassi mentioned passion as well when he said that by going to the Fab Lab “you can improve yourself and share your passions with others”.

In the netnography it appears that participants use online communities to ask for help, whether they have difficulties with the technology or they want some suggestions about their designs. For instance, in the 3D printing Google+ community, there is a section called “Questions/Help” where people can ask for advice and any other kind of help. The other members of the community are answering with detailed information and seem willing to help.

Another way in which communities can be useful is for realizing projects, as Hod Lipson puts it:

“There is also a practical element for some, which is to have ideas take off. And they are not so much interested in the social relationships, but in having access to machines and expertise”.

This can happen in Fab Labs for instance, where as Enrico Bassi, Director of Fab Lab Torino, said:

“It is very hard to define a specific target. [...] Some other people come because they understand that it is a cool place where to stay and try out things, test and develop stuff. Then there is people that work and they enjoy the idea, the philosophy and come here to develop something they cannot do at work as well as something for the work they are doing” but “mainly these guys are students. They come here because they need it for school”.
When we were there for the ethnography, in fact, there were three students from Politecnico printing an object for homework and one expert from Fab Lab was there to help them.

To sum up, at this stage the marketplace orientation of the community increases. More companies enter in the community and try to build a profitable business through the development of the community. All the actors that compose of the community become essential in order to build the competitiveness of the company. They are resources that companies start to incorporate in order to be successful in the industry. Companies also start to appropriate the value generated in the community through the licensing activity (i.e. creative commons). However, there is friction between the actors on the appropriation of resources.

Findings

The community

We find that the 3D printing community can be assimilated to what Callon (2004) defines as hybrid and heterogeneous collectives; as such, it allows the participation of diverse actors. Heterogeneous communities encompass an assemblage of different actors such as consumers, producers, resources, objects and technology (Chalmers et. al, 2013). These actors can have a different orientation towards the community according to the roles they have and the meaning that they build in relation to the community (Chalmers et. al, 2013).

Chalmers et al. (2013) classify heterogeneous communities according to different structural elements: the focus of the community, the heterogeneity of the actors, the sense of belonging of the members to the community, the duration, access, dispersion (localized vs. dispersed), and marketplace orientation.

The focus of the 3D printing community is the technology. We find that, in the 3D printing community, the innovative technology itself has an active role in shaping the heterogeneity of the actors; indeed the newness of the technology encourage the involvement of different stakeholders, who share the interest for the unknown technology but are driven by different interests. Specifically, we identify five groups of actors: the Proactive Members, the Spokespersons, the Entrepreneurs, and the Companies. Equally, the ‘physical space’ (i.e. the Fab Lab) has an active role in the definition of the community as well. Within Fab Labs, members are extremely proactive and have different expertise. We find architects, engineers, software and hardware developers, designers and researchers that aim to contribute in different way to the advancement of the 3D printing technology.

The Spokespersons have an important role since they allow the community to grow and the technology to advance. They have different backgrounds but they are equally visionary toward the technology and they tend to experiment more than the average community participant. They have the aspiration to create machines that can improve the future and they also have the ambition to diffuse the 3D printing. Considering themselves on the edge of radical innovations, these actors contest the mainstream technology system, for example proposing alternatives to the proprietary systems of patents. They are in a way invested of an authority. The Entrepreneurs are people who decided to realize business ideas using 3D printing as production process. There is a variety of entrepreneurial ideas and start-
ups projects around the 3D printing. However, these entrepreneurs are also ideologically motivated. They believe that through their activity they can trigger an industrial revolution. They put into practice the project of the Spokesperson. The ideological involvement of the proactive members, the spokespersons and the entrepreneurs make of the 3D printing project a social movements. Most of the times, these actors are in-fact associated to “Maker Movements” of “DIY movement” that tend to challenge the mainstream technological system with radical innovation. Out of these network, and at the edge of the community, there are traditional companies (i.e. Lego) that are using the 3D printing only at the R&D stage at the moment. They are embracing this radical innovation in a traditional way. Their motivation of being in the community is not to miss the momentum and try to develop sustainable forms of 3D printing. However, they are not able to innovate since they do not take part to the entire 3D printing movement.

The main motivations of actors for participating are: the desire for collaboration, sociality, usefulness and passion. The desire for collaboration and sociality give actors the chance to feel empowered and not feeling isolated. As result, actors are more productive given the enhanced feeling of collaboration. Self-promotion is observed when this collaboration is created to achieve specific individual goals or group projects, such as building a cheaper 3D printer, selling designs or improving 3D models. Gathering in community is also linked to usefulness and problem solving. Members meet in the physical space or online solve practical problems such as issue with the technology and its applications. However, this motivation has to be seen also as a way that the proactive members has in order to turn ideas and creativity into physical objects. For these reasons, actors within this community show a strong sense of belonging to the community.

The community is both dispersed and localised. Dispersed because it represents an international imagined community that acts worldwide. Localised because the actors mentioned above meet in a physical space. The physical space (Fab Labs) has a key role in the definition of the phenomenon. Fab Labs are spaces of intermediation; the main function of Fab Labs is to allow people to produce in small scale. They are usually equipped with several computer-controlled tools, such as 3D printers. Rather than a space to produce physical objects, the Fab Lab is the space where the 3D printing movement happens. The Fab Labs offer a point where all community members can gather. It connects different disciplines and consequently generates synergies between them. They are considered as educational spaces. They also promote the 3D printing values such as technology democratization and having fun with technology.

Conclusions
This research explored the role of communities, as intermediaries, in impacting the competitiveness of the firm. The purposes of the research were to understand whether the users’ network around a firm is a source of competitiveness, and to unpack the factors and network actors that lead to a firm’s competitiveness.

These findings show that the technology shapes the access and the roles of the different actors within the community. The motivations of the different actors to participate
to the community boost innovation of the technology to the extent that technology is associated with ideological movements. The space forges the interactions that boost the radical innovation as well. Companies have different roles at different stages of development of technology in appropriating value generated by the community. Specifically, when it was observed that when the marketplace orientation of the community is higher, companies have more interested in engaging with the community and in appropriating the value generated by it.

We would like to discuss in the conference how companies can foster their competitiveness leveraging on these actors within the community implementing the following strategic actions: (1) developing personalized strategies in order to address different community members, (2) investing resources in stimulating collaboration and sociality within the community, in order to encourage the enhancement of innovation, (3) being aware that contributions from different actors (including non humans) are extremely diversified and there is the need of having internal competences in order to discern among them and embrace the consequences that different contributions have on firm’s ecosystem and operations/supply - chain, (4) considering the physical space as an active part of the community and understand its logics, (5) understanding that community members consider the 3D technology as part of the community and aim at developing themselves in parallel with it.
Incomplete list of References:
Siggelkow, N., 2001, Change in the presence of fit: The rise, the fall, and the renaissance of Liz Claiborne, Academy of Management Journal, 44(4), pp. 838-57