From Invention to Industry from a social movement perspective: The emergence of the 3D Printing Industry

Christian Lechner (Christian.Lechner@unibz.it)
https://orcid.org/0000-0003-2721-4407
Abeer Pervaiz
Libera Universita di Bolzano Facolta di Economia https://orcid.org/0000-0002-6951-1672

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Abstract

In the entrepreneurship literature, the phenomenon of industry emergence has been largely investigated from an institutional perspective. Appropriate institutions would allow then a group of individual entrepreneurs ('the heroes') to create an industry through innovative ventures. New ventures create new industries and firm entry, survival and exit drive industry evolution. Our research, however, explores what creates the favorable set of circumstances for new ventures to emerge and focuses on the pre-emergence phase and we propose that the patterns of emergence resemble those of social movements. Through an actor perspective, this research highlights the existence of diverse actors, not necessarily entrepreneurs, who are necessary to trigger a collective action during the pre-emergence phase of industries. This research is also distinct from entrepreneurial ecosystems as its development already requires some successful entrepreneurial action. The 3D Printing industry was chosen as a single longitudinal case study, where the actors are the embedded units of analysis. The findings of the study lead to the identification of three aggregate dimensions; "Social Movement Composition", Temporal Engagement" and "Coalitions Development", that were prevalent during the pre-emergence phase of the 3D printing industry. Our propositions emphasize the importance of large collective action and the role of multiple actors in order to create the conditions for, first, firm emergence and the second, to the process of industry emergence.

Introduction

Most industries began with some sort of invention, such as the telephone, light bulb, radio, television and so on. While the credit of the invention goes to the inventors, the credit of industry creation goes to the entrepreneurs founding new firms. Research that investigates patterns of firm entry, survival and exit to understand emergence and evolution of industries make an important contribution (Klepper 1997) but cannot explain what creates a favorable set of circumstances for these firms to emerge in the first place. However, this research gives one important insight: the idea of redundancy. Redundancy means that more firms need to emerge in order to create a few relevant and successful firms. Entrepreneurial agency understands the outcome of entrepreneurial action as the interaction between individuals and their environment (Goss and Sadler-Smith 2018). If we combine the insight of redundancy with the actor-based approach of entrepreneurial agency then there is an utmost need to identify not only how an industry emerges but what exactly happens before it emerges (pre-emergence)? What actors are involved? When are they involved? How are they involved? Though the questions asked in this study are broad, they tend to explore knowledge and understanding of the phenomenon of industry emergence and its relation to entrepreneurship at a deeper level. Indeed, within management and organization literature, what happens between the invention and the formation of an industry is not well understood and the question 'how industries emerge?' is still ambiguous. Research tends to favor institutional explanations or prototypical actors that fulfill mechanically specific functions.

Even the concept of entrepreneurial ecosystems, despite its emphasis on embedding entrepreneurship as a social process, is unable to bring clarity when it comes to which actors or how many actors are involved in a particular ecosystem as actors in ecosystems are reduced to prototypical functions such as venture capitalist, business angel, etc. (Stam and Spigel 2017). According to O' Shea, Farny and Hakala (2019) studies related to entrepreneurial ecosystems are mostly "typological" and "theoretical" in nature and currently fail to properly integrate the entrepreneurial process in further development of the concept, favoring a view of efficient institutions rather than redundant actors. Moreover, entrepreneurial ecosystems appear to require already some successful entrepreneurial action as role models in order to develop fully (Isenberg 2011). Cavallo Ghezzi and Balocco (2018) emphasize that future research on entrepreneurial ecosystems should make an effort to try and involve a wider range of actors that have a significant role within the entrepreneurial ecosystem lifecycle – "i.e. its creation, growth, stability or sustainability – in order to advance the entrepreneurial ecosystem research along the right lines" (p.22).

However, some scholars have identified the importance of several diverse actors, besides the entrepreneur, that may be responsible for industry creation, reinforcing the idea of redundancy (e.g. Eliasson 2000; Mezias and Kuperman 2001; Sine and David 2002; Van de Ven 1993 a, b). This in turn has led to studies where collective action and social movements (SM) are being implemented to understand how industries emerge (e.g. Barnett 2006; Carlos, Sine, Lee and Haveman 2014; Lounsbury, Ventresca and Hirsch 2003; Pacheco, York and Hargrave 2014; Pacheco and Dean 2015; Schneiberg and Lounsbury 2008; Soule 2012; Walker 2012; Weber and King 2014). Most SM studies related to industry emergence are based on institutional perspectives rather than actor perspectives. Therefore, our research objective is to understand how the idea of redundancy can be applied to an actor perspective of industry emergence. From an actor perspective, participation of aligned actors is key for understanding collective action (Oliver and Marvel 1988). This leads us to the research question of how necessary participation for industry emergence is enabled and why actors get and stay involved.

Our study argues that industry emergence is a social process that is embedded with diverse actors, entrepreneurs, communities, institutions and organizations, allowing also for redundancy of actors. Our objective is to develop a conceptual framework that can act as a complementary method to understand the emergence of an industry from its inception. Our objective is first, to complement the arguments of the "hero entrepreneur"(Reynolds 1991) and efficient institutions (Sine and David 2010) with the possibility of other diverse actors that may be responsible for the creation of an industry. The concept of SM aids in understanding this process because; first, it helps in the identification of actors and second, its wider approach tends to involve the whole society as a collective action rather than just the entrepreneur(s) and/or institutions. Furthermore, emphasis is placed more on the pre-emergence phase of the industry which is somehow left untouched in management literature (Forbes and Kirsch 2011; Gustafsson; Jääskeläinen, Maula and Uotila 2016). Given this perspective and research objectives, the 3D Printing industry is chosen as a single case study and the participants are the actors as the embedded unit of analysis.

The study begins with a theoretical foundation of the research followed by the research methodology section. After the data analysis, the findings are presented followed by the discussion section. Finally, it proceeds towards the limitations, future research and conclusion.

Theoretical Background

The general focus of entrepreneurial scholars has been on either individual entrepreneurial behavior or the activity of entrepreneurial (new) firms (Reynolds 1991). Recent studies on entrepreneurship have started seeing entrepreneurs from a sociological angle distributed among several actors (Jennings, Greenwood, Lounsbury and Suddaby 2013). This portrays entrepreneurship to be distributed among several actors where switching back and forth as projects evolve seems to be the mode of action (Delbridge and Edwards 2008; Lounsbury and Crumley 2007). These studies tend to decentralize the individual entrepreneur by emphasizing the entrepreneurial phenomenon as a broader field that involves “temporal”, “spatial”, “social, organizational” and “market dimensions” (Zahra 2007; Zahra, Wright and Abdelgawad 2014).

Entrepreneurship can be viewed as an interaction among individuals, social communities and the whole of society (Welter 2011). Yet, in prior studies the focus has been on the role of the entrepreneurs as firm founders, “who are considered as leaders in the creation of new industries” (Mezias and Kuperman 2001, p.210). However, entrepreneurs’ embeddedness in communities extend this view: communities create more openness (West and Kuk 2016) and spaces for sharing ideas (Felin and Zenger 2007). The case of user entrepreneurs emphasizes that communities emerge where like-minded individuals come together to share and engage in similar activities and practices related to products and technologies (Fredreiksen, Dahlander and Auito 2008). Industries, such as the 3D printing industry, are conducive to openness and user entrepreneurship as they provide entrepreneurial opportunities at various points along the industry’s value chain (Holzmann, Brietenecker, Soomro and Schwarz 2017). The concept of user entrepreneurship and openness within community are similar to the concepts of SM, in the sense that diverse actors having similar goals form together a community that allows sharing of ideas, that eventually allows growth of the movement, or in this case the industry.

Management scholars and sociologists have observed the contentious nature of the social construction of markets and recognized that social forces play an important role in the emergence of industries (Pacheco et al. 2014). According to Weber and King (2014) through SM organizational scholars were able to explain bottom up purposeful change without depending on individualistic models of behavior. Furthermore, the concepts and perspective of SM have been successfully applied towards understanding the emergence and transformation of organizational fields, markets and industries as contested forms of collective action.

In technology-intensive industries, fragmented interests across industry participants often complicate the collective action process. Such competition can hinder collective action as industry participants promote their own interests and fail to advance the interests of the overall industry in obtaining legitimacy (Aldrich and Fiol 1994; Barnett 2006; Van de Ven and Garud 1994). Oliver and Marwell (1988) highlight that the real issue of collective action lies in realizing the existence of a social mechanism that allows having enough people that share similar interests and resources over which they act upon. If heterogeneity exists amongst a group that can make large contributions, and if the members are connected to one another socially in such a way that they act together, then the possibility of collective action within larger groups is more likely to take place.

According to Van de Ven (1993 a, b) industry emergence depends on the ability of individuals and actors to transform into nodes in value chains and industrial infrastructure, while combining the interests of their newly formed industry with the interests of other players. SM theory provides insight into the process where actors can translate their shared interests through collective action (Weber and King 2014). This leads to new collective identities and solidarity that creates new industries of organizational forms (Rao, Monin and Durand 2003; Sine and Lee 2009; Weber, Heinze and DeSoucey 2008). Most studies have acknowledged and implemented the concepts of SMs successfully in understanding the emergence of organizational fields, markets and industries (Barnett 2006; Carlos et al. 2014; Lounsbury et al. 2003; Pacheco et al. 2014; Rao 1998; Rao et al. 2000; Schneiberg and Smith 2008; Sine and Lee 2009; Walker 2012; Soule 2012; Weber and King 2014). However, the implementation of SMs in understanding the emergence of industries has been limited to an institutional and entrepreneurial perspective and that too on already established industries such as the US recycling industry, American Insurance, Dairy, Grain and Windmill Industries. What remains still an unanswered realm is what happens in the earlier history of the industry and how can SM play its role? Our research tends to ask (1) how does an industry emerges through collective action of actors from diverse backgrounds (which also includes entrepreneurs, communities, organizations, firms, institutions)? And (2) Are there any predictable patterns in the industry emergence process?

Research Approach And Methods

A qualitative approach is believed to be an effective method for this study as both the research questions and the chosen industry have human and social elements which allows the flexibility to ask ‘how and why’ questions (Agee 2009). According to Pratt (2009) qualitative approach is an appropriate method to ask ‘how’ questions rather than ‘how many’ which allows understanding the world from the viewpoint of the subject being studied (i.e., informants) and for examining and articulating processes. In our case, the limitations of institutional approaches, the view of the hero entrepreneur, as well as entrepreneurial ecosystems, lead us to the exploration of collective action for industry emergence: This in an under-researched topic, where we lack sufficient knowledge for the development of hypotheses. Grounded theory allowed deeper analysis and space for theory to emerge from the data set. This will be further explained in detail.

Context and Framework

The specific industry chosen, to explore its emergence by looking at the actors involved, is the 3D printing industry . A single case study design with embedded units (where the embedded units are the actors) was chosen because of (a) the existence of how and why questions (Yin 2003) and (b) the uniqueness of the phenomenon being investigated. The 3D printing industry provides a distinctive research setting, having only been recognized as an industry from the past few years. Even though the technology was recognized in the late 70s, it is still in a relatively emerging stage as an industry. Its status also helps in setting this study apart from earlier studies that are based mostly on already established industries. Furthermore, it also gives a unique edge in initiating the study from an actor perspective rather than from an institutional and/or entrepreneurial perspective. Recent studies such as by West and Kuk (2016) and Holzmann et al. (2017) have studied 3D printing from a community perspective, but already at the later stage of startups and the in the development of effective business models. Whilst there is an abundance of studies on the emergence of 3D printing from a technology perspective in the field of engineering and robotics, we have focus on collective action in the pre-emergence phase of industries. Since there is limited empirical evidence related to the emergence of the 3D printing our study expands on these insights by examining the actor perspectives during the pre-emergence phase, thereby providing a better understanding of the emergence process of how diverse actors come together, along with entrepreneurs in order to enable industry emergence.

Case Study Background

The late 1980s marked the earliest 3D printing technologies, they were more known as Rapid Prototyping technologies. These processes were considered originally to be fast and most cost-effective methods to create prototypes for product development within an industry (3Dprinting, 2014). Bourell et al (2009) referred this technology as additive manufacturing where the late 1980s and early 1990s saw a number of additive manufacturing processes to emerge. On March 9th, 1983 an inventor known as Charles Hull used a computer-controlled, ultra-violet laser to trace out and solidify a single layer of an object on the surface of a tank of liquid photopolymer. Using this process he was able to create a small blue plastic teacup. Hull had thus invented 3D printing. On March 11th, 1986 Hull managed to get the US patent for his Apparatus for production of Three-dimensional Objects by Stereolithography. He also co-founded the company 3D systems Corporation where he along with his team also created the STL file format that makes computer aided design software data to be used for 3D printers. 3D Systems also sold its first commercial 3D printer or Stereolithography Apparatus, SLA-250 in 1988 (Barnett, 2014). In 1989 Stratasys Inc. co-founded by Scott Crump filed for a patent for Fused Deposition Modelling which was issued in 1992 (3D printing, 2014). Stratasys alongside 3D systems was another corporate giant in the printing world. Crump discovered this invention while he was using hot glue gun to build layers of a toy frog for his daughter. By 1992 Stratasys introduced its first 3D printer “3D Modeler” (Barnett, 2014). Other 3D printing technologies and processes were also emerging during these years, namely Ballistic Particle Manufacturing originally patented by William Masters, Laminated Object Manufacturing originally patented by Michael Feygin, Solid Ground Curing originally patented by Itzchak Pomerantz et al and ‘three dimensional printing’ originally patented by Emanuel Sachs et al. And so the early nineties witnessed a growing number of competing companies in the rapid prototyping market but only three of the originals remain today — 3D Systems, EOS and Stratasys.

Early 3D printing industry was dominated mostly by engineers who were the only people who used computer aided design software to create 3D printed objects. The first two and a half decades of 3D printing was seen more like a specialized tool in a highly specialized profession (Emmino, 2012). It wasn’t until the late 90’s that scientist’s started using 3D printing as a tool for organ development. In 2000 Object Geometries launched the first ever 3D inkjet printer followed by Zcorp introducing the first multicolor 3D printer. In 2001 Solidimension introduced the first desktop printer (van Wiljk and van Wiljk 2015). In 2002 scientists from the Wake Forest Institute for Regenerative Medicine were able to create a miniature functional kidney that was able to not only filter blood but produce urine as well in an animal (Van Wiljk and van Wiljk, 2015).

According to Heater (2014) though the first wave of 3D printers were developed by American entrepreneurs who were highly inventive in their garages, similar to Apple and HP, but the advent of modern desktop 3D printers surprisingly emerges from an open source project that was launched by a British University. The mission of this project was simple, yet it seemed impossible and that was to create a machine that had the ability to replicate itself. Through a grant given to the University of Bath in the UK, Adrian Bowyer, a senior Lecturer in mechanical engineering at that time, started working on a technology that would have the ability to replicate itself. On 2nd February 2004 RepRap (Replication Rapid-Prototyper Project) was invented with the goal to create a self-replicating device which could be used by individuals all over the world at low cost and the ability to manufacture objects that could be used in everyday life (all3dp, 2016). It could be said that RepRap was basically the start of a new open source movement that would allow individuals from all walks of life to use a technology that would enable them to create products on their own. Reprap was able to see the true colors of its success in the following year when the first replaceable part was printed by an early prototype. In 2008 the RepRap 1.0 Darwin successfully printed out half of its own rapid prototyped components (Heater, 2014).

2007 saw the open source movement of 3D printing when three individuals came together in a hackerspace tech community to create an open source company known as MakerBot. It was followed by the opening of an online repository known as Thingiverse that allowed individuals from all over the world to build a community where they could use 3D printing as a means to design and print. 2012 was the year that alternative 3D printing processes were introduced at the entry level of the market. It was also the year that many different mainstream media channels picked up on the technology. 2013 was a year of significant growth and consolidation. Various 3D applications are being developed in different sectors such as medicine, aerospace, automotive, jewellery, art, design, architecture, education, food and many more (Barnett 2014).2015 was the year of major developments in the 3D printing sector such as medical advancement with regards to facial surgery, advances in metal 3D printing, 3D printed houses, Nike, Adidas and New creations creating 3D printed shoes, the joining of major corporations such as Michelin, HP, Canon, Ricoh, Toshiba, Lenovo, Autodesk and Apple and NASA launching 3D printers in space (Kira 2015).

However, there is still a gap between what 3D printing technology can do and what it will end up being used for and it has led to the development of many startups working in these different sectors. More and more startups and new ventures are coming into the 3D printing industry and trying to bring new applications which could lead to the possibility of evolution of this industry [1]

Data Collection

Data collection was a three-part process based on (1) Available documentation, (2) Semi-Structured, face-to-face interviews and (3) Observations. Our main source of information was collected through the interviews and the documentation and observations assisted us in triangulation of the data and to support any claims made by the participants, where deemed necessary (Miles and Huberman, 1994).

Documentation

Data collection began by going through existing 'internal' and 'external' sources (Forbes and Kirsch 2011) such as documents, existing interviews, archival data, online articles, company websites, reports, books, videos etc. It was necessary to gather as much information available to determine whether there were enough sources available. Most of the archival data was collected from the Wohler Associates webpage where the owner Terry Wohler had provided information regarding 3D printing from his own personal account. The archives dated from 2003- 2017 and around 180 documents were collected for analysis. Through this, enough information was gathered that allowed one to understand and identify the key actors that were involved in the industry from the beginning. This process of instrumentation gave some direction and clarification regarding what kind of data was needed, from whom it can be extracted and what kind of analysis will be required in the research process (Miles, Huberman and Saldaña 2014).

Observations

Field research was also part of the process (Forbes and Kirsch 2011) where 3D printing conferences and workshop such as the 'Maker Faire' in Rome, Italy the 'Inside3Dprinting' in New York and other local events organized by 3D printing startups were visited. The purpose was to get further information in terms of what special expressions were used (if any) by the people involved in the industry or if they had a specific language that they spoke amongst one another. Detailed notes were taken during the observation period, specifically, while meeting these individuals that assisted in recording their reactions and helped in forming the initial questions.

Interviews

The main source of data, however, was gathered through phenomenological semi-structured interviews from various actors belonging to the 3D printing industry . The objective was to understand the emergence of industries from an actor perspective which meant deriving theory from first person accounts (Gentles, Charles, Ploeg, and McKibbon 2015) while allowing the interviewer and/or the interviewee the flexibility to diverge their responses in more detail (Gill, Stewart, Treasure and Chadwick 2008). Such method generally leads to discovery of information that is important to participants but my not have been deemed pertinent by the researcher or research team. Through secondary research and observation, it was made sure that the interview questions were designed in such a way that they were clear and easy to understand to collect interpretable results (Patton 2015). It was also made sure that interview questions were flexible enough to cater to the type of individual that was being interviewed. For example, questions such as, 'When did you first hear about this technology?' 'How did you get involved in this industry?' 'Why is 3D printing term so dominant in your view?' This led to more probing questions and further gathering of information. Ethical issues were also part of the interviewing process where the participants were informed beforehand about the nature of the research and their permission was asked to record the interviews (Miles and Huberman 2014).

Sampling

Chosen sampling for this study was small and purposive (Gartner and Birley 2002; Marshall 1996; Miles and Huberman 2014; Pratt 2009) to "yield the most relevant and plentiful data" (Yin 2011, pp. 88) as well as to "obtain the broadest range of information and perspectives" (Kuzel 1992, pp. 37). Considering the pre-emergence phase of the industry and the actor perspective the sample of individuals was grounded on a certain criterion. This was based on how far back they went to the 3D printing technology as well as how well experienced they were in terms of their involvement with the industry. Based on the information collected from the secondary research a database of the prominent individuals that were part of the industry, was constructed. Out of those individuals, 2-3 main key players were shortlisted based on the degree of their experience, knowledge and role. Furthermore, a detailed study was done on the participants that were attending the 'Inside3Dprinting' conference in New York. This was done by going through their company profile and professional profile to determine whether they fit the criteria. Around 10 participants were shortlisted and were contacted through email prior to the event asking them for an interview. Some of the participants replied positively while few responded that they will not have enough time to give an interview. However, interviews with 4 participants were secured from the event. Further participants were gathered through different mediums such as direct emails, connecting through LinkedIn, Facebook groups, personal websites and through referrals. In total 15 participants were secured out of which 9 were male and 6 were female. Their profiles were a blend of different backgrounds that ranged from academics, engineers, journalist, designers, management orientated and self-employed. The purpose of choosing such a sample was to be able to allow as much as diversity possible however, this does not necessarily mean that they are the single representatives.

The interview process was based on an unscripted framework where the context and the type of participant was kept in mind. Furthermore, the interviews were an informal mode of conversation that lead to deep discussions and probing questions hence leading to two-way interactions (Yin

2011). Most of the interviews lasted between ranges of 30 to 60 to 90 minutes. In total, the number of hours of the interview was around 583 hours. Those that were part of the technology since the beginning (that is the 80s and 90s) took the longest duration since they were enthusiastic in providing more information. This required intense listening and to make sure that we heard and understood what they were trying to convey (Rubin and Rubin 1995) while simultaneously making mental and physical notes of further questions one can or may ask them. Some interviews took face to face, while some occurred through Skype and telephone. As participants were from UK, USA and Europe most mediums of interview took place through Skype/Telephone. All interviews were recorded with the consent of the interviewees and they were transcribed respectively. Table 1 provides information of the participants.

Table.1: Participant Data

Participant	Occupation	Gender	Background	Organization
AB	Owner/Inventor	M	Engineer/Academic (Retired)	RepRap
CO	Additive Manufacturing Engineer	F	Engineer	LAI International
CL	CMO/CEO (former)	F	Marketing &Sales Professional	3D Systems/ Desktop Factory
CP	Self-Employed/Sculptor/Product Designer	M	Designer	Pardell
DG	VP Business Development	M	Engineer	3D Hubs
DL	Chief Investment Officer	M	Investment Advisor	3D Tech Plus
HC	CEO/VP	F	Engineer	Stratonics
JM	3D Printing Historian/Physicist	M	Engineer	Layer Grown Model L.L.C
MN	President	M	Management	Fabrisonic
MV	Founder/CEO	M	Engineer	3Degrees
NT	Founder/General Manager	F	Management	Women in 3D Printing/Sculpteo
RG	Creative Director/Experiential Technologist	M	Designer	Son.Im
SG	Editor in Chief	F	Journalist	3D Print.com
SC	Owner/Inventor	M	Engineer	Stratasys
SH	Owner	F	Fashion Designer	Heisel

Data Analysis

The interviews were transcribed and then entered in NVivo (qualitative software) (Strauss and Corbin 1990). A quick analysis was done by reading through the interviews and developing various nodes (Bazeley and Jackson 2013). Specific quotes were then highlighted from the interviews and entered in the respective nodes that fit well with them. For a deeper and thorough analysis, each interview was read and prescribed through a line by line open coding method (Strauss and Corbin

[1] A more detailed description of the 3D printing Industry can be found in the Supplementary Appendix.

Findings

After coding, similar concepts were then grouped into specific categories. Following the Gioia methodology several first order codes were developed by reading the interviews. Then second order themes from the codes were derived which then lead to the development of aggregate dimensions. This formed a data structure as shown in figure 1. (Gioia Corley and Hamilton 2013) . The findings are discussed further.

First Order Codes

In the initial reading of the transcription, several first-order (informant) terms were identified (Van Mannen 1979). These were followed with descriptive accounts as it allowed unpacking the content and nature of the theme. It led to detection of content, allowed refined categorization and assigning of the descriptive data to these categories followed by classification where groups of categories are given classes at a higher abstract level (Ritchie, Spencer and O'Conner 2003) that is leading to second order themes. Figure 1 shows the descriptive content in the first column labeled first order codes. For validity and reliability, the information that was being provided by the respondents was triangulated (Baxter and Jack 2008; Golafshani 2003; Patton 2015). For example, when asked one participant when he/she heard about the technology, the participant mentioned that he/she read it in a magazine published in 1974. The source of the magazine was cross checked. This was done consistently wherever there was a need. Once the categories were classified, it went on with the second order themes.

Second Order Themes

The identified themes were given specific labels as seen in the second column of figure 1. According to Gioia et al (2013) these emerging themes may help in describing and explaining the phenomena being observed. More importantly it provides space to focus and examine the emergence of new themes. Assuming entrepreneurial agency (Goss and Sadler-Smith 2018), exploring different actor typologies, their perceptions, functions, and types of involvement.

Actor Typologies

Actor typologies help to understand who has been playing fundamental roles in achieving collective goals (McCarth and Zald 1987). Most of the participants were engineers, who were also inventors of the technology itself, while some were those that had non-scientific backgrounds such as designers, academics, researchers, managers etc. Engineers had an obvious interest in the technology because of their background but it was interesting to find other actors of different backgrounds interested in the technology as well. In SM, diverse group of actors connect with one another since they are working towards similar goals but why the 3D printing actors connected with one another having diverse backgrounds? The participants were asked when it was the first time they heard about this technology? This allowed a deeper insight into how they became involved with this technology. Most of the respondents got to know about the technology through different mediums such as magazines, videos, YouTube, word of mouth, through academia, jewellery exhibitions and maker faire's. Some however, got into it by accident when they were looking for a job or while they were already working in a company that introduced them to the technology:

'Well 3D printing the first time I heard about it was in like 89 or 91 when I saw some demonstration of the potential for the technology. But you know it was pretty coarse and it was ridiculously expensive'.-CP

Most of the actors did not came into the industry with a pure entrepreneurial objective. They were mostly involved in it either as researchers, inventors, hobbyists, designers or engineers whom out of some later integrated the technology as part of their companies or started their own entrepreneurial initiative(s):

"I am more of an academic than an entrepreneur really. I am not sure I am a very good business person. I'm pleased to say our company makes profits but I wouldn't really think of myself as being an entrepreneur."-AB.

The participants showed similar behavior in the way they identified themselves to the industry or the technology itself. This also correlated with the initial observation which were made during the data collection phase when various 3D printing individuals were visited at the Maker Faire in Rome. This was observed while asking them to introduce themselves or through asking questions. Some were quick in identifying themselves as initiators/ protagonists while some were humbler about it. For most of them, it gave a sense of recognition and a sense of being an influential part of the industry. What can be deduced from these findings is that though these participants had different backgrounds they had one thing in common and that was '3D printing' and their objective to be a part of this industry and to see it progress further, something that is similar in a SM setting as participants within a movement are working towards the same goals.

Views/ Perception

The actors' perceptions, and thus, how they see the environment is instrumental for the potential development of a movement identity (Eyerman and Jamison 1991). Therefore, we explore the actor's perspectives (Rao et al., 2008) Though the participants were diverse they shared a similar interest in 3D printing. However, there were also some varying views and perceptions of the participants specifically regarding the application of the 3D printing technology in terms of it replacing manufacturing. Most respondents believed that while 3D printing was initially thought to replace manufacturing, realistically it is not possible:

"*I never believed it would replace manufacturing, in certain industries it won't touch manufacturing. My father was a tool and dyeing engineer and they would spit out a hundred thousand products in a minute…just boom boom…3D printing will never replace that"-DL.*

3D printing could act as a technology that aids manufacturing, but it cannot replace manufacturing completely. However, other respondents were more optimistic and believed that 3D printing would outnumber traditional manufacturing to a certain extent:

"So, we will have machines who can take printing electronic chips as oppose to the conventional process for making electronic chips which will eventually end. Umm and we will have machines building large engineering structures, umm components for large engineering structures at least."-AB.

Almost all the participants believed that 3D printing was an industry except one who claimed that he/she viewed 3D printing as a technology that assists other industries:

“I would comment that I don't look at 3D printing as an industry. I look at it as a set a set of technologies”-CL

Despite having different views and perception all the actors were still involved in the industry and shared similar interests to a great extent. This highlights another important component that is parallel with SM theory where participants despite having different views come together because they share similar goals.

All 15 participants agreed that 3D printing was an industry (technology) that had tremendous growth opportunities. They believed that the industry could grow further by acting as a complementary technology in industries such as aerospace and healthcare and that entrepreneurs will push the industry forward:

“I think a lot of the complementary technologies will continue to evolve and push the boundaries of it and the entrepreneurs of the world will continue to push the boundaries and how we're going to use it. So definitely.”-CO.

Actor Functions

Actors need to mobilize resources for collective actions and the functions of actors that participate in promoting an industry needs to be investigated (McCarthy and Zald 1987). Davis and Thompson (1994) state that actors portray their shared interests into a collective action. Group formations around interests of a set of actors are governed by certain feature that define the interests, i.e., small in number, shared, and/or readily recognized. Whist interviewing the participants, a certain pattern was noticed where the actors were sort of performing complementary functions. In simpler words one or more actors were assisting one or more other actors either through becoming their voice or by creating a certain platform that allowed other actors to come together:

“*So instead of letting the then CEO and the founder hide behind the curtain back in headquarters. I made him get out and talk about what they were doing, and I got them on to the podium and I got him to speak and that was not easy because these guys were more technologist than and they were speakers. Scott Crump is just like that. He's very intelligent and insightful but he's not a great speaker. So, you had to really work with them, but I think ultimately we, you know the reason I joined was to help get that message out and go get new users and to create case studies and that was a tough part”-CL.*

This showed that some actors had a more complementary role in which they tried to push other actors forward. By doing so these helped the actors to reach out other actors and hence create more knowledge and awareness about 3D printing. Furthermore, one participant recognized that there was a certain gender gap within the industry and a lot of actors specifically female actors were missing from the industry. Hence, she started to build an all women 3D printing platform called “Women in 3D printing” that not only encouraged female participants but also pushed other organizations and actors belonging to the 3D printing industry to become a part of this community. It kind of formed a movement organization that created awareness of the existence of female participants and initiated functions and roles of females in the industry:

“Yeah I have to say NT has done a fabulous job. I mean it wasn’t that long ago I met her at a conference and she is like I am starting to put this little group together and I am like okay and now I see all that she is doing and wow and so she has told you know if you need a resource right, of women in Additive and boy she has got a primo list”-HC.

This also highlights a SM pattern where actors are coming together and forming collations by meeting in conferences and meetups and hence forming a movement type pattern.

Elements of Actor Participation

Participation is an important element in SM since without participants a movement cannot thrive (Weber and King 2014). However, participation might be only temporal and drop-outs might happen (McCarthy and Zald, 1987). Most of the actors that were interviewed had been in the industry for long but what was also observed was that some of them had a more temporal relationship with the industry. By temporal it is meant that though the participant were involved in the industry, at some moment in time, they had decided to either leave the industry completely or partially. There were several reasons that came up as to why the actors made such a decision. These were divided under the labels of voluntary drop-out and involuntary drop-out. Within SM settings there is an assumption that every individual that participates has a certain threshold value that determines how many other participants must be there before that individual decides to participate (Granovetter 1978; Granovetter and Song 1983, 1986). However, Sandell (1999) tries to extend this knowledge by examining interpersonal influences that leads to drop-out behavior by participants. In other words, even in SMs there exists temporal behaviors from participants which means that participants may drop out from the movement at any given time. The reasons in SM theory regarding drop out varies however, in this study the focus will be on the reasons that were discovered while interviewing the participants. Firstly, under voluntary drop-out, there were reasons such as moving on and finding other opportunities, problem of availability, less resources and time. However, age may have played a role as well:

‘Now I happen to be an older individual, so I'm 66, so whatever my next decision is and I will probably make something in the next 3 to 4 months, it's going to be more about helping people understand the value of the Technologies or helping people achieve their greatest potential because I've had an amazing career and that might be more meaningful than just focusing on a single technology’-CL.

Involuntary dropouts occurred when actors were forced by law or by change in perceptions and values. One respondent gave a detailed account of forced drop out. For example, the founder of the Model Maker, Roy Sanders was legally sued by Solidscape (3D printing company) based on patent infringement[1]. Another involuntary drop-out that was discovered was the difference of opinion that had formed between two founders, Bre Pettis and Zach Hoeken, who had started the company MakerBot. The company originated on the principal value of keeping it open source however, Bre Pettis decided it was time to make the company closed sourced which went against the values of Zach Hoeken who believed in keeping it open-sourced. Hence, Zach Hoeken eventually had to drop-out of the company forcefully:

'In 2009, I invited my friends Adam Mayer and Bre Pettis to go into business with me building 3D printers. Thus, MakerBot Industries was born. Fast forward to April 2012 when I was forced out of the very same company. I do not support any move that restricts the open nature of the MakerBot hardware, electronics, software, firmware, or other open projects. MakerBot was built on a foundation of open hardware projects such as RepRap and Arduino, as well as using many open software projects for development of our own software. I remain a staunch supporter of the open source movement, and I believe the ideals and goals of Open Source Hardware remain true. I have never wavered from this stance, and I hope that I never do. Future me, beware.'-(Hoeken 2012)

The drop out did, however, not only concern just a single firm or an individual but a whole subgroup within the 3DP movement. For many, the 3DP technology was next open technology, so many technology interested individuals had chosen 3DP over other technology because it was going to be open. Makerbot's move was a strong signal that the future would be different and many disappointed dropped out. What was observed from the responses and behavior of these actors was that participation in the emergence of an industry can be on a temporary basis. The choice of leaving an industry may be dependent on many factors such as personal motivations, differences in opinions and/or forced drop-out.

Knowledge Dissemination

Knowledge sharing and dissemination are critical to create opportunities for effective collective action (Tarrow 1998). The 3D printing industry was a very quiet affair from the start and it only started gaining recognition as an industry when it started coming into the limelight:

"3D printing was held back for a long time because it was so tightly controlled by a few companies and their patents."-SH.

During the data collection period it was understood that the open source movement had a significant role in the 3D printing industry that allowed the technology to be more accessible. However, open sourcing of the technology only started in 2005 when RepRap was developed. It was important to identify how diffusion of knowledge took place which allowed the industry to gain traction. The senior participants mentioned that they were unaware of the existence of other companies because they were all specializing in one specific form of 3D printing technology. It was only during conferences that they were able to gain knowledge of the existence of other companies that were working on 3D printing as well. Here it is important to mention that through secondary data collection important archival information was collected from the personal blog of Terry Wohler of Wohler Associates. Through this archival data and response from the it was identified that most of the conferences, where 3D printing was mentioned, were mostly engineering conferences. This highlights the fact that 3D printing at that time was not considered as a separate industry and was mentioned more as a technology, used by different industries, in engineering conferences:

"I attended COFES2003 last week in Scottsdale, Arizona. (COFES is The Congress of the Future of Engineering Software.) I sat in on an architectural/engineering/construction industry session that debated the pros and cons of designing and communicating in 2D versus 3D. It became clear that the A/E/C industry has not progressed much in its transition from 2D to 3D over the past several years, compared to manufacturing"-(Wohler 2003).

Though conferences related to 3D printing started emerging they were still accessible and known to only a few actors that were using the technology. Here is where open source played its part in spreading the knowledge to the masses. As mentioned before open source was an important element in making 3D printing accessible and most of the credit goes to the academic researcher who developed RepRap, a self-replicating machine:

"When I started the RepRap project, I decided to make it open source and give all the software, all the 3D cat designs everything you needed to make a machine all the documentation. I decided to give that all away for no cost and no royalties."-AB.

By making it open source 3D printing technology became less costly and more accessible:

"*Yeah I think the open source piece was very critical to the success. It's really tough to say what would have happened without it but I mean the industry basically sat idle for so long and then the open-source aspect help kick-start it and bring it to the limelight and most average users they maybe don't even realize that it the technology 3D printing has been out there for such a while."-DG*

Though most participants agreed that open source was essential for making 3D printing more prominent they also mentioned how it got overhyped which made the industry lose its focus:

"*The hype was ultimately quite damaging because the technology presented at the time couldn't live up to what people were saying and increasingly now more premises are being met much more is possible but people don't take it seriously because they don't see a purpose before and the technology just wasn't there yet and it's still not there yet to a great extent.'-SG.*

The respondent believed that the hype was fueled mostly by media outlets, presidential speeches, movies, and articles etc. which although brought positivity to the industry but there were also some negative impacts as well. However, they also mentioned how they were happy that the hype cycle had died now which meant the 3D printing could be more focused now:

'I'm actually quite happy that the hype has died down. I think it will be a lot easier as there aren't any expectations. But long term there is the growth of industry there. There are a lot of incredible things that you can do, that you can't do any other way.'-MV.

It is worth mentioning that one of the positive effects of the open sourcing and hype was the entry of entrepreneurial actors. Once RepRap came into the market entrepreneurs like Bre Pettis and Zach Hoeken started working on the technology. Individuals with entrepreneurial initiatives started meeting in places such as hackerspaces and Fablabs to use the technology and start their own startups.

The participants were further asked about what their views were on the entrepreneurs, who on the onset of the hype, started opening their own 3D printing startups. Most of them believed that entrepreneurs were a driving factor that had pushed the industry forward:

"I think that the entrepreneurial role in additive is probably similar to that of a lot of other technologies in that they are going to be the ones that are going to push the limits and they're going to be the ones that are going to drive the creativity. So, I think that it's very similar you know it's going to continue to be pushed outside the box and see what we can see what we can do with the technology. I think that those startup have most entrepreneurial like ideas have already really influenced a lot of the new things that we can do and when you pair the entrepreneurial spirit with the background and the funding and the research that these big organizations want to do that's where you're actually going to get substantial progress.'-CO.

What can be deduced from the responses is that entrepreneurs play a vital role in bringing the industry forward but also through the collective efforts with other actors, organizations etc. However, a few stated that the though entrepreneurs did push the industry forward being less knowledgeable caused more problems:

"*A lot of the entrepreneurs coming into it really don't know much about the history nor much about the technology. They were actually seen as causes of some problems, because it started giving the industry bad name because they come in with poor quality and poor engineering. That's not to say that's true to a point because there are some very good innovators out there, but I think 7 out of 10 entering it are causing more problems in the industry rather than solving problems."-MV*

The outcome from these responses demonstrated that entrepreneurs were indeed involved in bringing the industry forward, but it also meant that they needed to be equipped with certain knowledge and resources that made them capable enough to create more innovative products and services with the technology.

Community Building

Community building is an essential precondition for promoting effective collective action (Welter 2011; Weber and King 2014). While the open source led to more dissemination of knowledge it meant more doors opened for more collaborations and engagements between different actors and organizations such as academia, which also fostered community building:

"*I know that if we had gone alone and no one else was there for let's say 20 years...I don't think we would had grown anywhere near as fast because we were getting people to invest in new idea, new technologies, new markets, new customers that didn't exist, new profits that never existed.*"*-SC.*

Some participants mentioned the importance of collaborations and community building within schools and universities while some emphasized how the 3D printing was an ecosystem that was helping in development and sharing of strategies and practices. They unanimously agreed that 3D printing industry was very collaborative, and this led to sharing of resources such as funds, knowledge etc. enabling the growth of the industry.

A very interesting outlook was from the female perspective. As mentioned in the previous theme, actors played complementary roles and in 3D printing industry a prominent example is the organization called "Women in 3D printing". The person behind the organization believed that it was essential to bring forward the women in 3D printing to bring more diversity in the industry:

" I really truly think that the next big change in the 3d printing comes from different backgrounds and we have to share this. And this is really how the idea of the blog started. The idea was to share the background of the women in the 3D industry."-NT.

Aggregate Dimensions

From these themes three aggregate dimensions, "Social Movement Composition", "Temporal Engagement" and "Coalition Development" were identified (see column 3 of Figure 1). The first three themes showed a diverse set of actors pursing similar goals for 3D Printing coming together and acting as complementors hence creating a SM composition. The fourth theme highlights the participants motivation to be part of an industry, hence creating temporal engagement. The last three reveal further strengthening of ties and networks between actors, communities and organizations that led towards development of coalitions. This formed the complete data structure as shown in figure 1, which is an important component that demonstrates the detailed and rigorous analytical phase of qualitative research.

[1] https://www.solidscape.com/news/solidscape-sues-sanders-design-international-its-founder-royden-sanders-and-its-president-albin-hastbacka/16

Discussion

The purpose of this study was to better understand the emergence of an industry, in this case the 3D printing industry, with the focus on the pre-emergence phase. Our analysis of the pre-emergence phase of the 3D printing industry suggests that process of industry emergence goes through three initial phases: social movement composition, temporal engagement and industry foundation: they form our aggregate dimensions. All three phases can be related to the idea of redundancy. In the following section, we will discuss how our findings contribute to the industry emergence literature and generate propositions.

Diversity and movement formation

First, we derived social movement composition based on the actor typologies, views and the roles they played which, displayed the actors as part of a social process, like SMs, where they all had mutual interests and despite having different views were willing to engage with one another. Whilst these findings explain the components of the SM process, what isn't apparent is how this movement actually takes off? To understand this, we need to explore the reasons behind how the movement is formed with these diverse actors. Actors primary goals play a relevant role. We could speak of the specific objective of the participants and the meta-objective that forms the SM. Entrepreneurs are interested in creating their firms and industries (Swaminathan and Wade 2001), some stakeholders in the entrepreneurial ecosystems favor startups to create industries (Spigel 2017). However, other actors might have other primary goals. i.e. an engineer in materials to adapt 3DP to different materials for the sake of scientific knowledge. Thus, actors are willing to participate in a given movement if the movement is functional to their primary goals. To fit the primary goals, there needs to be a meta-goal (or even more meta-goals) that is large enough to gather diverse groups of people (Klandermans and Oegema 1987). An important group of supporters at the beginning were individuals interested in open source and they saw 3D printing as the next open technology. Their primary goal was open technology. Women in tech jumped also on 3D printing because they saw it as an opportunity to increase the weight of woman in technology in general, forming user communities (de Jong and de Bruijn 2013) Others used 3D printing as a means for challenging the law, especially those on strict IP appropriability. The famous case of the non-profit organization 'Defense Distributed' that tried to diffuse blueprints of fully 3D printable guns, challenged the State (Barnett, 2013). Obviously, there were a core group of initial actors which primary interest was the specific technology. They started to engage with others who had similar goalsand hence a movement started forming (Earl 2017). However, different actors with different primary goals form the movement and therefore sustain the initial core group, hence, forming a *collective good* (Klanderman 1997). Even, if primary goals might differ, all saw enough potential in 3D printing to serve as a vehicle for the goals, so that the development of 3DP was a sufficient meta-goal to accommodate for a variety of interests. Hence, this leads to the following proposition:

Proposition 1: The probability of industry emergence increases with its inherent meta-objective that allows to align the primary goals of a variety of sub-groups and actors and therefore to increase the number of participants of the movement.

Proposition 1 would also indicate that very narrow technologies with a limited set of applications would be less likely to emerge as a new industry even if there might be a more solid core group of technology specialists, as they create insufficient levels of redundancy.

Meta Objectives within movement participation

Second, and following our first proposition, temporal engagement has a key role for understanding industry emergence. So, if meta-goals help to gather more groups with varying primary interests, industry emergence depends on the number of actors joining the movement and if they stay effectively long enough with the movement. According to Jasper (2004) the goals of the actor (participant) may become more salient as the chance of obtaining it becomes higher. On the other hand the same goal may fade away when faced with adverse circumstances . The two questions depend on other alternatives to serve primary goals of subgroups and the persistence of the meta-goals. Our findings show that actors during the emergence process faced voluntary and/or involuntary dropouts. Movements are in competition for resources such as governmental funds for research, interests of investors, etc. To have a relevant impact, movement size is critical (Johnson, 2008): it concerns both the attraction and retention of actors for a useful time span . If there are less actors participating, then the movement may be too small to enable industry emergence. In the case of 3D printing industry the actor participation was diversified, and the number of participants grew with time which led to the growth of the movement. MakerBot is an emblematic case when one of the co-founders decided to switch from an open source approach to a proprietary system (Barnett, 2014). Not only did other co-founders leave the firm but also all those actors who believed in open source began to leave the movement (Brown 2012) putting a real threat to industry emergence. So basically, just as movement size is decisive for the growth of any SM (Van Dyke and Amos 2016) it is also decisive for industry emergence; however, that also means that it is not the absolute number of people dedicated to a given industry or technology but the total number of people that can somehow ascribe to the meta-goals of an industry. Ironically, industry emergence is more likely, the more the people join the movement that are not necessarily interested in the emergence of a specific industry and that these people stay long enough within the movement. Therefore, the open source community, women in tech community etc. are critical in pre-emergence phases.

We may see temporal engagement as a "bandwagon effect" or "domino" effect i.e. being part of a movement due to social influences. According to Granovetter (1978) different individuals have different levels of thresholds which explain why collective action can happen despite general unfavorable preferences and how it causes a bandwagon effect. For example, some individuals may have higher thresholds while some may have lower thresholds. Those with higher thresholds may be seen as protagonists /leaders that have highly specific goals while those with lower thresholds may be seen as sympathizers/bystanders with less specific but coherent goals. Within the movement, the higher threshold actors will attract other actors that may have lower thresholds which creates a bandwagon effect. This also means that concentrically over time, people might join the movement despite having less interest in the specific initial goal. For instance, after the entry of woman in tech, actually gay groups became interested in the use of 3DP technology, such as the gay group on the Thingiverse 3D printing forum. This leads to our second proposition.

Proposition 2: Industry emergence is dependent on the relative degree of actor diversification and participation attracted by the movements' meta-objectives. The more diversified and the greater participation of actors, the higher the initial growth of the movement. The size will attract necessary resources to realize the specific goals, thus the length and timing of temporal engagement of subgroups of a movement determine the likelihood of emergence of industries.

From proposition 2 derives an important insight also for entrepreneurial ecosystems. Entrepreneurial ecosystems need to attract and mobilise public and private resources for their development (Spigel and Harrison 2017). Assuming limited resources, alternative allocation opportunities for these resources and therefore competition, movement size will influence the probability of the development of entrepreneurial ecosystems.

Availability Hypothesis and degree of participation

Our findings suggest that collective action was a process that first started from actors connecting with one another. This led to spreading of knowledge and awareness which also led towards more research into the technology. Subsequently, sub-groups also started joining the collective action because of alignment with meta-objective. The information spread to the masses once open source was implemented on 3D printing technology (For example, The MakerBot). It became more accessible and less costly thereby creating a hype that brought in a flux of different actors, institutions, organizations, communities etc. This provided opportunities for entrepreneurs who were interested in the technology and had innovative ideas to launch new products and services. Some early entrepreneurs may be identified as user entrepreneurs who were familiar with the technology and through a collective process were able to bring forward an innovative product/service (Shah and Tripsas 2007).

However, if temporal engagement of actors is a function of the primary interest and meta-goals of a movement, it is important to understand what other factors make actors stay in a movement to allow industry emergence. As already discussed, it is the question of primary goals and alternative options. SM theory offers also another explanation in the so-called availability hypothesis. The availability hypothesis states that the degree of participation in a movement is dependent on the requirements of the movement in terms of resources including time and the availability of actors to dedicate these resources to the movement (McAdam 1986) . In the case of industry emergence, there might be moment of infrequent and less regular collective action, which allows more people to participate (in SM, we could think of occasional protest walks); however, with increasing resource mobilization (Jenkins 1983), the collective action becomes more continuous (e.g. continuous protest marches), requiring more and more dedication of resources (e.g. one-month occupation of a house). As a consequence, those loosely coupled groups need to evaluate the value of participation against the cost, or simply they will not be able to always be available. A professor at the university might be able to present at a few events to give support but not present continuously on a technology roadshow.

The concept of opportunity costs within entrepreneurship states that entrepreneurs are likely to take over entrepreneurial activates when the opportunity costs are lower than the value of the opportunity itself (Amit, Muller and Cockburn 1995). The same argument was also made for user entrepreneurship (Shah and Tripsas 2007), especially for products related to babies and toddlers that were often created by parent user entrepreneurs during their parenting time. However, availability hypothesis (McAdam 1986) extends this concept by making it more general. In the mentioned case, these parents were available for a given time but also constrained in their total ability. In case of industry emergence, actors having a lower opportunity cost will stick to the movement generally longer than those actors that have higher opportunity costs. Therefore, it is more likely that people with high opportunity costs need to exhibit at the same time high risk-taking propensity in order to continue substantial support. We could think of a researcher that calls in sick at work to make him or her-self available to a movement (the researcher would have high opportunity costs but take risks). This in turn would also means that the probability is generally high that movements' protagonists are made of a high proportion of outsiders. Outsiders how are often considered as a source of radical innovation (Ferriani, Garnsey and Probert 2008) and their lack of constraints (work, family, reputation) makes them highly available to demanding movements.

This leads to the following proposition:

Proposition 3: Industry emergence is dependent on actors availability or willingness to take risks, thereby growing the movement followed by their commitment through the subsequent stages.

Conditions for industry emergence

To summarize, the identification of the aggregate dimension lead to the development of an industry emergence process model as shown in figure 2. A dynamic relationship between the aggregate dimensions that were established in column 3 of figure 1 is represented in the model. All three are important elements in the process of industry emergence. These three influences act on different levels and phases within the pre-emergence phase. The participation of highly diverse actors is related to the movements size, the question how long participants stay with the movement is related to the successful shift in resource allocation and the number of sufficient available actors on the final emergence of the industry through people that are dedicated to the specific case of firm foundation and favoring industry emergence. So redundancy, an oversupply of participants plays a role in industry emergence. This leads to the following proposition:

Proposition 4: The existence of meta-goals of a movement (influencing the movements size), the sufficient temporal engagement (assuring the attraction of necessary resources) and a sufficient number of available actors (for the realization of the specific objectives) are necessary conditions for industry emergence.

In proposition 4, we argue that a way larger and diverse community of available actors with non-permanent engagement finally create the favorable circumstances that allow a much smaller initial set of entrepreneurs to emerge and create new firms that will set the stage for further industry emergence and evolution.

Contributions and Limitations

The contributions of this study show an effort to understand industry emergence from the pre-emergence phase through an actor perspective with the aid of SMs . The implications that can be derived from this study are not only limited to understanding industry emergence but also shifts the focus from the individual entrepreneurial hero to the community, or to the efforts of many other individuals (Garud and Karnøe 2003). This study explains that industry emergence is a social process that does not emerge overnight, and social aspects are determinant in the growth of the industry where the concept of collective action cannot be disregarded. The notion that industries are created by entrepreneurs only explains half of the story which is more like the second half of the movie after the intermission. Scholars such as (Sine and Lee 2009; Schoonhoven and Romanelli 2001) themselves place importance on the amalgamation of collective action within the study of entrepreneurship. This study recognizes that collectivity between different actors is an integral part of the emergence process. Furthermore, it emphasizes that diversification of actors, coupled with their meta-objectives, and their availability of taking risks are essential factors that not only keep the movement alive but also pushes the industry forward. So, basically the movement builds a community that affects how resources are mobilized and how entrepreneurial opportunities start to emerge thereby allowing user entrepreneurs to create new and innovative firms leading towards a new industry. We have also tried to give an overview of how SM effects evolve as the industry grows (Carlos et al 2014) , but since the 3DPI is still emerging , it should be acknowledged that this isn't definitive and the effects will change with the growth of the industry.

Theoretical Implications

From a theoretical perspective, the implication of this study shows how SMs can be used as a tool to understand the process of industry emergence. It highlights the use of interdisciplinary research arenas within entrepreneurial studies that enables theorizing at a deeper level. Furthermore, it identifies the importance of actor centric studies that can help in understanding complex phenomenon such as industry emergence as well as how entrepreneurship theories can further develop. Furthermore, by using qualitative methods we were better able to understand the complexity of the emergence process which is somehow unexplained in the literature regarding industry emergence and entrepreneurship. It was critical to focus on actors for understanding what role they play and how they impact the industry emergence process and also to determine where, when and how exactly entrepreneurial actors bring the industry forward. By doing so, we provide greater depth and understanding of the industry emergence process from an actor and entrepreneurial perspective.

There are two main contribution to theory. First, industry emergence literature is also somewhat goal centric. As it focuses on technology driven entrepreneurs, the use of the technology is one of the primary goals for setting up the firms. We show that the technology might be a vehicle for a variety of primary goals that do not necessarily need the specific technology to reach the primary goal nor lead to new venture creation. Second, we extend the concept of opportunity to cost under the more general concept of availability (McAdam 1986), which might also better explain why people with similar opportunity costs (but differing risk propensity) might make themselves available. It can also explain, why people with differing opportunity levels and especially people with higher opportunity costs might initially engage in entrepreneurship (because they are more available).

Managerial Implications

For policy makers, the research gives a direction that can enhance economic development initiatives. They can learn to make new strategies applicable in the creation of new industries. They need to understand that not one strategy can fit when it comes to understanding industry emergence. Specifically, with the advent of digital transformations, movement towards sustainability and circularity there is an utmost need for policymakers to devise new strategies and to understand the social processes involved.

Limitations

This study has its own set of limitations. First, our study was limited to a single, embedded case study where we chose the 3D printing industry. While this approach gives an in-depth inside, it reduces generalizability and conclusions can only be drawn from the case to the theory (Yin 2003). Considering that we wanted to understand the pre-emergence phase of an industry, the 3D printing industry provided us with a unique setting, as it is still in its emergence phase. Through this case we were able to draw conclusion from the rich data that we gathered thereby leading to theoretical propositions (Yin 2011). We were able to interview a diverse set of actors that allowed us to gather contrasting views and a sufficient representation of the industry. It is possible that the conditions that we have identified for the emergence of 3D printing industry are not generalisable to other industries. However, we think that SM emergence is an important factor that may play an important role in industry emergence and may be applicable over other industries as it emphasizes on coalition effects. Future research on multiple industries can provide a more holistic view and contribute towards a richer understanding of the industry emergence process. Given that this is the first step towards understanding industry emergence from a SM and actor perspective it was incumbent to have an in-depth case study to form the basis of a clear and rich context and we also think that it can lead towards future research in the form of multiple case studies and empirical studies

Future Research And Conclusion

There is a dearth in studies related to emerging industries, specifically in entrepreneurship studies, theoretically as well as empirically (Forbes and Kirsch 2011). Therefore, there is a need to address this gap and to produce more robust studies that can explain the phenomenon of industry emergence, specifically from the pre-emergence phase (Kirsch, Mooeen and Wadhwani 2014). Hence, in terms of future direction, this study can be implemented in different settings to get more alternative views and results regarding how SMs can assist in the creation of industries. Therefore, a multiple case study would be one way to examine more in detail the process and whether the effects are the same. Furthermore, due to digital innovation entrepreneurial ecosystems are also changing (Sussan and Acs 2017), which is effecting existing industries (e.g construction, transportation etc.) that are either being transformed into new industries or creating sub-industries. Therefore, applying a social movement approach to analyze how these new industries are being created is another research avenue. A rise of movements for a circular and sustainability economy is pushing industries, organizations, firms, and entrepreneurs to re-examine their business models (Oghazi and Mostaghel 2018). As these movements not only try to shift the allocation of to a new activity but actually try to transform the economic system, social movement theory might be an appropriate lens for studying this phenomenon. Furthermore, efforts should be made to collect empirical data relative to 3D printing industry to gain more robust results leading to more theoretical as well as empirical studies.

To conclude, the actor-based approach tries to lay a skeletal image of the process of industry emergence through a SM pattern. The objective is to shift the emphasis away from the entrepreneurial hero towards acknowledging that a socio-relational framework can be adopted in entrepreneurship studies. This study is a first step in this direction and could lead to further contributions to the entrepreneurship literature: not only for understanding industry emergence but also to make entrepreneurs, startups, firms, organizations and policy makers aware of the embeddedness of their actions in a wider system in order to generate necessary collective action.

List Of Abbreviations

3D = three dimensional

3DPI = three dimensional printing industry

SM = social movement

Declarations

Availability of data and materials

The datasets generated and analysed during the current study are not publicly available due to granted anonymity to the interviewees as typical in case study research but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Author's contributions

The authors were jointly involved in all phases of the research. The authors contributed equally to this manuscript.

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Figures

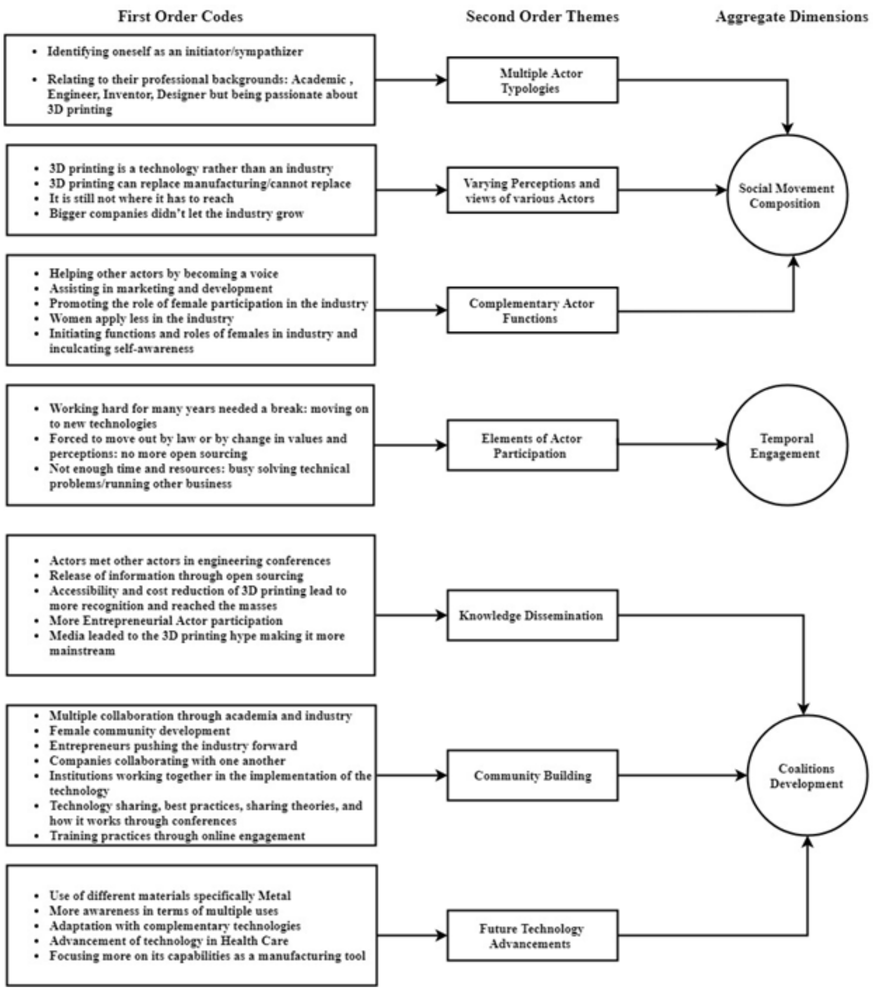

Figure 1

Data Structure

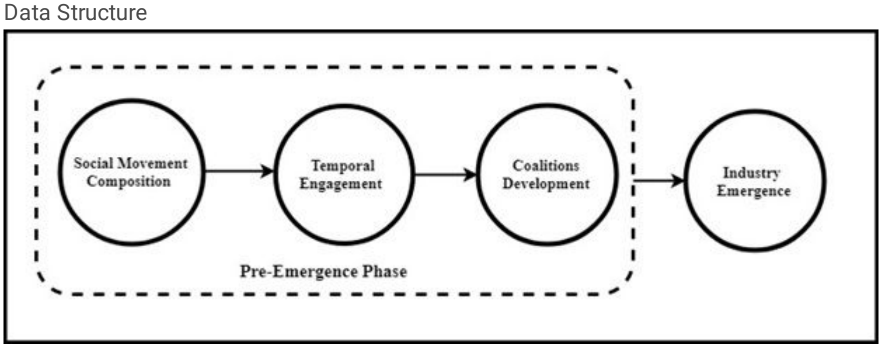

Figure 2

Process Model

Supplementary Files

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- SupplementaryAppendixJIERV1.pdf