How do Fab-spaces enable entrepreneurship? Case studies of "Makers" - entrepreneurs

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ABSTRACT

Fabrication spaces (fab-spaces), such as TechShops or FabLabs, provide access to sophisticated digital manufacturing technologies to individuals. They could be a new institutional context which influences entrepreneurial behaviour. To understand how this might happen, we used a grounded approach to examine the experience of 8 individuals who have benefitted from fab-spaces to push forward their entrepreneurial ventures. This examination led to the development of new hypotheses regarding the potential role of fab-spaces in the entrepreneurial journey. In particular, it has emerged that fab-spaces might affect the entry phase of a new venture by lowering the "perception of performance" threshold. Fab-spaces also affect post-entry barriers, as they provide an opportunity to entrepreneurs for fast learning, and consequently, to establish effective routines. However, this paper also shows how these positive effects might be moderated by fab-spaces' institutional setup, chiefly their location and cultural characteristics.

KEYWORDS:

FabLabs, Makespace, Hakerspaces, TechShops, fabrication spaces, Makers, Peer Production, 3D printing, additive manufacturing, barriers to entrepreneurship, crowdfunding, Knowledge Intensive Business Services, Incubators

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1. Introduction

In the last few years, the interest in the diffusion and democratization of manufacturing technologies, once mostly only accessible to engineers and designers, has risen significantly (Gershenfeld 2007). An important opportunity to access professional manufacturing technologies is represented by fabrication spaces (fab-spaces), such as Makerspace or FabLabs, where sophisticated manufacturing technologies are available to non-specialists. Fab-spaces provide individuals with access to numerous computer numerical control (CNC) and non-CNC equipment (including additive manufacturing), in order to carry out a variety of projects. Presently, Makerspaces, Hackerspaces, FabLabs and TechShops are amongst the most famous physical fab-spaces, which offer direct use of tools and machines, the chance to meet other like-minded and skilled people, and the opportunity to carry out creative projects. These environments are the cultural hot-bed for the "Maker Movement" (Anderson 2012) which advocates: knowledge sharing, experimentation with new technologies, and the exploration of cross-disciplinary projects motivated by enjoyment and personal achievement. To develop their ideas into products, users could also opt for web-based fab-spaces (Gavetti, Greve et al. 2012). These latter type of fab-spaces, rather than offering the direct use of machines, manufacture goods for the customers on the basis of designs submitted online and mail back the finished products. Their services often include online platforms on which individuals can share, sell and buy object designs (Troxler and Schweikert 2010).

As well as portraying the positive social implications of such creative environments, the media has been reporting numerous examples of products which were developed thanks to fab-spaces, and of new business launched as a result. One example is Oru Kayak (www.orukayak.com), a kayak which can be folded and unfolded in minutes so that it can be stored easily even in small apartments. An even more striking example is that of Makerbot

Industries, a producer of low-end additive manufacturing equipment for hobbyists and home users that grew out of a fab-space, NYC Resistor[1].

Whilst not all the users of fab-spaces are necessarily interested in starting an entrepreneurial venture (Moilanen 2012, Dougherty, Thomas et al. 2013), these environments and facilities seem to provide fertile ground for entrepreneurship (Aldrich 2014), and potentially could significantly reduce barriers for the individuals who, under the correct circumstances, might become entrepreneurs (Sarasvathy 2001, Sarasvathy 2004).

This paper is dedicated to analysing the effects fab-spaces may have on the "entrepreneurial journey". As little is yet known about these environments, we took a grounded approach (Glaser and Strauss 1967, Strauss and Corbin 1994) to researching their effects. We interviewed a sample of 8 entrepreneurs (theoretical sampling (Patton 1990)) and examined their accounts of their entrepreneurial venture and its relationships with fab-spaces. A simplified and linear venture creation process was used for analysing the accounts, which was derived merging the venture creation with the new product development processes. During this research we also evaluated how the frequentation and exploitation of the fab-spaces influenced the ventures, in particular in terms of reducing the entrepreneurial entry and post-entry barriers (Autio, Kenney et al. 2014).

The paper is structured as follows. In section 2, a literature review is used to derive an appropriate analytical framework for the study , which includes a usable entrepreneurial process (section 2.1), the associated key barriers (section 2.2) and the cultural influence of the context in which the process is immersed (section 2.3). The case study methodology itself is described in section 3. In section 4, results are presented highlighting the particular advantages and the limitations of fab-spaces, identified through the entrepreneurs' accounts.

[1] http://makezine.com/2013/05/22/the-difference-between-hackerspaces-makerspaces-TechShops-and-fablabs/

Finally, section 5 discusses the most significant implications of this work, and the implications for future research.

2. Literature

Fab-spaces are a new institutional context (Autio, Kenney et al. 2014, Zahra, Wright et al. 2014) which might influence "entrepreneurial action" (Aldrich 2014).

Several elements concur in supporting this argument. The competencies and resources provided by fab- spaces might increase the chances for individuals to innovate, by improving existing products or by developing totally new ones. This potential for user-driven innovation (Von Hippel 2005) might, in turn, lead to an increase in the number of individuals attempting to establish new ventures and becoming “accidental entrepreneurs” (Shah and Tripsas 2012). Furthermore, fab-spaces are seen as potential providers of manufacturing resources (Birtchnell and Urry 2013, Petrick and Simpson 2013), and hence could support individuals interested in producing, commercialising and propagating their innovation. Also, as the culture and influence of peers is known to affect entrepreneurs' conduct (Nanda and Sorensen 2010), the sharing culture which typifies fab-spaces (Moilanen 2012) might be expected to impact on individuals’ entrepreneurial behaviour.

However, not much is yet known about fab-spaces and about how entrepreneurs interact in this type of environment. In response to this gap, this paper takes an exploratory approach, and evaluates the experiences of a group of entrepreneurs in fab-spaces, to understand: How did fab-space influence entrepreneurs? What were the contributions and limitations of these spaces in support to the entrepreneurial action? At what stage of their entrepreneurial process did fab-spaces contribute the most?

As a background to the investigation, we define a generic model and phases of the entrepreneurial venture along which to establish the influence of fab-spaces (session 2.1).

Further, we draw out the expected barriers along the entrepreneurial process (session 2.2) and the expected cultural influences of fab-spaces (session 2.3).

2.1 Entrepreneurship, a three-stage process

A broad template for the entrepreneurial process was initially developed by Bruyat (1993) and later taken up by others (e.g. (Fayolle 2007)). It includes three stages: 1) The initiation of the entrepreneurial process; 2) The commitment to the venture; 3) The completion of the venture. However, there is not yet a clear view of a universal entrepreneurial process and how it deploys (Alvarez, Barney et al. 2013). For instance, scholars take two distinctive views about the starting point of the entrepreneurial activity. Some authors subscribe to the traditional economic view that entrepreneurs "discover" existing opportunities, which are provided by the asymmetries of the environment, by virtue of their own personal circumstances and characteristics. Other authors promote instead the idea that entrepreneurs "create" opportunities through their action (e.g. (Sarasvathy 2001, Alvarez, Barney et al. 2013, Aldrich and Yang 2014)). According to this second school of thought, a particular category of entrepreneurs can be distinguished from the rest, because they become entrepreneurs as a result of their user-innovation activities and their commitment to solving the problems they experience with products. After realising that there is support and demand for their innovations, these individuals might take the decision to start a new venture. This category is referred to as "user-" or "accidental" entrepreneurs, and their process has been highlighted by recent works (Shah and Tripsas 2007).

However, Shane and Venkataraman's definition of entrepreneurship is the "scholarly examination of how, by whom, and with what effects, opportunities to create future goods and services are discovered, evaluated, and exploited" (Shane 2000)(p. 219). This shows that the entrepreneurship concept is broad, and that different types of entrepreneurial operations such as production, innovation, start-ups, new ventures, corporate venture spin-outs and spin-

ins are included under the umbrella of this discipline (Woo, Cooper et al. 1991, Jennings, Greenwood et al. 2013).

Despite the various views about entrepreneurial typologies and processes, it is generally acknowledged that, as part of the process of venture creation, entrepreneurs need to look after the development (from ideation to production) of new product/service concepts. This phase of the venture creation process is differently interpreted, and made explicit, by entrepreneurship scholars. It is often not described, but only signposted as a necessary part of the venture creation process, for example in the work of scholars such as Bhave (1994), who refers to it as the "product and product development" phase, at the boundary between the "technology setup and organisation creation" and the "exchange" stages of venture creation. Others identify that, rather than being chronologically bound to a specific stage of venture creation, technology (products) and organizations often coevolve (Shah and Tripsas 2007, Brem 2011, Shah and Mody 2014).

In agreement with Brem (2011), we think that in the entrepreneurial path, often several processes overlap. One relates to innovation-new product development, to which a good amount of effort is devoted. The "Ideation, Conversion, Diffusion" process (Hansen and Birkinshaw 2007) is a classic template to describe this innovation activity within any firm (Brem 2011).

As fab-spaces are frequented by "Makers" (Anderson 2012), who are characterised by the desire to tinker and develop interesting projects, it is reasonable to assume that the entrepreneurs frequenting these spaces would be engaging in some form of innovation or product development activity. Following this logic, and given that we do not know in advance what particular type of entrepreneurial individuals we would meet, a simple three-

stage model is derived which attempts to coarsely describe the entrepreneurial process, merging the venture development with the new product development phases.

Stage 1: IDEATION and opportunity recognition. The individual finds an idea and understands its potential embedded commercial value. This stage includes the opportunity recognition (Shane and Venkataraman 2000, Ardichvili, Cardozo et al. 2003), and the problem solving phase of new product concept ideas (Shah and Tripsas 2007), which could be assimilated with new inventions (Utterback 1971) whose value is assessed (Brem 2007).

Stage 2: DEVELOPMENT and conversion. The individual develops his idea towards a product concept and tests its manufacturability and feasibility. The initial concepts or ideas need to be improved, developed and refined in order to achieve technically robust and manufacturable designs (Ries 2011). In this development process, several variations of the original ideas might be conceptualised and assessed, leading to the selection of a product design and a manufacturing process (Roper, Du et al. 2008). To this end, prototyping has been demonstrated to be particularly helpful (Mascitelli 2000) for the generation of variants of the original concept (Bogers and Horst 2014), the selection of the best ones (Hansen and Birkinshaw 2007), and of the best production technology (Bhave 1994).

Stage 3: PRODUCTION, DIFFUSION and commercialisation. Here, individuals work towards scale up to launch the production, and try to reach a market. To reach a market, entrepreneurs need to establish production capabilities, including a production supply chain (Bhave 1994; Hitt, Ireland et al. 2001), to "spread the new products, businesses, and practices across desirable geographic locations, channels, and customer groups" (Hansen and Birkinshaw 2007).

2.2 Barriers along the entrepreneurial process

Autio et al. (2014) propose to concentrate on two key levels when studying the effect of the context on the entrepreneurial-innovation ventures: entry and post-entry effects. Entry effects impact on the decisions to engage in entrepreneurial behaviour and continue to influence the strategic decisions of the entrepreneurs throughout their ventures. The factors deriving from the characteristics of the individual that self-selects to become an entrepreneur could be encompassed under this umbrella (e.g. their personal background and motivations). In this respect, Degeorge and Foylle argue that at this level both 'intention' and 'displacement' affect the start of the entrepreneurial process (2011).

Post-entry effects refer to the influencers which kick-in once the venture has started and will concern "the perceived desirability or feasibility associated with alternative entrepreneurial actions" (Autio, Kenney et al. 2014). When at the center of the new venture there is a new product to be developed, as expected in the case of entrepreneurs who interact with fab-spaces, these two types of barriers overlap with the obstacles to new product development or innovation. Hence, entrepreneurs will face "deterring" barriers which prevent the subjects from committing to innovation, and "revealed barriers", which concern the challenges met within the innovation process and can be overcome through learning, through direct and indirect experience (D'Este, Iammarino et al. 2012). For young and unestablished firms, amongst the deterring barriers, D'Este et al. (2012) recognize the lack of resources and capabilities, in both organizational and technological aspects (Katila and Shane 2005) as well as the unfavorable market structures (D'Este, Iammarino et al. 2012). Taking a Resource-Based View (Barney 2001), and its extension in the Knowledge- Based View, fab-spaces could be seen as providers of resources and competences. As for larger firms, a venture could be progressed via accessing different types of complementary resources through the relationship with other providers (Miotti and Sachwald 2003).

Fab-spaces could be an opportunity to access a number of professional-grade machineries to otherwise resource-constrained entrepreneurs and hence contribute to lower the deterring barriers. Further, as fab-spaces are attended by individuals with wide ranging backgrounds, they could hence also be providers of expertise (know-how and know-what) and might be useful in the identification of networks of other competence providers (know-who) which are known to aid the entrepreneurs at different stages along the venture path (Martinez and Aldrich 2011, Tidd 2014).

Further, entrepreneurs need to learn by going through a path of establishing, adapting and abandoning routines (Aldrich and Yang 2014). Hence, if fab-spaces will be demonstrated to be conducive to learning and developing appropriate routines, they could be seen as environments which lower the revealed barriers.

2.3 Interactions of entrepreneurs at fab-spaces

The cultural characteristics of the environment around entrepreneurs have been shown to influence the entrepreneurial journey, in that they provide the "[..] norms, values, legitimacy and justifications of worth that have consequences for supporting or discouraging entrepreneurial behaviour" (Thornton, D. et al. 2011). Fab-spaces are new environments and can be characterised by varying cultural norms (Moilanen 2012, Moilanen and Vadén 2013). Some fab-spaces originate from a particular socio-cultural context - rooted in the software "hacker" and "Open source" movements - which in some instances advocates for particular forms of economic and social transformations (Rigi 2013). How are these aspects of the context influencing the entrepreneurial behaviour/journey?

As a result of this literature analysis, the research framework in Fig. 1 could be derived and used as an exploratory lens.

3. Methodology

This research was conducted in 2013 (May - August), during a period when fab-spaces started to become more widespread. The work aimed to provide an initial view of how entrepreneurs interact with fab-spaces, and how in turn these support entrepreneurs in their process of developing and launching their products and ventures.

The aim was pursued via a holistic multiple-case design methodology (Yin 2009), based on grounded theory (Glaser and Strauss 1967, Strauss and Corbin 1994). This research design was deemed suitable because of the relatively little prior work available on this emerging phenomenon, and because it is particularly useful to link the significance of events in people's minds with the symbols they adopt to express those meanings (Glaser and Strauss 1967).

Data were captured through semi-structured interviews (see sample selection and data gathering in section 3.1). The literature review was performed to identify the area of investigation and a direction for the analysis of the data (see section 3.2 for the description of the data analysis approach).

3.1 The sample

Our sampling should be considered theoretical (Patton 1990), looking for pertinent and data-rich cases. Interviewees were sought in various locations (in the USA and Europe), amongst the people who used fab-spaces. We prioritized those who were using such spaces with the idea of pursuing new ventures and who were in advanced development or commercialization stages of their products. This focus enabled a more reliable account of the *realised* benefits of fab-spaces, rather than of projected benefits. Within these constraints, we attempted to gather a broad overview of perspectives, endeavouring to include a spectrum of entrepreneurial venture types. We included experiences from people whose business venture process seemed consistent with user-entrepreneurship processes, serial entrepreneurs and nascent

entrepreneurs, individuals who pursued a manufacturing venture, and those who attempted to establish themselves as artists and designers.

At the time of this research, we were aware that several models of fab-spaces had started to emerge. As there is still a limited knowledge about these organisations, and a definitive typology is still unavailable, we included interviews with individuals who had experience of different fab-spaces, in various locations, to attempt to encompass more variety.

To identify the case studies, an e-mail was sent to 20 fab-space managers in USA and Europe, asking them for the contact details of individuals who used, or were using, their fab-space to develop products for commercial purposes. A request for involvement was also posted directly in fab-spaces' mailing lists or discussion groups such as http://hackerspaces.org/wiki/ and http://wiki.fablab.is. Through this method, we identified 8 individuals who were available to discuss their experience of developing their venture, and their views of how fab-spaces supported them (see table 1).

A free-form interview protocol was used. However, to remind the interviewer of the breadth of information sought, a questionnaire was compiled (see the outline of questions in appendix 1), but not strictly enforced, to allow entrepreneurs as much freedom of expression as possible. The interviews lasted approximately 1 hour and were conducted telephonically. All interviews were tape-recorded and later transcribed verbatim[2]. The interviewee was firstly given a quick account of the research topic, and then was asked to talk freely about his/her experience and the role that the fab-space(s) played in their entrepreneurial process. When the interviewees naturally exhausted their flow, the interviewer asked further questions with the intention of teasing further the entrepreneurs' narratives. For instance, the interviewer asked

[2] The interviews in French were transcribed by a French-born researcher in English. The interviewees' comments in quotations are translations that attempt to capture the true nature and intonation of what was said in French

for clarification and for more details, attempting to cover the interaction with fab-spaces along the 3 stages defined in section 2.1 above (ideation, development and commercialization). This “life stories” or “narrative” method poses an emphasis on how interviewees express themselves and their identity by the references they make to past, present, and future actions and by the expressions they choose (Lieblich, Tuval-Mashiach et al. 1998).

We focused on specific part of interviewees’ lives rather than documenting whole life stories (Elliot 2005). Table 2, reports a brief account of each individual’s entrepreneurial journey, pertinent to their use of fab-spaces.

		Entrepreneur's Background	Fab-spaces used
A **Serial entrep.** **Social entrep.**	**USA**	After obtaining a business degree, A worked for few firms in Texas and then developed his own software business for a couple of years. Then "just got very tired of sitting in a cubicle and looking at a screen and decided [he] wanted to make things in the real world". He quitted his office job and developed his first venture. He then moved to California where "[he] now make[s] things as [his] primary job". He is developing a number of ventures, some with the intention to support farmers and local communities in Africa. His current idea - a social gardening assistant is a box which automatically regulates the soil moisture, the light and the temperature to keep food growing optimally. Moreover, it shares updates with the owners' virtual friends, letting them gain experience about how to best grow different plants.	Instructables TechShop
B **Designer entrep.** **Nascent entrep.**	**USA**	After a degree in art, B worked as a teacher for several years. He soon got tired of the job as he felt it did not provide enough time to pursue his own artistic projects. He wants to pursue a self-employed career developing artistic artefacts. He is currently working at a table lamp, with an oak, digitally cut, paper top.	Hackerspace
C **User entrep.** **Nascent** **entrep**	**USA**	With a degree in computer engineering, C works for a software company but has developed a personal interest for hardware and has the ambition to develop a small Wi-Fi-controlled flying gadget. He has not yet made plans for a fully-fledged business, but, having been successfully backed by crowdfunding, he wants to deliver on his pledge and consider how to scale up his business through further crowdfunding campaigns.	Hackerspace Shapeways TechShop
D	**FRA**	With a degree in political science, D has been bought out of his share in his previous successful business by one of his partners. With the amount received he is pursuing the development of a new business, based on a market need identified	Hackerspace

Serial entrep.		in his previous company: a prevention system for deterring merchandise theft. To do so he is upgrading the technology and product system and he is acquiring customers.	University-organised fab-space
E **Designer entrep.** **Nascent entrep.**	**USA**	With a design degree, E has the ambition of becoming recognized as a designer and of developing innovative products for the fashion industry. Her current idea concerns the sale of her jewelry range. She has been backed on by a crowdfunding community for this purpose.	TechShop
F **User entrep.** **Serial entrep.**	**USA**	With a degree in botany, F attempted a number of businesses, some of which more successful ("successfully sold") than others. This is a deliberate lifestyle choice: "I have been an entrepreneur for quite a long time, I do not think I ever- I rarely worked for someone else". He founded a supportive group of entrepreneurs who meet regularly. Identifying the benefits of working at a computer from a standing position, he decided to develop a special desk and to build a business around it.	TechShop
G **Nascent Entrep.**	**FRA**	G studied engineering. With a group of friends had the intention of starting an engineering business to develop agricultural robots after finishing the studies. An automatic agricultural robot is their business idea, defined after a market research with the local farmers. After initially being rejected by the local business incubator as their idea was still too weakly developed, they were eventually accepted after having developed the first working prototype with the support of the local FabLab community and having obtained funds through crowdfunding.	Fab Lab
H **User entrep.**	**USA**	With an engineering degree, working knowledge of batteries and a passion for outdoor sports, H decided that he wanted to develop a lightweight and compact lamp. After starting developing this idea in his spare time, the project took on and he pursued the scale-up of a fully-fledged new venture.	TechShop Shapeways

Nascent entrep.			Own community of tinkerers

Table 1 Entrepreneurs interviewed

Case	Chronology
A	A came up with his idea at home. He developed a first CAD model and prototype at home which was functional but far from the finished version. He posted his designs on "The Instructables" online platform and got feedback from this community to improve the prototype. He then ordered 100 PCBs from an external supplier, manufactured 100 products at home and sold these as DIY kits on the Internet to get early feedback from buyers. Despite receiving useful feedback from the first users he did not develop another product version for 3 years because he lacked tools and time. In 2012 he moved to California where he subscribed to the local TechShop. He became an instructor and took many advanced classes to get qualified on almost every machine. Moreover, he learnt to solder components on circuit boards thanks to the help of other members. He developed twenty prototypes within three months while at TechShop, where the staff and the other members provided him with advice in design and engineering, to finally get a pre-production prototype ready. He received advice from other TechShop members who knew local PCB suppliers and helped him to select one. Meanwhile, he developed a production process, thanks to the help of other members and launched a crowdfunding campaign. By the time he had finished to develop his production process, he had raised funding. He ordered 100 PCBs and manufactured 100 products with the TechShop capabilities, which he shipped to his crowdfunding supporters and other customers. He is now developing a third version of his product with new features at TechShop. However, his next production will be outsourced as the tools provided by the TechShop are inadequate to manufacture this new product.
B	B has been a member of a local hackerspace since 2008 where he learned about Arduino and the potential of this technology. His ambition is to produce artistic artefacts. He had this passion since his studies at college. After leaving a teaching job, he developed one idea for an interactive lamp while watching other hackerspace members using tools and by looking at products on "The Instructables" online platform. He started to show drawings of the product to other members and through their feedback selected the design to prototype. Then he developed a first CAD design thanks to low-end design software provided by the fab-space and, using the mill and the laser cutter, developed the first prototype. He benefitted greatly from the help of other fab-space members also in the product development process. He specifically remembers two participants who were really helpful: a retired scientist who had worked for an OEM and another very knowledgeable member who frequented the fab-space almost daily and offered consistently to help others. Once his prototype was ready for production, B posted a message on the fab-space discussion group to ask whether other members would be interested in buying parts in bulk from China to reduce the shipping cost and made a common order. Once he received his parts, he manufactured few lamps at hackerspace and sold them via an art gallery. At the time of the interview, B was planning a crowdfunding campaign and the development of a website on which he could sell his products. For this also, he was counting on the support of the fab-space members many of whom had web design skills.
C	C came up with his idea of developing a new flying gadget discovering an increasing interest on hardware. The idea came whilst watching videos on YouTube and thought of how to improve the existing products' features. C first developed a CAD design with low-end CAD freeware and tutorials available on the Internet. He then subscribed to a local Hackerspace. As he could not access the laser cutter and the 3D printer as often as he needed as they were respectively always booked or broken, he turned to Shapeways to get his parts. The parts were returned in three weeks but were not yet right. Concerned about further costs and waiting time decided not to continue using web-based fab-spaces. Instead, he used the tools available at the Hackerspace to modify the parts he had received via Shapeways and developed a new prototype, which unfortunately did not function. The Hackerspace was not equipped with tools to measure electronic signals and figure out the problem. When a TechShop opened in the area, he subscribed to it and took classes to use the 3D Printer and laser cutter. Within a day, he managed

	to understand why his first prototype was not working thanks to the testing tools provided by the TechShop and to the help provided by other members. Within another day, he iterated four versions of the prototype. In parallel, he raised considerable funding on a crowdfunding platform and, with the feedback from their community, started to understand the consumers' needs. While looking for PCB suppliers to launch the production of this new product version, he received advice from other TechShop members who had already worked with local PCB suppliers. Iteratively, by using a number of machines and attempting other manufacturing approaches, he developed a more viable production process. Once the last technical issues would be resolved, he is planning to produce the first small batch of 100 products using the TechShop equipment, to be shipped to his crowdfunding supporters. If he will be successful in achieving this result, he is planning to launch a second crowdfunding campaign with the aim to identify manufacturers to scale up his operations.
D	D co-owned a company which offers in-flight services. As part of this previous venture, they developed an electronic security system. When D was bought out of the business, he decided to create a new venture around this system. He wanted to improve the technology, but lacked the technical competence. In the past he attempted to work with external technology consultancies but had bad experiences (long time and high costs for not satisfactory results). Hence, he decided to join a Hackerspace to acquire the necessary competences. He found that the Hackspace was not suitable for both pragmatic (the machines were not always available, some were broken) and cultural reasons. Hence he joined a University run fab-space which in the meantime had opened in his area. Here, he learnt how to use the laser cutter and the 3D Printer, developed a CAD design thanks to low-end design software provided by the University run fab-space, tutorials on the internet, and, most importantly, thanks to the help of other fab-space members. Within 3 months, he developed a pre-production prototype and a production process with the help of the members' community. He bought himself a few pieces of equipment, including a 3D printer, and established them in his basement. D is currently presenting his pre-production prototype fabricated at home and at the fab-space to prospective customers.
E	E has a background in design and started to use a laser cutter when she was at school, where she also came up with the idea of making felt jewelry. Soon after she graduated, she met a supplier of fine felt and this event encouraged her to pursue her idea which she considered innovative because of the unusual combination of material and manufacturing technique. She subscribed to the local TechShop and tried to identify machines that would be appropriate to develop these products. She took basic classes offered by the staff at TechShop on how to use the laser and the vinyl cutters. It took her 4 months to develop a process to cut the felt with the laser cutter without burning the fabric, as TechShop did not allow her to use the laser cutter more than 6 hours/week and as this machine/material combination was unusual and nobody could advise her. She initially launched a low volume production with the TechShop's laser cutter and sold her products on the web and in local craft shops. In order to raise money for the first production batch, she launched a crowdfunding campaign. This was also the opportunity to test the market and understand whether people liked her designs. She raised funding but failed to develop, with TechShop equipment, a large enough production to satisfy her backers as the lenses of the laser cutters were worn. She then identified a manufacturer who could produce a batch of 800 items at a viable cost and higher quality standards. At the time of the interview she had already sold 650 products and was still working in the TechShop to develop a new collection. She further had plans to move to developing different products such as furniture.
F	F had the idea of developing a working desk which could be folded and carried easily. He presented his idea to a community of entrepreneurs and other relations, receiving positive feedback and decided to develop a prototype. The first functional prototype was developed at home. He learnt of the existence of a local TechShop and subscribed to it after the first visit. He took many classes to learn how to work on wood and metal. In three months he developed ten prototypes supported by TechShop members and had decided on which machines and material to use for the production. He then realized that the larger scale manufacturing

	of one part would have taken too long with the TechShop's equipment and decided to outsource its manufacturing. After 6 months, F had developed the final version of his product, ready to be commercialized. He tested the manufacturability of his creation before launching a crowfunding campaign, by producing a batch of fifty desks in the TechShop. He then raised a considerable amount through crowdfunding. He shipped the 50 products to the backers and started to produce 300 more in the TechShop. Meanwhile, he received feedback from the backers who had received their products, which he took into account and modified the prototype. In the following 6 months, 300 additional products were manufactured in the TechShop. He outsourced several components of the product, but he was still using the fab-space for one. He also assembled each product manually in the fab-space.
G	G and a group of university friends wanted to start a venture and came up with a product idea while still enrolled in their engineering course. After graduating and testing the initial product idea with local farmers and receiving negative feedback, they moved on to developing an automatic agricultural robot with the support of their local relations. As investors and incubators showed tepid interest and asked to see a working prototype to prove the idea feasibility before accepting them to the local incubator, G called the manager of the local FabLab, who he knew from his university time. He was hence invited to present his project to the FabLab members at the regular weekly meetings. FabLab members contributed suggestions and offered their help in different areas such as electronics, mechanics and power supply. One member even gifted two electronic motors to develop a first prototype. G and his colleagues then started to develop a prototype in a garage, and regularly went to FabLab to ask members for advice in design and engineering. They did not use the FabLab equipment as they were not appropriate for machining metal parts. In parallel, they raised funding through a crowdfunding platform. Within a year, they had developed a first prototype with the help of the FabLab members. This prototype was not fully functional but its development helped to design the product specifications. Then they outsourced the development and the manufacturing of the mechanical parts to a technical consultancy, as they lack the specific tools, but still relied on FabLab to develop the electronic designs. Once the mechanical parts were delivered, they used the FabLab to build encasements for the electronics and to assemble the product. With the functional prototype, they finally were accepted in the local incubator and received funding from investors. At the time of the interview they had five functional "beta-prototypes" which they were trying to sell to lead-user farmers.
H	With a passion for outdoors sports, H worked as an engineer for a company developing batteries for medical devices. Realizing that a great number of batteries were consumed and wasted during outdoors activities, he decided to create a better designed rechargeable lamp. He shared his ideas with friends who helped him to develop the first concept. He bought a second-hand CNC mill for $1k, he installed it in a former factory where other tinkerers had rented spaces and started to work. Six months later, a TechShop opened in the area, and H subscribed and took advanced classes to learn how to use machines and materials. With help from other members, he develop the design with the high-end CAD software available. For each prototype version, he first created a CAD design which he tested with the TechShop's low-end 3D printer. He then sent it to Shapeways to get a higher-quality part printed. The sixth prototype version, with PCBs ordered from an external manufacturer, was deemed ready for production. For this, H tried to develop an injection molding manufacturing process at TechShop. After three months of failing to produce a high quality mold, he decided to outsource it. In the meantime, through crowdfunding, he raised considerable capital with which he could outsource his production to a Chinese manufacturer, identified through a relation met at the workspace where he had installed his CNC mill.

Table 2 Chronology of each entrepreneurial path

3.2 Data Analysis

For the analysis, we started by constructing chronologies for each entrepreneur's story (see table 2), looking for common elements (Elliot 2005). In the meantime, we proceeded to analysing content - through iterative stages, starting with open coding (Creswell 2003) - whereby each story was read multiple times to identify significant elements of interaction between the entrepreneur and the fab-spaces, along the 3 steps process developed in section 2.1. These elements included for example, reasons and timing to approach the fab-space, competences and resources available, opinions regarding their usefulness or limitations, experiences with the staff (or about other people at the fab-space), significant events, chronology, and other resources that concurred to help them move forward and their link with the fab-spaces (if any). Progressed codes (and process phases) were obtained by reviewing and re-reviewing the data to expand open codes (Creswell 2003), systematically tabulating the quotes on a template, which captured the product development/venture process on one axis and, on the other, a time line (consisting of before the interaction with fab-space, at fab-space, after/other actions outside the fab-space). By doing so, second order themes emerged from each case. These were carried over to the next case and complemented with new emerging codes. As a result, data were mapped (a portion is portrayed in Fig. 2 as an example). After this within-case analyses, a cross-case analysis was performed, looking for similarities and differences across the interviewees' stories (Yin 2003). At this point, we started reflecting the observations against theory (Creswell 2003).

4. Results

Starting with the identification of which stages in the interviewees' entrepreneurial process were supported by fab-spaces, this section reports also their views about the advantages and limitations of these organisations.

4.1 At what stage of their venture/product development process did the entrepreneurs use fab-spaces?

As a result of the analysis, the entrepreneurial process, developed through literature review (section 2.1), was refined. As part of the "development" stage, product and process (manufacturability) designs were made explicit. The Production/Commercialisation phase was split into 1) Small batch production; 2) Scale-up production; 3) Marketing, as these were mentioned by the interviews as separate phases/tasks to which they were giving attention. Table 3 reports an example of these steps taken from the narrative of case F.

	IDEATION	DEVELOPMENT		PRODUCTION		
	Ideation	**Product design**	**Manufacturability**	**Small Batch production**	**Scale Up**	**Marketing**
F	I've been an entrepreneur for quite a long time, [..]I've been using a standing desk for a little while, just something kind of mishmash made from a kitchen rack, and it was such a crucial thing for me [..]. This type of desks are really expensive out on the market [..].	I discovered TechShop, and that was when I decided to go in, check it out, and take a tour, and realised there that they had so many more tools, and so many more abilities, things for me to be able to solve the prototype.	I took an injection molding class. I have never made a mold, and I have never injection molded on that machine as of yet; but I still found it to be one of the more valuable classes, because [..] it taught me some of the theory behind what to do, and then that helped me to do something that was very important, called design for manufacture. Those classes helped me understand the process that might be used to manufacture, so that I could alter my designs to make sure that I actually could get it manufactured.	A couple of weeks before I even launched the [crowdfunding], I was beginning to do the first run. I was going to do a run of about 50 desks. That was kind of a test run of manufacturing at lower level [..]	I have a sewing house in the East Bay that I use, and the poles come from, of course, a manufacturing company over, I believe, in Utah or Pennsylvania. And then the straps came from a place in Georgia, and I did all the assembly myself. I cut the inserts at the TechShop, the wood inserts that go into the desk, and I also fabricated the metal brackets at the TechShop.	I started doing some marketing for that very early, and getting people on mailing lists.

Table 3 – Example from case F along the emerging venture creation/new product development process

Table 4 reports where interviewees indicated that fab-spaces had the strongest contribution within the refined venture creation/product development process (see Table 3). The recognition of the entrepreneurial opportunity (Shane 2000) always happened outside fab-spaces, as each interviewee detailed how his/her prior knowledge about a problem (Shane 2000), or their personal motivation to start a self-employed career, were at the basis of their entrepreneurial venture. Only B described the frequentation of fab-spaces as an inspiration for his products. However, even in this case, the inspiration from the fab-space was related to the ideation of a new product and its features rather than about the idea of starting a business.

The cases analysed showed instead a marked impact of fab-spaces on the development of prototypes (product design), and most interviewees (A, B, C, E, F, H) commented how the direct experience with the manufacturing of their prototypes at fab-spaces made them realise the importance of identifying the most viable production route. Further, A, B and F developed their small-scale production using fab-space tools

and facilities, whilst E attempted this route but had to abandon it. Still working with batch production, F started scaling up the manufacturing of his products, still using the fab-space facilities to produce some parts.

	IDEATION	**DEVELOPMENT** **PRODUCTION**		**COMMERCIALISATION**		
	Ideation	**Product design** **(prototype)**	**Manufacturability** **(prototype)**	**Small** **Batch Production**	**Production Scale-up**	**Marketing**
A		TechShop				
B	Hackerspace					
C		Hackerspace/Shapeways TechShop				
D		Hackerspace University fab-space				
E		TechShop				
F		TechShop				
G		FabLab				
H		Own Community TechShop Shapeways				

Table 4 – Summary of the stages in the New Venture/New Product Development process where interviewees associated the highest impact/interaction with fab-spaces

4.2 What were the advantages of fab-spaces in the eyes of entrepreneurs?

4.2.1 *Acquiring resources and competences*

A) **Knowledge:** All entrepreneurs mentioned accessing knowledge directly or indirectly as one of the key benefits received at fab-spaces. Know-how (e.g. technical skills), know-what (e.g. understanding what skills were needed) and know-who (e.g. accessing other's network via the frequentation of fab-spaces), were all mentioned as important advantages. For the acquisition of the know-how, teaching classes were mentioned by several interviewees as an initiation in the use of machines, whilst the expertise of the community of other members and staff was emphasized more strongly as pivotal for the success of ventures. In particular, because this was highly qualified expertise, *"There is a retired rocket scientist at [hackerspace]. I am not joking! [..]" (B) "You have pensioners, who are wonderful. In the [university fab-space], [..] there are a few guys ranging from 65 to 80 years old. They're engineers with 30 to 35 years of experience in industry. They know their stuff." (D).* Although those who frequented different fab-spaces seemed to indicate that the level of expertise was variable: *"At hackerspaces, the community there, it is a little more interesting [..] Hackerspace, kind of, attracts a lot more experts. I think TechShop attracts a lot more hobbyists" (C).*

The value of this expertise was often mentioned in comparison with that obtained from external consultancies in terms of money and time. To start with, the fact that knowledge is available at short notice, ready to be tapped ad hoc for specific needs was considered important: *"[..] working at TechShop I was able to just run into someone there who was an expert on it [..], he walked me through it. It took him 10 minutes, but it saved me huge amounts of money and headache." (A). "Finding a good consultant is a job on its own, you know? [..] You get to focus group ready for you all the time if you want [..] Yes, you've got key people that act like, I don't know, private consultants that you would pay tonnes." (B).*

However, also the long term benefits of acquiring these skills were emphasized: for instance, entrepreneur D felt that technical knowledge was a key missing skill in his small venture, and attributed to this ignorance the previous failures with external design consultancies. *"I wanted to understand how it was possible to make things, to be in a position to have an informed discussion about prototyping. (D)",* and *"They [members at fab-space] made me discover some technological applications that I find inspiring and helpful*

for a number of future projects. They have stimulated my creativity." (D). As a result, several entrepreneurs saw fab-spaces as opportunities to stock up on technical competences: *"I was able to take all the classes for free. [..] I just started learning as much as I could and ask people as many questions as possible [..]."(H).* The know-who was particularly mentioned in the context of identifying people whose competences would be helpful for the latter stages of the process (e.g. manufacturing supply chain, marketing, IP protection (B, F, H)).

B) **Resources**: The quality and availability of tools were highlighted as fundamental (e.g. *"They had all this equipment that is just absolutely phenomenal and something I could never even consider affording: $100,000 machines, million of dollars of equipment that I could justify with $130 a month just to use it. It's basically a gym membership."* (C)). Testing equipment to appreciate why products did not operate (e.g. electronic), were repeatedly mentioned. However, some (e.g. B, F, G) also emphasized that, through fab-spaces, materials were more easily accessible than elsewhere, both directly via the fab-space (e.g. *"Usually the things that TechShop has, the materials, they tend to be better- they tend to be cheaper through the TechShop than they are actually in other places."* (F)) or because the community self-organises to order in bulk (e.g. *"Other people when they're ordering stuff, usually post [on the internal mailing list] and if you order more than $1k worth of stuff, everybody gets this 20% discount." (B)).*

The availability of knowledge and resources at an accessible cost implies a higher freedom to experiment with daring projects (e.g. *"[having all these equipment available] makes you more willing to try a crazy idea, because the price of failure is also consequently way lower." (B)*; "*It opens up possibilities of what someone can do by themselves or with a small group of people" (C))* or to overcome personal limitations (e.g. *"I was able to learn things that I didn't know before at all like surface mount sawing, I was very intimidated by it." (A)).* On top of this, it helps the firm to achieve more professional results with reduced resources, with the consequence that it rises the perception of the value of the venture in the eyes of important stakeholders. For instance, D managed to present a convincing prototype to the prospective clients ("*I was [..] in competition against a company with several thousands [of] engineers working for them, and our project was credible*.", whilst G managed to obtain funding from investors and be accepted by a local

incubator, who previously denied their support, because they had developed a working prototype with the help of a fab-space.

4.2.2 *Learning opportunity*

Besides the advantages above, most interviewees mentioned the opportunity to shortcut their learning curve. At the top was the opportunity to iterate designs quickly and to learn what works and what does not in their prototypes. This advantage was again mentioned in comparison to what happens when relying on other types of external services (e.g. *So [..] I have been able to come up with this idea and to rapidly experiment with new concepts [..] on the same day that I had the idea. [Whilst] Even if you have these 3D models ordered online, it still takes a month [..]. I spent an entire day at TechShop, I went through at least 2 or 3 revisions of the design (C))*. Further, this direct experience is educational as it uncovers unexpected learning needs and helps to identify what other competences are necessary (e.g. *So when I did it with Shapeways initially, it didn't even cross my mind that it would be an issue for production. But when I did it at TechShop, and I had to wait, and wait and wait, I realised that it's not really a production primary path.[..] it's something you don't think about when you do it online because [..] you throw a design at a black box and they send it to you. (C))*. This learning translates into higher organisational competences and the establishment of new routines (e.g. "*I think that a really powerful thing for TechShop is understanding when to do it yourself, when to manufacture outside, and how to be able to make those decisions.* (F)).

4.2.3 *Cultural environment*

With the exception of D, interviewees universally referred to fab-spaces as environments supportive of individuals' undertakings, regardless of whether these were meant for personal commercial benefit. For A and F the most important aspect was the feeling of not being alone and isolated, which helped them to maintain the motivation, whilst for G the un-judgemental attitude was particularly important at the onset of a project, and in contrast with what he experienced with traditional business support organisations. *"What's really difficult when you start a project is the feeling of being permanently evaluated. You have to give evidence that it's going to work, that it's a good idea, that there's a business plan. But at the beginning, there's no evidence of that because you don't know for sure. [..] Whereas in a FabLab, if you say you're*

trying to create a robot to travel to the moon, no one will laugh at you. They'll start asking questions about what you're going to do, they'll give you advice. And that's really nice. [..] You don't have to justify yourself, you're not asked if you're sure it's a valid project." (G).

Although, opposite views were mentioned (see section 4.3.2), the collegial setup of fab-spaces, in particular those run by communities, was generally mentioned positively. B felt that the community recognizes that the success of an entrepreneur in her/his venture will reflect in benefits for the whole community. *"And no one [cares] if they're giving you their best possible advice about something that you're going to turn into a business. [..] if you make money at this business, you're going to buy tools for the shop. Because you already like "doing hackerspace", lifting everyone else's book. People are pretty egalitarian about stuff. [..] Just because of the karma from it, and how much it helped you." (B).* The moral obligation to give back to the community was shared by those who attended community run fab-spaces (e.g. D, C), but also those who attended TechShops highlighted that getting involved in other activities beyond their ventures (e.g. contributing to other projects by becoming qualified as instructors (H)) allowed them further benefits.

4.3 What were the limitations of fab-spaces in the eyes of entrepreneurs?

4.3.1 *Accessibility*

Several interviewees hinted at how important it was to be able to access the space, particularly in terms of physical distance (A, C, D, E, H). A abandoned his project for 2.5 years, because he could not afford other prototyping services, and only when he moved closer to a TechShop did he take up his idea again. The judgement of accessibility seems to occur against the costs to be sustained (monetary and time) (e.g. *"I think TechShop existed but I think it was only [..] about an hour from here. [..] And there was just no way that I was going to be able to drive down in order to do this. [..] That's when TechShop opened [locally], which is an easy commute for me." (H)).* Web-based fab-spaces seem not to compensate for distance, especially at the start of the product design process, when fast iterations are required (see above). However, accessibility refers also to the rules and setup of fab-spaces in terms of the allowed time for using a machine (e.g. *"Because you could only use the laser cutter for 2 hours. So in 2 hours, I had to figure out what worked and didn't work, only using it 3 times a week. That's why it took so long" (E)*) or the opening hours (e.g. *"[TechShop] closes at midnight, which is fine for most people, but that's where I think that the hackerspaces*

here in town had an advantage. They were open 24/7." (C)), or time required (e.g. *"hackerspace is self-grown. So usually, there's a whole board of directors, and you have votes, and you have meetings. And I honestly wasn't interested in doing any of that. I only wanted to use the equipment."* (C)). C recognised how TechShop is perceived by most as too expensive in comparison to other community-run places. Even if he was more than pleased with the offer of services, he claimed that the monetary investment locks one in:*"[..] you have this mindset that « oh, I've already spent in classes, I can't turn in my membership now, that would be a waste of money ». So, that's kind of the dark side there is. (C)"*. B, C and D remarked on the difference and expectations about fab-spaces standards (e.g. *"The problem with it [Hackerspace], I guess, was there was quite a lack of rules and process that you kind of enjoy with TechShop." (C)*; *"[after frequenting a hackerspace] I went to the [university fab-space] and I was astonished by the large range of equipment there, the large space, the professional feel of the place, the quality of the organisation, knowing that everything was free there." (D)*).

4.3.2 *Clashing cultural features/institutional setup*

Several felt that somehow exploiting fab-space facilities for their own venture somewhat ethically clashed with the spirit of the fab-spaces. In particular, D experienced a strong moral disapproval for his own status as an entrepreneur by the community of one fab-space: *"It was interesting but they had an anti-capitalist mindset [..]. I told one of the guys that I had some commercial objectives and it was pretty shocking to him. I am not judgmental but this was not for me. (D)).* Even when he changed fab-space, and found another where he felt better integrated, he personally decided that there was a limit to how much one can take (and exploit the space) and felt the pressure to be seen to give back. *"I didn't want to be perceived as a free-rider, as someone who comes all smile, benefits from others' expertise than makes a profit out of it for himself. [..] It would not have been right to print them at the university fab-space because you would have used for a long period of time a machine which could have been needed for training purposes or by other users. (D)"*.

The issue of how to protect the product emerged for D, as implicit in the rules of the fab-space there was the creative commons license. He felt that this was a limitation to continue develop his product there.

C felt that the setup can be occasionally not flexible enough to respond to the users' needs. *"I think that's where [..] a downside for TechShop is [..]. It's a large company. So, if you need something, if something needs to be changed and they aren't able to do it there, you'll have to deal with the management corporate and, you know, get your request filed and follow a process."(C).*

4.3.3 *Tool/resources constraints*

Several mentioned limitations in the equipment available (low-quality machines, low number of machines, not the right type of equipment, more convenient to have something done elsewhere) as constraints for the use of fab-spaces (A, C, D, E, G, H). For instance, the development of printed circuit boards was mentioned by many as better outsourced than developed within the fab-space. Paradoxically, the availability of different types of equipment was mentioned negatively, as it induces the temptation to try to do everything on your own first, wasting precious time *"I actually tried to make moulds, to inject-mould parts myself […as] TechShop has a little injection moulding machine. [..]But they were not production quality parts that you could actually sell to anybody. So, that was probably 3 months [..] of wasted time there, in hindsight."(H).*

5. Discussion

With this work, we attempted to analyse the effects of the emergence and availability of fab-spaces on the entrepreneurial journey. For pragmatic reasons, we followed a simplified, and linear, venture creation process which encompasses three main stages: Ideation, Development and Production/commercialisation (as shown in section 2.1). Along this process, we evaluated the experiences of eight entrepreneurs and observed how the frequentation and exploitation of the fab-spaces influenced their ventures, in particular in terms of reducing the barriers along the way. Hence, the work described here provides an initial understanding of the mechanisms by which fab-spaces might impact on the entrepreneurial journey, and allows the formulation of several hypotheses and potential areas for future work.

5.1 Entry effects of fab-spaces on deterring barriers

The data collected suggest the hypothesis that there is no entry-effect (Autio, Kenney et al. 2014) of fab-spaces on the intention to start an entrepreneurial journey (Degeorge and Fayolle 2011). On one hand, none of the entrepreneurs interviewed was stimulated towards creating a new business because of the fab-space

environment. However, we are aware that this might be a by-product of our sampling approach. As fab-spaces are relatively recent, at the time of our interviews, individuals might have been excluded from the study who recently had ideas for new businesses whilst frequenting the fab-spaces. We are also aware that "intention" is a ‘hazy’ concept, which often merges with the individual’s aspiration for a career path rather than for a specific venture idea (Degeorge and Fayolle 2011).

Even if we did not observe any exogenous effect of fab-spaces on the ‘entrepreneurial intention’ (Degeorge and Fayolle 2011), the data confirm the hypothesis of a ‘displacement’ effect (Degeorge and Fayolle 2011). In fact, fab-spaces increase the opportunities to access resources and competences, lowering market barriers (D'Este, Iammarino et al. 2012), and in turn impact on the individual decision to move closer to setting up an independent business. For instance, the provision of moral and practical support was pivotal for G. He remarked on how the feeling of being supported, regardless of the demonstration of the likelihood of success, helped him to maintain his motivation, and to attempt to move forward by continuing to gather what was needed to be included in a business incubator. As a supportive culture is a decisive element in entrepreneurship, fab-spaces seem to be an important element of innovation systems which could complement other business support organisations with performance-based incentives (Stephan and Uhlaner 2010).

Linked to the above, we could observe that interacting with fab-spaces (in conjunction with other new institutional elements, such as crowdfunding platforms) seemed to influence the perception of failure and, as a result, the "threshold of performance" – i.e. the level of performance below which the constituents of the firm will decide to dissolve the organization (Gimeno, Folta et al. 1997). Fab-spaces allowed interviewees to initiate work towards their idea of venture, by pursuing small scale projects whose possible failure did not represent overwhelming costs to the individuals. They could maintain the perception of pursuing their overall idea of business, even in the face of setbacks. In fact, in many cases, the interviewees regarded their ventures as ‘projects’, rather than their overall business enterprises. This observation might contribute towards the emotive approach to explaining ‘failure’ (Khelil 2015), whereby fab-spaces change the perceived gap between actual rewards and the entrepreneur's anticipated expectations (Cooper and Artz

1995). Also, this observation might contribute towards the understanding of how user-innovators might transition to become nascent-user-entrepreneurs (Shah and Tripsas 2007). It also supports Sarasvathy's hypothesis that, under the right circumstances, potentially every individual could become an entrepreneur (Sarasvathy 2004).

A further observation, is that the fab-spaces' influence (i.e. the provision of competences and resources, the support to individuals' motivation) is subjected to the conditions of offering. In particular, the accessibility of fab-spaces (in terms of cost, time and distance), and the institutional and cultural setup, emerged as moderating factors for the effect of the fab-spaces on entry barriers. The evidence collected showed the importance for entrepreneurs of being able to work personally with machines, and to be able to access local knowledge and expertise. This shows that, to encourage individuals to take the first steps towards fulfilling their venture, the "local buzz" dimension is more relevant than other types of knowledge channels (Bathelet, Malmberg et al. 2004). Furthermore, the fit of the entrepreneurs' culture with that of fab-spaces was also apparent as a moderator for the influence of the fab-space. Whilst the collegiality and the aspect of sharing resources was not a deterring issue for B and C, the experience of D shows that some fab-spaces are permeated by a particularly strong anti-capitalistic culture, which can deter individuals from frequenting and acquiring the technical competences needed.

As a result of this analysis, several hypotheses emerge:

H1: The availability of fab-spaces does not affect the intention of individuals to become entrepreneurs

H2: The availability of fab-spaces positively affects the rate of individuals (with an entrepreneurial intention) who will start a venture

H3: The fab-spaces' impact on entrepreneurial entry is related inversely to their accessibility (in particular their geographic distance)

H4: Fab-spaces' impact on entrepreneurial entry is directly related to the cultural fit between fab-space and the entrepreneurs

5.2 Post entry effects & revealed barriers of fab-spaces

Fab-spaces emerged as environments where individuals could learn the necessary skills to push their venture forward through direct experience (Levinthal 1996), imitation (Beckman and Haunschild 2002) and experimentation. Hence, they are in the position to help entrepreneurs to establish routines (Aldrich and

Yang 2014). For instance, via fab-spaces, D acquired the technical knowledge necessary to interact with design consultants and hence developed an increased absorptive capacity (Cohen and Levinthal 1989). In addition, by continuously meeting new challenges and being presented with new knowledge, the interviewees appeared to be building the dynamic capabilities (Teece and Pisano 1994) needed to seek new knowledge and competences, and to be able to combine and recombine them to push their venture further.

The speed of learning, most importantly during the new product development and manufacturability stages, emerged as the most important advantage of fab-spaces. Those fab-spaces which allow a fast iteration of business approaches, and the discovery and anticipation of problems which might be found further down the line, seem to be more relevant for overcoming the revealed barriers. The availability at close range of individuals with technical (all interviewees), and entrepreneurial (A, B, F) experience, and the availability of different equipment types (A, B, C, F, H), seems to be important. Hence, entrepreneurs attending fab-spaces that had a thriving community, with varied expertise and varied technical machines, are more likely to proceed further in their ventures, and not fail or to drop out at a later stage, than those who rely on on-line and remote assistance.

The quality of equipment, and its speed, becomes more relevant towards the end of the manufacturability stage, to allow entrepreneurs to access and test a market, with the production and diffusion of a small batch of their products.

Also for revealed barriers, there seem to be moderating factors on the impact of fab-spaces, linked to cultural and institutional setups (e.g. the costs in terms of personal involvement with the fab-space).

H5: Physical fab-spaces will positively impact the rate of late failure (or no failure) in ventures

H6: The quality of machines provided by fab-spaces positively impacts the rate of late failure (or no failure) in ventures

H7: Fab-spaces' impact is directly proportional to the cultural fit between fab-space and the entrepreneurs

6. Conclusions

Notwithstanding the intrinsic limitations of the paper, chiefly the small and imperfect sample, and the data reconstructed from accounts referred to past experience, this paper has shown initial evidence of how fab-spaces can lower barriers in the new product development/entrepreneurial process. Two main conclusions can be drawn:

1. The observations made in this paper support the idea that fab-spaces could encourage the individuals, who already manifested an intention to become entrepreneurs, as they can impact on their "effectual path" (Sarasvathy 2001). Through fab-spaces, entrepreneurs can find better conditions to operate, with affordable losses and limited risk-taking when uncertainty is very high. Hence, fab-spaces might help to reduce the fear of failure (Khelil 2015) and to modify the "performance threshold", i.e. “The level of performance below which the dominant organizational constituents will act to dissolve the organization” (Gimeno, Folta et al. 1997).
2. Fab-spaces are a new setting in which entrepreneurs will be enabled to learn the skills and establish a correct set of routines to grow and survive (Aldrich and Yang 2014). They enable a particular feature of a high "learning speed".
    a. At the beginning of the venture process, the quick iterations of designs help nascent entrepreneurs to understand the key features of the products and how to manufacture them.
    b. At a later stage the availability of professional-level production technologies and accessible supply chains for material procurement help nascent entrepreneurs to test the market and decide whether to scale-up their operations.

Both these advantages are however moderated by the characteristics of the fab-spaces' setup - in particular the accessibility (i.e. distance and cost) - at the earliest stages of the venture, and the cultural alignment between the fab-space community with that of the entrepreneurs.

The above indicates that fab spaces may now be positioned amongst other Knowledge Intensive Business Services (Consoli and Elche-Hortelano 2010), as a new and complementary category in the group of "business support services as incubators and science parks" (Phan, Siegel et al. 2005).

Future work should attempt to deepen these observations, and to gather more extensive data to refine and test these hypotheses. Further, as fab-spaces support entrepreneurs mostly by virtue of the communities attending these spaces, more research is needed to understand how these 'meta-organisations' can be designed (Gulati, Puranam et al. 2012) to support organisational sustainability in the long term, and also potential organisational scale-up. One step towards the achievement of this understanding might be to develop, following Landry et al. (2013), an "ecology" of fab-spaces according to their business models.

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7. Appendices

7.1 Interview questionnaire

Stage	Theme	Questions
General Information	General information about the interviewee	▪ What is your background? ▪ How many people are involved in your venture? Where did you meet?
	Stage of entrepreneurship	▪ At what stage of your product development are you?
	Fab-spaces	▪ What fab-spaces did you use?
	General information on the company	▪ How old is your business? ▪ What was its last annual turnover? ▪ How many employees?
Ideation	Opportunity identification	▪ When did you first get your idea? ▪ When you first joined a fab-space, was it with the idea of developing a product and becoming an entrepreneur? ▪ If yes, did you already have an idea of a product to develop? ▪ Did the other users/staff of the fab- space help you develop this idea? ▪ Did you use other services to develop your idea? ▪ If so, which ones and Why?
Development	Product development	▪ When did you make your first prototype? (from simple sketch) ▪ What machines did you use to build your prototype? ▪ How many prototypes did you make? ▪ Did you need to take lessons (e.g. to use CAD software and the machines? Did you take many lessons or are you a self-taught person?) ▪ How much money did you spend during the prototyping stage? (including classes, materials, membership, …) ▪ What skills did you lack? How did the Fab-space help you to overcome this lack of knowledge? ▪ Did you use other services than the one provided by the hackerspace to develop your product? ▪ If so, why?
Production commercialization	Production, commercialization and business financing	▪ If there has already been a first production, how was it made? ▪ Did the fab-space help you to start your production? If so, how? ▪ Did the fab-space help you to reach your first customers? If so, how? ▪ Did you get external funds? If so, from whom? Any help from the fab- space? ▪ How did you start the production/reached your first customers?

9. Figures

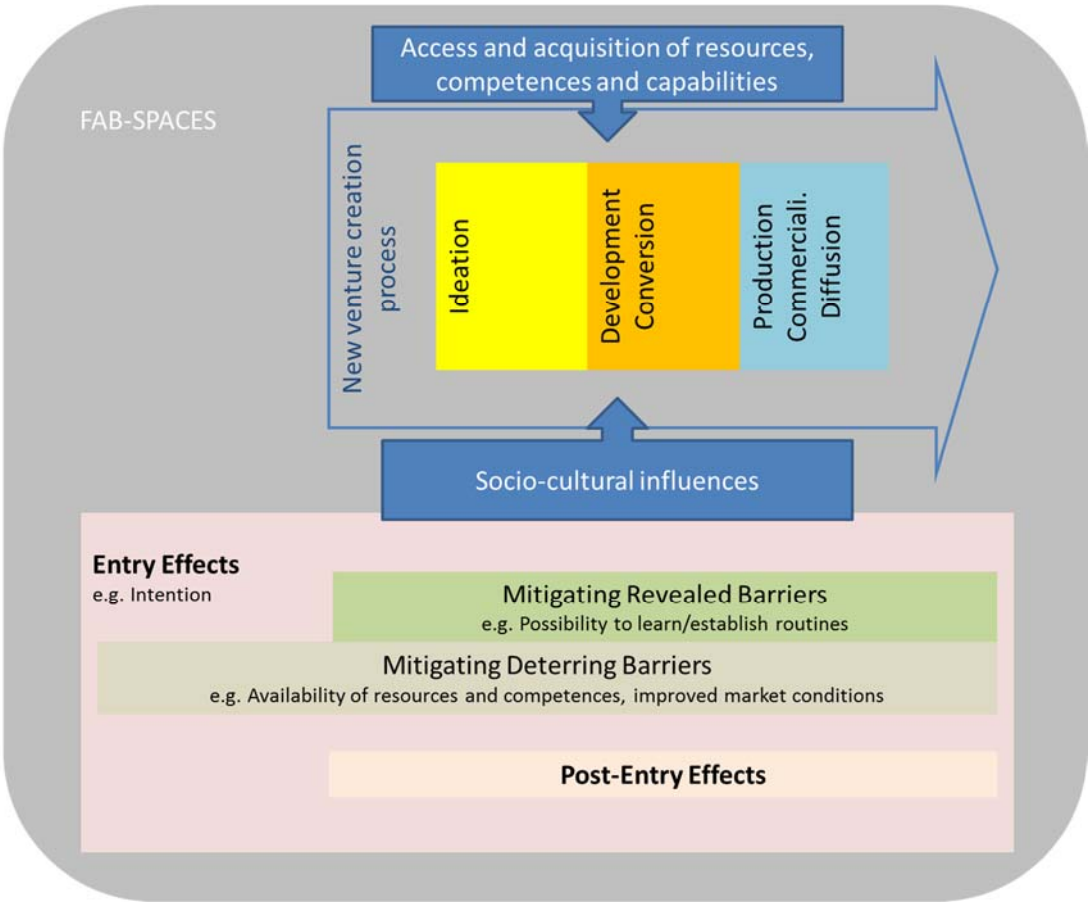


Fig. 1 The exploratory framework to understand Fab-spaces influences on the entrepreneurs' venture creation process

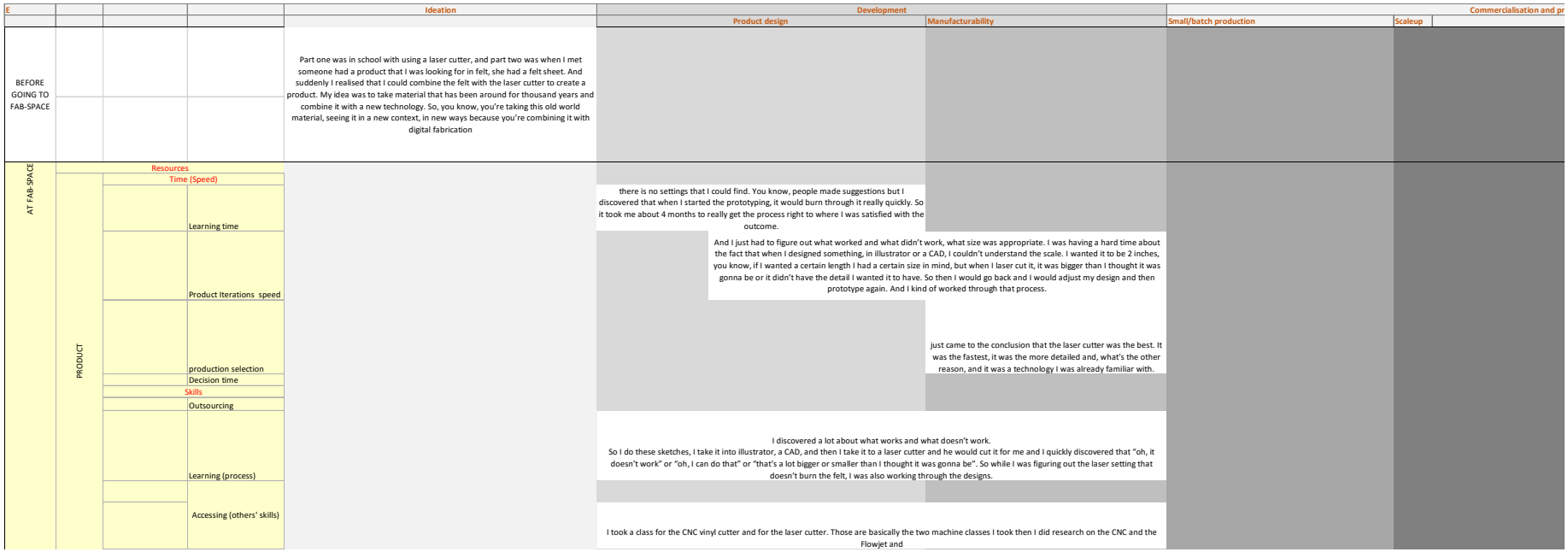


Fig. 2 A small portion of the data analysis sheet

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