International opportunity exploitation through 3D - additive manufacturing: An analysis of value chain activities

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ABSTRACT

This study investigates international opportunity exploitation of firms that have adopted 3 D additive manufacturing technologies. The firm's three main strategic decisions as to its activities' configurations in terms of "locus", "modus", and "focus" are under analysis. We find that 3 DAM makes the firms more competitive and attractive nationally and internationally. Opportunity exploitation in adopters who are driven by external pressures, more than internal motivations vary substantially. This study contributes to both international entrepreneurship research and corporate entrepreneurship, because our set of in-depth case studies includes smaller entrepreneurial ventures and the larger multinational enterprise.

Keywords: 3D printing; advanced manufacturing; additive manufacturing; international opportunity; business model innovation; value chain

INTRODUCTION

Additive Manufacturing[1] (AM) or, colloquially, 3D printing, is a potentially disrupting technology expected to change production processes (Berman, 2012; Mellor, Hao, & Zhang, 2014; The Economist, 2011) but also, more in general, to give rise to value creation and capture through the re-shaping or the emergence of new business models (Borges, Hoppen, & Luce, 2009; Strange & Zucchella, 2017). In line with such expectations, extant literature has mainly focused on the technical aspects of AM and their impact on firm-specific production processes and applications in different industries (Amon, Beuth, Weiss, Merz, & Prinz, 1998; Bak, 2003; Gao et al., 2015; Rengier et al., 2010; Wu, Thames, Rosen, & Schaefer, 2013; Zhai, Lados, & LaGoy, 2014) and, more recently, studies regarding business models (BMs) and business model innovation are emerging (Bogers, Hadar, & Bilberg, 2016). The recent Special Issue of the Journal of Technological Forecasting and Social Change (Ford et al, 2016, p. 158) has helped to make important steps forward, but it "is still very much the tip of the iceberg in research terms and numerous gaps in knowledge remain". One of the gaps in knowledge pertains to a more fine-grained understanding about value capture through 3D and AM (3 DAM, ibid). This is an important topic because 3DAM can enable firms to become more flexible and more responsive to market and partner needs, to the extent that new business models and activity architectures can emerge. To the best of the authors' knowledge no empirical study has in depth investigated how adoption of 3DAM can affect the firm's activities configuration. To do so, we set our study at firm level. Differently to extant work, which investigated mainly business model (re-) configurations, we study the 'activity system' in terms of value chain activities associated with 3 D and additive manufacturing.

[1] Generally, AM refers to the "process of joining materials to make objects from 3D model data, usually layer upon layer" (Piller, Weller, & Kleer, 2015) in contrast with traditional manufacturing which is undertaken through substractive processes (Janssen, Blankers, Moolenburgh, & Posthumus, 2014; Sasson & Johnson, 2016).

In order to track how 3DAM affects the firm's activity configuration, we investigate the role of 3 D printing in the process of exploitation of (international) opportunities, where opportunities are "situations in which new goods, services, raw materials, markets and organizing methods can be introduced through the formation of new means, ends, or means-ends relationships" (Eckhardt & Shane, 2003).

The present paper aims to answer the following research questions *How is the firm's value chain activity system reconfigured in consequence of the adoption of 3DAM?*

To answer this question, the firm's three main strategic decisions as to its activities' configurations in terms of "locus", "modus", and "focus" are under investigation. Locus decisions entail the geographical location of activities, and ultimately involve the spatial configuration of the firm's value chain. Modus decisions regard the definition of governance issues: whether activities should be undertaken in-house, delivered in collaboration with partners, or alternatively be outsourced to external suppliers. Lastly, focus decisions concern the allocation of resources to the different activities and the identification of core ones, ultimately determining the span of the firm's value chain.

The above set of decisions, in its essence, can be observed through and mapped on the companies' value chain activities and their governance. We consider the value chain perspective appropriate for two main reasons. Firstly, because opportunities can emerge at different stages of the value chain (Mainela, Puhakka, & Servais, 2014), and, secondly, because it allows the in-depth understanding of the firm's key activities and their configuration in terms of modus and locus (Onetti et al. 2014) in a parsimonious yet comprehensive manner.

The empirical analysis is explorative and based on five case studies of small and larger firms.

Our case analysis evidences that 3 DAM assists in entering international value chains, international partnerships, and international markets. 3 DAM adds breadth to company activities and portfolios, it helps realize differentiation through increased product/service

variety and customization, and it comes with significant process improvements which make the firm more flexible and cost efficient. Companies overall become less vulnerable to change as the flow of the product/service and the information throughout their internal and external value chain is improved. Put together, 3 DAM makes the firms more competitive and attractive internationally.

We have studied 3 DAM early adopters, who proactively implemented the new technology in order to realize a firm turnaround and survive (HSL), to break out from being squeezed as a non-strategic supplier (TreeDfilaments), to realize synergies in markets, achieve growth (SIMA), and customization in a vertically integrated company (Luxottica), and, finally, to realize a dream of sustainable homes in disadvantaged areas of the world (WASP).

We encompass different typologies of firms, from smaller young (international) new ventures, to the large, global firm (Luxottica). In doing so we will discuss about international opportunity exploitation in younger and smaller firms as well as corporate entrepreneurship i.e. "the activities that are used to create newness within established firms" (Ireland & Webb, 2009: 471). Among the various forms of corporate entrepreneurship, there is the capture of opportunities to enter into new (international) markets (Covin & Miles, 1999). As such, International Corporate Entrepreneurship (ICE) and International Entrepreneurship converge in the common focus on "[…] the exploitation of opportunities –across national borders- to create future goods and services" (Oviatt & McDougall, 2005: 7).

Overall, we contribute to the entrepreneurship field by analyzing the role of an emerging technology in capturing (international) opportunity in small and larger firms. We address a relevant gap in International Entrepreneurship (IE) where, in general, technology is implicitly present but not at the center of attention and where contexts of opportunity exploitation are overlooked. This emerges from a closer look at the recent review of IB/IE studies on the topic of (international) opportunities by Mainela et al (2014) where most of the reviewed studies'

research focus relates to opportunity creation, discovery, exploration. Our main focus instead is on how the opportunity of adopting a 3DAM-BM is exploited.

The reminder of the paper is structured as follows. First, we set out our theoretical framework, then we illustrate our methodology with data collection and analysis protocols, presenting our case studies' key facts and figures. We then proceed by illustrating our findings through single case and cross case comparison. Last, we highlight our study's main contribution to extant body of knowledge in the field.

THEORETICAL BACKGROUND

The theoretical background of the study is framed within i) the literature on value chain activities transformation in consequence to 3 DAM adoption, and ii) the entrepreneurship/international entrepreneurship research on international opportunities' exploitation.

Adopting 3 DAM BMs: consequences on value chain activities

Many authors have argued that 3 DAM technologies are going to substantially transform BMs in multinational enterprises (MNEs) (Campbell, et al., 2011; D'Aveni, 2013; Fenn, 2010; Lipson & Kurman, 2013; Wittbrodt, et al., 2013), but also – thanks to the constant decrease in cost – in smaller and younger ventures (D'Aveni, 2013; Petrick & Simpson, 2013; Rayna & Striukova, 2014). The impact will involve the three above-mentioned decision dimensions "focus", "modus" and "locus". Particularly, regarding the "locus" dimension, AM technologies are seen to re-configure international value chains (Hannibal & Knight 2018; Laplume, Petersen, & Pearce, 2016; Strange & Zucchella, 2017).

Nonetheless, despite the substantial amount of anecdotal evidence and theoretical pieces of research arguing about the potential transformation of value chain activities in consequence to the adoption of 3 DAM BM, very scant empirical research has been undertaken to date.

Theoretical research on AM adoption predicts that one of the most impactful transformations taking place with the adoption of a 3 DAM-BMs regards the production of low scale parts close to B2B customers (for instance this is the case of Original Equipment Manufacturers in the aerospace industry) (Bogers, Hadar, & Bilberg, 2016).

The transition towards a fully customer-centric production system will be disruptive in the case of B2C where 3 DAM BMs can allow extreme personalization shifting production activities close to end users or the end consumer, so that they become 'prosumers', ultimately determining substantial changes about the "focus" dimension of the BM. In this respect, manufacturers may give consumers the option to create their own designs and print the product at home or in "3D printing hubs". Eventually the manufacturer can offer specific parts to the consumer for printing specific customized products previously designed through an on-line platform. Bogers et al (2016) – building on Zott & Amit's (2010) framework – speak about a transition from a manufacturer-centric to a customer-centric value logic, where AM implies a shift of value adding activities from the manufacturer to the customer and/or co-creation with various stakeholders in more general.

In sum, moving from a "manufacturing-centric" to a "consumer-centric" view (Bogers et al, 2016) will imply the shift of value adding activities to the consumer and the emergence of decentralized supply chains (ibid). Accordingly, the value chain will be affected in that the reduction of general inventory levels, aiming for a supply chain logic based on a transition from "lean" to "agile" (see Tuck et al, 2007), allowing for increased responsiveness to highly unstable and uncertain demand. In addition to the advancement of AM technology itself, big data analytics and the Internet of Things (Gress & Kalafsky, 2015) have further enabled the

digitization of value chains globally, making them more agile and apt to respond to consumer demands in real-time (Woodward 2015). This implies a consistent re-structuring of the firm's international value.

Adopting 3 DAM can further affect the configuration of firms' supply chains for instance the reduction of tooling requirements and inventory holding (Sasson & Johnson, 2016). Moreover, 3D printing can allow innovative products requiring new value chains (because it provides the conditions for markets of less commonly demanded manufacturing goods to emerge), and it can positively impact sustainability leading to the emergence of sustainable, circular value chains (Chen et al., 2015).

In respect to the international re-location of activities, AM type of production is characterized by small scale production processes that will be organized at the level of individual countries or regions (see Hannibal & Knight, 2018). Laplume et al (2016) instead propose the configuration of a typical 3D printing global value chain where – in contrast with traditional manufacturing international value chains – production is most likely to occur in households, local print shops, and online print shops. Bogers et al (2016: 225) foresees "a move from centralized to decentralized supply chains, where consumer goods manufacturers can implement a 'hybrid' approach with a focus on localization and accessibility or develop a fully personalized model where the consumer effectively takes over the productive activities of the manufacturer". AM thus also implies greatly lessened costs for reaching customers located in markets distant from production locations, in turn reducing logistics and transportations costs. AM allows to produce customized products, in small batches (Laplume, 2016), potentially reversing "the trend towards global specialization of production systems into elements that may be geographically dispersed and closer to the end users" (ibid: 1).

Regarding "modus", while not being very specific, Ben-Ner & Siemsen's (2017) and Laplume et al (2016) indicate potential changes in governance in consequence to the adoption of 3DAM

In all, the effects of adopting 3 DAM BMs on the firms' value activities seem to have been predicted quite extensively "theoretically" but extant research lacks for investigations about what happens "in practice". We still do not know whether and which type of activities have been re-located, whether there have been changes in the governance of this activities and how much *the firm's* value chain and its position in global value chains has, overall, been re-configured in terms of "locus", "focus", and "modus" in consequence of adopting 3DAM BMs. Öberg, Shams & Asnafi,(2018) review the literature on 3DAM BMS impacts on value chains and find that – despite widespread acknowledgment of potential disruptive changes – more empirical work is needed in order to understand how supply chains are modified in consequence to the adoption of 3DAM BMs.

3 DAM and international opportunity exploitation

We adopt Reuber et al's (2018) extended notion of global factory, which is "inherently *opportunity-based* [emphasis added], and involves the integration of both entrepreneurial opportunities (new means-ends relationships) and international opportunities (new geographic markets)" (ibid: 400).

We aim to investigate the firm activities' value added, their modus, and their locus in order to understand the role of 3D printing in capturing (international) opportunities (Alvarez and Barney, 2007; Covin and Slevin, 1991; Shane and Venkataraman, 2000). Specifically, we focus on the phase of opportunity exploitation given the lack of studies in the field.

The debate about opportunities is lively in the entrepreneurship field and still shows a number of research gaps. Entrepreneurship research on opportunities is concerned with understanding the "exploration" phase of opportunities: whether these are "discovered" (Shane, 2000), or "created" (Alvarez & Barney, 2007; 2013) or, more recently, how they complement each other's and co-evolve (Mainela, Puhakka, & Servais, 2014). Albeit the concept of opportunities

is widely accepted among scholars (e.g. Dimov, 2007; McMullen and Dimov, 2013; Sarasvathy, 2001), extensive inquiries regarding the activities involved in the exploitation phase have not been performed yet (Wicklund & Shepherd, 2005). Studies have shown that many factors influence a firms' ability to recognize and exploit opportunities (Cliff et al., 2006; Cooper & Park, 2008). However, few studies have looked at how technology adoption may enable international opportunity exploitation.

The concept of international opportunity has grown in importance in the IE field. In their seminal contribution Oviatt and McDougal (2005) argue that International Entrepreneurship is the discovery, enactment, evaluation and exploitation of opportunities – across national borders – to create future goods and services" (ibid, p. 540). Also in IE studies, few empirical research has investigated how international opportunities are exploited in consequence to the adoption of a disrupting technology.

In BM studies, the business model has been described as the link between innovation and value creation (Chesbrough & Rosenbloom, 2002) as well as the link between entrepreneurial appraisal of the opportunity and its exploitation (Fiet & Patel, 2008)" (ibid: 88). George and Bock (2011) had advanced an "opportunity-centric" conceptualization of business models according to which "as the firm acts to exploit the opportunity, the elements of value creation and capture likely adjust with the development of resources and boundary-spanning activities" (ibid: 101). This perspective builds on Amit and Zott's (2001) conceptualization of business models and their activity architecture as "transactive elements" i.e. the mechanisms for opportunity exploitation.

Nonetheless, to the best of the authors' knowledge, there have not been empirical studies that have followed these conceptualizations. The mechanisms by which opportunities are exploited, via firm's activity architectures and respective focus, locus, and modus decisions still represent a gap in the literature (George & Bock, 2011).

METHODOLOGY

Research design and data collection

The research design is a multiple exploratory case study (Eisenhardt, 1989; Eisenhardt & Graebner, 2007) of five firms that have adopted 3 DAM. The complexity of the linkages that we investigate, coupled with the paucity of previous research are acceptable criteria for choosing a qualitative design. This methodology was deemed as most suitable in order to obtain a fine-grained understanding of the potential transformation of value chain activities in consequence to the adoption of 3 DAM.We purposefully selected our cases according to criterion sampling (Patton, 2015). Our main criterion was the identification and selection of information-rich cases (ibid). This involved identifying and selecting firms that had adopted 3DAM out of a proprietary database used in a former explorative analysis made of around 50 firms. Out of this database we selected ten firms with the phenomenon of interest (Cresswell & Plano Clark, 2011) and along variation in terms of firm age, size, industry, and overall firm and 3 DAM strategy. So we could narrow the list down to 10 firms which were mailed an invitation to participate in our primary data collection via in depth interviews. We subsequently called (September 2016) the companies for a follow up and to identify the most knowledgeable contact regarding 3 DAM in the companies. 5 firms agreed to be in depth interviewed on the topics of our projects. Because 3D printing technologies can be involved at different stages of and to a different extent in the value chain, the five cases considered vary in terms of breadth of value chain activities (e.g. R & D and design, manufacturing and quality control, sales and marketing). This allows us to model upstream and downstream opportunities associated with 3D. It also enables us to account for the firms' position and role in their 'external' value chain and to identify potential change. We thus tackle the issue of new value capture at the intersection

of internal and external value chain activities consistent with the entrepreneurial stance of opportunity.

All our firms, in their attitude towards a breakthrough technology such as 3DAM - show a high entrepreneurial orientation which - as argued by Covin and Slevin (1989) – consists in adopting an innovative, proactive and risk-seeking behaviour.

The choice of a heterogeneous sample follows a theoretical replication approach (Yin, 2014) aiming to explore different practices in terms of the firm and 3 DAM strategy, and product characteristics. Secondary data collection and analysis via industry reports, specialized magazines, and business press helped to identify a number of candidate companies according to the above-mentioned criteria. The interviews took place from October to November 2016. We were able to interview the CEOs of HSL, TreeDFilaments, and WASP, the Head of R & D in Luxottica, and the Head of Sales in SISMA[2]. All these informants were the most available and willing to participate. This is important because they have the ability to communicate experiences and opinions in an articulate, expressive, and reflective way (Bernard, 2002).

Interviews were semi-structured and focused on the following topics. We started with a brief presentation of the purpose of our study, asked the interviewees to present their company and their role within the firm and then moved to a description of their experience and key activities with 3 DAM. According to our theoretical objective we prompted details on focus, modus, and locus if the interviewees did not elaborate on it.

In order to minimize informant bias, we follow the guidelines by Huber and Power (1985), i.e. we identified the most knowledgeable person about the issue of interest. In all our cases the key informants coincide with the person in charge of 3 DAM, related value chain re-configurations

[2] We are in the process of conducting a second round of interviews with these informants, plus additional interviews to other knowledgeable informants of our five firms.

and their modus, locus and focus. In all the case firms, the interviewee was personally involved in the international opportunity exploitation.

Interviews lasted on average 90 minutes. They were recorded on a digital device and transcribed within the next 24 hours. In the case of any missing information or differences in the transcripts, the respondents would have been contacted either by e-mail or phone in order to resolve the ambiguities. Respondents provided their consensus to publish the content of the interviews' transcripts.

We triangulate (Creswell, 2007) the primary data gained via interviews with secondary data about the firms: company's documents provided by the respondents during our interviews, retrieved information on companies' web-sites as well as from industry reports, business press, the LexisNexis database etc. Table 1 illustrates key facts and figures of our five case studies.

Table 1: Case firms' key facts and figures

Company	Sector/ business	Firm size	3 DAM activity - processes	3 DAM-Governance
HSL	jewels / interior Automotive; Design/ manufacturing	Established, small, international	Early mover, - Design, prototyping, production, service, R &D	In house
Luxottica	Eyewear design-manufacturing-sales	Large, multinational	Early mover,– Research, design, prototyping, production; high quality impact, production	In house, overall highly integrated
TreeD filaments	Plastics/material	(established) + spin-off young, small, international	Early mover, new business 3 D, service & technological consultancy	In house
Sisma additive	3 D printers/ consultancy	Established, medium, international	highly specialized, customized machines in dental, jewelry	Inhouse; fully integrated
WASP	3 D printers/ social entrepreneurship	Small, young, multinational	Early mover 3 D based	Open and networked

Data analysis

Following best practices in qualitative research (Yin, 2014), data analysis is undertaken first by developing single in-depth case studies analysis, and, later, by cross-comparing cases to look for the emergence of patterns, similarities and differences across the cases.

Transcripts of each case firm were content analysed and coded by the researchers independently. In those cases of coding discrepancies, a third independent researcher in the field was asked to provide his opinion.

FINDINGS: SINGLE CASE ANALYSES

HSL (Hic Sunt Leones, indicating an unknown territory where only the most capable explorers dare to go)

Ignazio Pomini, the founder, president and CEO of HSL, is an engineer, passionate of creativity and design. His dream was to become a creative carpenter, a dream never realized because of 'family pressure, bad timing and, maybe, a lack of courage'. After studies in Milan he returns back

home to Trento (North of Italy) and starts working as a technician in a company where his father holds a minority stake. With the arrival of a German partner, the company makes a qualitative leap towards innovation and management capabilities. In 1988 he starts HSL, the first rapid prototyping company in Europe.

Pomini introduces 3DAM in 2009 to be able to stick to a sustainable high value offer - and to avoid the mistakes of the past. Pomini had been a pioneer already when introducing SLA systems, a stereolithograhpy system which solidifies liquid resin into plastic, very early on. He came to know it through his reading of an American technology magazine and had introduced it too early and too big for the Italian/European market. The system departed from CAD designs, which at the time were not well known and accepted in Europe. When the business finally took off, Pomini was not able to compete with the large firms which started to go alone, with smaller competitors who were closer to their clients, and/or to enter new industrial areas. 'We were too distant from the automotive center (Torino), our core market, and our competence/relationships were not easily transferable to other areas or insufficient to protect us from competition. It was a race without hope, we were not able to compete, neither in terms of price nor in terms of speed'.

The sustainable high value offering or the new mantra of the firm – speed, beauty, and technical perfection - he imagined in 2009 for his business was not only a better integration of prototyping and tooling but also the generation of ideas and the introduction of innovative processes. 3DAM represented, once more, an important investment for HSL but also for their customers. 3 DAM required experimentation, and the introduction and acceptance of new partnerships, changes that worked with some but not with all of their clients. Importantly, it brought new ones in. Through 3 DAM, HSL aimed at uniting design and industrial production, and at offering a valuable full service for those clients who sought the convergence between technical aspects and style. Potentially, this is beneficial in all product development processes, but it was for sure key to the automotive sector, HSL's primary customers. 3 DAM enabled HSL to revitalize and reinforce their key competence and further specialize in prototyping and design, in particular lighting. With the

new ‘service’ they enter the Formula 1, get new projects from Boing and ENI, and expand to the UK. Also their clients in automotive, that are *per se* innovation oriented, value the new approach which is reinforced with a University/industry collaboration. HSL further specializes in lighting for niche productions, i.e. one-off extreme luxury cars that come with very small production lots of 20-50 cars. For lighting, they work for example with a Lamborghini team which manages the projects and ensures overall highest quality.

As of today, in HSL, 3 DAM is used in design and prototyping but also for tooling and production. Most recently, the company has invested for validation purposes of 3 DAM production. 3 DAM in this context does not come with a cost advantage but with a quality advantage instead. Through processes and products that are better controlled, 3 DAM leads to more safety and reliability, which are of utmost importance in the automotive industry. HSL now manages a ‘full service’ in lighting which goes from design, feasibility studies, to prototyping, homologation and, finally, production. Most recently, it has been chosen by an innovative laser light provider, SLD Laser, from the US. The compactness of their lighting sources enhances design freedom to rethink the ‘eyes’ of tomorrow vehicles. SLD Laser, to this end, has partnered with HSL in Italy.

3 DAM also enables HSL to go beyond automotive and lighting. It has introduced a new business line for 3 DAM printed jewels, and furniture which has won several design awards. Also this business is being extended, e.g. with spectacles, to realize synergies but also to better exploit design and ‘prototyping’ competences. It now moves towards mechatronics and high performance components, building on their long experience on product- and technology integration.

WASP (World Advanced Saving Project)

WASP was founded in 2012, by Massimo Moretti, the CEO of the venture with long-standing experience in the world of R&D and project management. On average, he managed 2 projects per year, which gives him now the necessary technical knowledge and competence but also the reputation and visibility needed for Wasp. ‘After 20 years I felt the need to develop a project useful

for society, and to contribute to solving a global issue, i.e. economic housing. I was inspired by the potter wasp, master architects in building very economical nests from soil– I felt we could do the same'. He underlines credibility and reputation in the world of open source and makers but also the need for business skills and communication, 'especially if you are a nerd'. 'Our horizon is not only Italy but the world, so we need visibility'. His team is young, enthusiastic, highest and lowest-level profile, and shares the social mission of the company.

The overarching objective of WASP is to build a home for the poor – Eremo, the house which frees the human being because it comes without debt, provides shelter, does not consume energy, and produces a minimum quantity of food. Digital production, and sharing knowledge, stands at the basis of the concept of Eremo. Eremo is a home at '0 miles', using only material, for example clay, that is available at the point of construction, i.e. 3 D printing. It is replicable, it just needs a SD card which is exportable in the most remote places with the web, and 3 D printers as an instrument. Eremo thus builds on the idea of shared and distributed resources (e.g. knowledge and production facilities), where everybody can create and build, i.e. print a home, and where all contribute to creating human cities. Shamballa, the cultural project of WASP, represents this idea departing from the mythological place that symbolizes the city of peacefulness and happiness.

The project of Eremo is self-financed, by breaking it down into smaller projects, by partnering and by starting stepwise in order to be able, at the end, to assemble all the elements needed for a home. At its heart is a small and fast 3 D printer that materializes objects from bio-plastic, clay, silicone and biocompatible materials, which also mills wood and aluminium, and thus makes it easy to start mini-productions and to create what is needed by yourself. The revenues of this printer are reinvested in research and development of projects that focus on eco-sustainable materials and innovative systems. Successfully concluded projects have led, for example, to build ceramic and porcelain printers. Another big step taken is represented by the Bigdelta, a 12 m high portable printer that can be built in one hour by three people and which is run with a few solar panels, to be used in places where other energy supply is not available. In 2018, Wasp released the Crane

WASP, a collaborative 3 D printing system able to print houses. The first one, Gaia, was printed in 2018 in Italy. It is a low cost, eco-sustainable model which employs raw soil and natural waste from the rice production chain, aiming to achieve an efficient product from a bioclimatic perspective because it avoids the need for heating or air conditioning systems throughout the year. In line with its 'open source' model, WASP promotes hubs around the world. Expert people in digital production, in art, design, energy etc. are sought and thought to spread the word about WASP, its mission and objective, by providing a work environment and opportunity for innovation and discovery with the printers provided by WASP. The people who run the hubs thus need to be capable of doing education but also selling and servicing the WASP printers to make the hubs self-sustainable. Currently, 12 hubs, e.g. in Barcelona, Beirut, New Jersey, London, Berlin, Paris, Umea and in Italy (e.g. Venice, Milan, Macerata) are active. The hubs are connected and contribute to research and innovation through collaborative projects. Some of the hub projects realized contribute to lighting and digital craft, like the teardrops realized in London for Galaxia, but also workshops on digital ceramics etc.

Luxottica

Luxottica is a leader in the design, manufacture and distribution of fashion, luxury and sports eyewear. Its portfolio includes proprietary brands such as Ray-Ban, Oakley, Vogue Eyewear, Persol, as well as licensed brand including Armani, Burberry, Bulgari, Chanel, Coach, Prada, and many more. The group's geographic footprint is global: its wholesale distribution covers more than 150 countries across the five continents and is complemented by an extensive retail network of around 9.100 stores with e.g. LensCrafters, Pearle Vision, Laubman & Pank, Oticas Carol, Spectacle Hut, Sunglass Hut etc worldwide. Product design, development and manufacturing take place in production facilities in Italy, Brazil, China Japan, India, and the US.

Luxottica is an early adopter of 3 DAM which is used from design to production activities. 'It helps to confront the dichotomy of slow industrial (mass) production processes versus the constant

discontinuity in product portfolios as expressed in more than 2.000 new products per year (i.e. 60-70 % of the overall portfolio)', says Ing. Buffa, the head of R&D in Luxottica. The challenge arises from Luxottica's vertical integration, a key trait of the company, decided early on by its founder Del Vecchio and pursued and intensified along the company's lifetime. "Made in Luxottica" stands for a 360 degree view of everything from concept to finished product. For Luxottica this guarantees not only highest quality and cross-functional innovation, it also yields a unique understanding of consumer trends and tastes, advantages which have been key in attracting the most prestigious fashion houses to Luxottica's portfolio. This oversight of the entire value chain is seen as the key contribution to building and sustaining its competitive advantage. On the other hand, it is premised on solving the above-mentioned dichotomy of economy of scale and slow production processes versus fast innovation cycles required for products which follow fashion trends and continuous changes of collections.

Luxottica, already since many years, invests in the development of 3 DAM patents, mainly metal related. They partner with globally renowned companies all over the world, e.g. with Stratasys (printers, Israel), with Intel (US) and Deltagen (Germany) to improve software and CAD systems in order to develop 3 DAM further to their needs. One of Luxottica's objectives, which is already achieved, is to print highest quality components for jewelry collections, an extreme niche production for the most prominent fashion houses. 3 DAM here comes not only with a quality advantage it makes customization for smallest scale production possible. On the longer run, in line with its strategy of vertical integration, Luxottica sees its role as the one 'which puts the puzzle together' and seeks to govern the added value of the value chain.

Regarding higher scale production, 3 DAM is employed in all activities but production to make processes more efficient and to reduce complexity of the huge variety of models, material, and the related, different processes in a fully integrated company. 3DAM is used in the US, Chinese, Brazilian and Italian facilities for design and validation purposes. The digital production speeds processes through a 24/24 international interconnectedness between countries and functions, and

a standardization of instruments, crucially important to follow the rhythm of collections in the fashion industry. Buffa makes the case from catwalk to launching a pair of spectacles on the market which has a lead time of maximum 4 months: Luxottica uses 3 DAM for design and rapid prototyping for the show, once the models are decided multiple simulations with 3 DAM printed moulds are done internationally to check aesthetics and to avoid costly mistakes for production. Overall, 3 DAM in Luxottica is a B2B business because it allows the group to stay ahead of competition, to realize highest quality for highest quality partners, and because of the speed and quality in design and prototyping when it comes to realizing more mass market products. The potential for mass super-customization will be realized, according to Buffa, only when software is improved, more materials are available, and 3 DAM printers are distributed either in retails shops or directly in the home of the consumers.

SISMA

SISMA is a reference on a worldwide level for the design and production of highest precision machinery and laser systems. Founded in 1961, SISMA relies on the great experience it has acquired building over 130 models of machinery for the automatic production of gold chains over the years. Today, at the forefront of the development of laser systems, it has been able to extend its know-how to the creation of production solutions also for additive manufacturing. The 3 DAM line is 100% SISMA, decoupled from activities with its German joint venture partner TRUMPF, although they usually share R & D efforts. On market side 'there is no partnership, the better one wins'.

Although the 3 DAM market is only around 10% of its potential, and materials are still missing, SISMA commits early to this new technology because of its innovative vocation, because their technologies are complementary and will not cannibalize, and because they can extend their competences, technically and commercially. 'We are leaders in our value chain, and this position needs to be maintained', says C. Mantegazza, Head of Commercial Operations in SISMA. In some

of the markets they serve, e.g. jewelry, medical and dental, 3 DAM is already an option. For example, in dental, the printing of crowns is common practice because it is super-customized, much faster than traditional production and less costly. 'In one day I realize what usually was realized in a week, with absolute precision'. They comment that orders mainly arrive from abroad because of the difficult economic situation in Italy which makes huge investments in a new technology difficult, and because lead markets are elsewhere. Sometimes also the lack of knowledge on customer side makes the communication of 3 DAM difficult – 'they have difficulties to see the potential' - but on the other side it helps to reinforce our dialogue with them', says Mantegazza. Many of their distributors value the SISMA bundle, consisting of various technologies, of various process solutions, and of 3 DAM materials, others entered a relationship because of their 3 DAM solutions. It is 'advanced technology, reputation'.

TreeDfilaments

'3 DAM is an emerging sector', says Dario Negrelli Pizzigoni, the CEO of TreeDfilaments, 'it works like a catalyst, as it is open to everybody, but there is still a long way to go from an excellent idea to product innovation, to major efficiency with material use, to the wellbeing of the human being etc. 3 DAM has huge innovation potential but this needs focus'.

TreeDfilaments is born in 2015 from a traditional Brianza-based company (North West of Italy), that has been working with plastic materials since 1964, as a spin off, a small 'by-product' of the overall business. Dario Negrelli Pizzigoni, the second-generation CEO, inherits and cultivates excellent customer relationships. The major part of the customers are subcontractors which consider Negrelli's company almost a branch of their own activities, a colleague, but not more than a price-taker when it comes to price negotations. In the context of the deteriorating economy 'margins are becoming thinner and thinner: subcontractors are the first which suffer a crisis and the last ones to get back on track'. In six months, he loses 50% of the revenues but the shock, he says, was beneficial. 'If your company is at risk you need to act. I had three possibilities based on

our competences and capacities. I chose 3 DAM, not because of my thorough knowledge of it but because of the potential, the new and underdeveloped market, in particular with regard to materials, my core competence'.

3 DAM proves to be a winning choice, TreeDfilaments now is acknowledged as a technical partner, who has accredited material on offer, more than a seller of plastic filaments. It is not just about functionality and price, it is about reliability, serviceability, and usability, which are difficult to measure but important to consider. Clients do not lose expensive printing time and they avoid mistakes that may harm the customer's brand image. This means we need technological competence, R&D to guarantee that our filaments work as expected and find adequate solutions. The new business gives freedom, still we have the material at the center, but the focus now is on quality instead of price.

So far, TreeDfilaments is international through its clients (around 80 % of their filaments go abroad), their reseller network is Italian but they are looking for distributors worldwide. 'We need reputation, accreditation, word-of-mouth, it counts in Italy and it counts everywhere. Accreditation for sure will help but also our competence is getting to be known, there are a lot of synergies in 3 DAM and respective old and new networks. It brings us opportunities in new areas and new sectors. Incidentally, he says, with new material solutions he identifies new areas of applications which seem to open new horizons. With an industrial partner, TreeDfilaments in now developing a patent for bacteria-killing plastic tubes to be used in building and restauration. He also starts to cooperate with a renowned multinational in R & D, results are presented at an international trade fair and requests for cooperation multiply – with international giants, he says, that would never have noticed us before.

FINDINGS: CROSS CASE COMPARISON

Cross-case analysis reveals more commonalities than differences: firstly, all our case companies proactively and strategically invest in 3 DAM to exploit its potential to the full. All are internally-

motivated, early adopters and acting entrepreneurially with the objective to realize product/service and process innovation, open new business lines/partnerships, and new markets or, in the case of Wasp, grow a company and a network to tackle a huge societal issue.

With regard to '*focus*' we note that all companies add breadth and depth to their value chain activities, broadening the range and the competencies of their respective activities. Importantly, they are able to generate and capture more value out of these activities than they did before. For example, in the case of HSL and TreeDfilaments, the companies move from weak competitive positions (price taker; easy-to-replace partner) to highly differentiated service/offer providers that are now at the forefront of product innovation and technological consultancy. Luxottica, global leader in spectacles, maintains its position as undisputed partner for luxury brands, adds knowledge (and patents) in processes, and reduces complexity in the market and in production processes.

Capturing and governing value is also associated with the *modus* of value chain activities. All companies, except WASP, keep their key competencies and activities in house. There is no evidence of more distributed external value chains or co-creation with customers. Partners do come on board only in the case of non-core activities, such as patent development in Luxottica or R & D in the case of HSL and TreeDfilaments which instead seek protection through patents, accreditation and validation. The type of partnerships is, in all cases, high(er) level, and more international than it was in the past. HSL, Luxottica, TreeDfilaments, SISMA and WASP enter international value chains and partnerships but the '*locus*' of core activities does not shift. 3 DAM in this respect permits the companies to stay 'at home' or to keep their initial geographic footprint (Luxottica) because its digital nature and standardized instruments shorten distance to customers, partners and subsidiaries.

Differences are illustrated with WASP, our counterfactual case, which is the mainly socially-motivated venture. Its 'focus' remains on developing printers and the communication and coordination of their mission, i.e. printing homes for the disadvantaged. Having such a global

mission, the objective of the company is to become globally networked, known, and to share openly its knowledge and resources. Their 'modus' thus is collaborative, with many and diverse partners along the value chain of 'printing a home'. Its isolating mechanism is not based on patents, accreditation or similar, but on the overarching project and mission. The model thus is truly distributed at all value chain levels, increasingly international (hubs and common platform), and co-created with society at large, e.g. through partnering hubs, and educated public, and the one which gets closest to 'locus' as described in much extant literature.

DISCUSSION

In all our cases, 3 DAM has enabled opportunity exploitation by allowing for valuable reconfigurations in the firms' international value chain activities.

Cross case comparison revealed that the adoption of 3 DAM technologies assists in entering international value chains, adds value chain breadth, add/reinforce international partnerships and, international markets. Doing so we provide empirical evidence on *how* AM technologies may contribute to re-configure value chains (Hannibal & Knight, 2018; Laplume, Petersen, & Pearce, 2016; Strange & Zucchella, 2017) addressing a relevant gap in IB research.

Specifically, our cases highlight implications on focus, modus, and locus aspects of the business model.

With regards to '*focus*', both HSL and TreeD cases, 3 DAM adoption has allowed the firms to move the value chain up, from order taker to value provider. In the case of HSL 3 DAM allowed the firm to enhance existing competences and to differentiate its offer (from lightening and automotive producer, to introducing a jewelry product line). In the case of TreeD, 3 DAM adoption allowed the firm to move up its position in the value chain: from pure supplier to technology partner who find solutions and produces "accredited", innovative materials.

In these cases, 3 DAM adoption seems to be a critical driver for value chain upgrading. This finding has implications to the current debate on the interplay between innovation and global value chain dynamics (e.g. Pietrobelli & Rabelotti, 2011).

SiSMA case, on the other hand, shows that 3 DAM did not allow the firm to move up in the value chain but helped the company to maintain its position as a leader. The firm further exploits synergies in terms of reinforcing existing partnerships and at the same time is able to develop new partnership and increase its international sales.

In all our case firms, 3 DAM adoption represents a powerful isolating mechanism (Rumelt, 1984), a first-mover advantage associated to pre-emptive access to technological space (Lawson et al, 2012). This is a critical issue for IB studies interests in understanding the dynamics of global value chains since the stronger the IMs possessed by a firm, the more the firm will be able to resist the appropriation of its rents along the value chain (e.g. Lippman & Rumelt, 1982; Barney, 1986; Teece, Pisano, & Shuen, 1997).

A related finding – but with respect to the '*modus'* aspects – is about our firms maintaining technological knowledge and capabilities in house. They do not report about any benefit from outsourcing, nor from sharing knowledge to co-create with customers. This empirical evidence posits some limits to the theoretical assumptions about a shift towards co-creation paradigms in consequence to the adoption of 3 DAM. In particular, literature predicts that AM consumer-centric business models imply the co-creation with users as well as allow for a very high rate of product personalization, generating so-called "architectures of participation" (O'Rally, 2007) in which users co-create content (Brouthers, Geisser, & Rothlauf, 2016; Prahalad & Ramaswamy, 2004) offering digital platforms where customers interact with the producer to generate joint value through co-creation (Hannibal & Knight, 2018).

For our firms – as explained by our Luxottica interviewee - 3DAM allows for capitalizing on customer insights and is the pathway for balancing the need for reaching economies of scale and at the same time offer customized, unique products.

Last, existing IB studies on the potential effects of 3DAM on value chains and business models often somehow over-emphasize the effects of 3DAM on "location" aspects by shifting value chain activities closer to end users (Bogers et al, 2016). Our cases instead highlight a "stay at home" pattern, because – thanks to 3 DAM adoption - distance to the customer "disappears". It is true that our firms incrementally move towards a more "consumer-centric" BM yet this does not necessarily mean the shift of value adding activities to the consumer and the emergence of decentralized supply chains (Bogers et al, 2016). This is well exemplified in the case of WASP, 3 DAM allows the company to become a truly international networked, company from a remote place thanks to a network of collaborators and partners.

CONCLUDING REMARKS

This study was set out to investigate international opportunity exploitation of firms that have adopted 3 DAM BMs. We have analyzed the firm's three main strategic decisions as to its activities' configurations in terms of "locus", "modus", and "focus" and found that 3 DAM makes the firms more competitive and attractive internationally.

To date, this is one of the few empirical studies that has aimed to look for the actual changes in firms' BMs in consequence to the adoption of 3 DAM technologies. Our results provide empirical evidence of value chain reconfigurations in consequence to the adoption of 3 DAM BMs and somehow question some of the existing theoretical predictions. In particular we posit some limits to the co-creation evolutionary paths envisaged by IB literature on value chains configurations, as well as to the emergence of highly de-centralized supply chains.

Overall, this research contributes to entrepreneurship research on international opportunity exploitation by both smaller and larger ventures when these firms adopt 3 DAM BMs.

Future research will need to investigate other value chain activities and involve more case studies, also based in other advanced and developing countries. Future studies will also need to include case studies where 3 DAM adoption was "externally motivated", i.e. driven by changes occurring

in the firm's reference environment. More research is needed to gain a deeper understanding of value chain upgrading dynamics by the adopters of 3 DAM technologies. Longitudinal observation of both lead firms and suppliers from different industries, and countries would be highly beneficial to this aim.

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