

The Hidden Side of 3d Printing in Management*

*Federica Pascucci**, Andrea Perna***, Andrea Runfola****,
Gian Luca Gregori******

Abstract

3D printing is stimulating a flourishing academic debate. Hence, this article focuses on two main issues: (1) understanding what the current business/management themes are related to 3D printing; (2) identifying the theoretical and managerial implications concerning 3D printing. Recurring to a systematic literature review of published academic articles, this paper identifies and discusses five main thematic areas and consequent implications.

Keyword: 3D Printing; Additive Manufacturing; Industry 4.0; Global Markets; Sustainability

1. 3D Printing

The advent of the ‘Industry 4.0’ has triggered new opportunities and challenges for private and public organizations. In the current digital era ‘Industry 4.0’ or ‘The Fourth Industrial Revolution’ (Kagermann et al., 2013) refers to the dawn of new technologies which are supposed to facilitate the management of some specific processes – such as the manufacturing processes – with the purpose of obtaining superior performances and reduce costs (Marr, 2016).

Among the different available technologies within the new paradigm, the 3D printing seems to have received an increasing attention by both academics and practitioners within national and international contexts. 3D printing represents a revolutionary technology (Berman, 2012) – consisting of new generation of machines able to print small objects or even products from 3D CAD software – that might impact on several aspects related to the production and consumption of goods.

However, the academic debate on this topic looks more focused on the ‘technical’ dimension and on what the economic implications of 3D printing are at institutional level: but the implications of this phenomenon from a managerial and business perspective seem less explored. And since nowadays businesses are stretched over

* The Authors: F. Pascucci § 2,4,7, A. Perna § 3,8, A. Runfola § 5,6, G.L. Gregori § 1., G.L. Gregori, A.Perna and A. Runfola equally contributed to § 9.

** Researcher in Marketing, Università Politecnica delle Marche (f.pascucci@univpm.it)

*** Researcher in Business Marketing, Università Politecnica delle Marche (a.perna@univpm.it)

**** Associate Professor of Marketing, University of Perugia (andrea.runfola@unipg.it)

***** Full Professor of Marketing, Università Politecnica delle Marche (g.gregori@univpm.it)

'global' markets (Brondoni, 2014) and are looking for new forms of business models (Rieple and Pisano, 2015), it seems fair to investigate the 3D printing and its effects considering the relation between this technology and the very complex business arena where companies are embedded.

Our study is aimed at offering an overview of how 3D printing is investigated from the business and management perspective. Specifically, we are interested to answer to the following questions:

- What are the current and the emergent topics within the 3D printing scenario?
- What are the major implications – from a theoretical and managerial point of view – of the available studies?

To deal with the above research questions, we have developed a systematic literature review based on the international and available literature. Several topics have been identified and grouped into five main areas. Therefore, the contribution of this study concerns the discussion of the current state of the art around 3D printing with a specific interest on the next potential research areas in business and management.

As for the structure of the paper, a short description of the technology is offered in the next paragraph. It follows the methodology and the findings of the literature review. The article ends up with implications and suggestions for further research.

2. Additive Manufacturing and 3d Printing

AM is an emergent technology, originated in the late 1980s from the rapid development of advanced manufacturing technologies (Bourell et al., 2009) and may be positioned in the broader phenomenon of digital manufacturing (Annunziata and Evans, 2013). According to the ASTM standards (2012), it may be used in a process of joining materials to make objects from 3D model data usually layer upon layer, as opposed to subtractive manufacturing technologies. Similar to AM, also 3D printing refers to the layer-by-layer creation of physical objects based on digital files that represent their design. In fact, the first stage of 3D printing involves creating a digital model of the object to be printed, through a CAD modelling software or using dedicated online services or 3D scanners. The second stage consists of the decomposition of the object into successive layers that are printed one at time.

There is a debate about the meaning of the terms AM and 3D printing; they are often used interchangeably and are considered as synonymous by some authors (Weller et al., 2015). On the contrary, other authors consider AM and 3D printing two different phenomenon (Gibson et al., 2010; Mellor et al., 2014). As stated by Ford et al. (2016), AM is not just a single technology, but it encompasses a range of technologies. 3D printing has a similar definition, but it is also referred to as a type of technology which employs additive manufacturing along with stereolithography, fused deposition modelling, and selective laser sintering (Mellor et al., 2014). According to Rayna and Striukova (2016), 3D printing is a form of AM. Gibson (2017) stated that AM can be best viewed as a process, which in turn could be combined with other processes to create more complex combinations.

Regardless of the different definitions, what is relevant is that both AM and 3D printing are introducing a new paradigm of industrial production (Lipson

and Kurman, 2013; The Economist, 2012; Ford et al., 2016), also disrupting the ways in which companies capture value. The many advantages of these technologies over other manufacturing processes include the following: freedom of design, waste minimization, fast prototyping, no need for special tooling existence in part fabrication, decrease of time and cost of manufacturing for individualized parts and small-quantity productions, opportunity to fabricate novel components and structures of complex geometries and heterogeneous compositions, and compression of the supply chain.

Despite all these benefits, these technologies still have yet to reach high levels of adoption, because of some challenges that hinder their widespread use, such as regulatory and legal issues, the cost of initial investment, the increase in the electrical energy in comparison to traditional methods, the need for new skills and competences (Schniederjans, 2017; Ford et al., 2016).

At the moment, we can distinguish among three main stages of 3D printing adoption (Rayna and Striukova, 2016):

1. in the early 1990s its first application was rapid prototyping, using only plastics as material; at that time the level of details and quality were rather low, printing was slow, expensive and restricted to small objects;
2. in the second half of 1990s it was adopted in the rapid tooling, such as in the production of moulds, thanks to the advent of 3D printing using heat resistant polymers and metal;
3. in the late 2000s 3D printing began to be used for the manufacturing of end-use products, thanks to the decrease in cost and the improvement of quality.

In the past 20 years increasing attention has been given to AM, and especially since 2010, the number of papers on this topic has doubled (Jin et al., 2017). But more information is needed in order to progress on ways to enhance adoption, in particular in reference to the management literature (Schniederjans, 2017).

3. Methodology

Reaching a higher understanding of additive manufacturing in business and management does not result an easy task due to the relatively academic ‘youth’ of this phenomenon.

We have been searching on the database Scopus the following key words ‘Additive manufacturing’ as well as ‘3D Printing’ in the title, abstract and key words. We have limited the results to the subject area of ‘Business, Management and Accounting’ and obtained 686 results. As second step, we have eliminated the articles which did not address specifically the theme of 3D-printing from a business perspective: for instance, we did not consider articles whose main goal was to offer insights regarding the technical and engineering perspectives of that technology. That process has been carried jointly by the four Authors and the sample shrank from 686 to 58 articles. The left 58 articles have been further analyzed and 21 of them have been discarded since they did not match our predominant criteria of focusing on the relation between 3D printing and business/management perspectives. Therefore, the final sample resulted based on 34 articles.

The third step consisted of carrying out a full text analysis of the 34 articles in order to classify them in respect with the business/management themes faced by

those articles. We came up with the following categories: *3D printing technology adoption and use*, *3D printing and business models*, *3D printing and supply chain*, *sustainability and 3D printing*. Our last category has been named as *additional themes* and it includes articles which do not match with the above categories but anyways they face other complementary issues such as the relation between 3D printing and policy system, etc.

The categories have been identified after a careful reading of each of the 34 articles: the authors agreed on identifying what were the major general research themes faced by the articles and afterwards they jointly grouped them within the above mentioned categories.

The results of our literature review are represented in the following table 1:

Table 1: List of Selected Articles Sorted by Themes and Year of Publication

Article title	Authors	Year	Journal
Technology adoption and use			
Critical success factors for adoption of 3D printing	Yeh, C-C and Chen, Y-F	2018	Technological Forecasting & Social Change
Additive manufacturing in SMEs: empirical evidences from Italy	Marzi, G. et al.	2018	International Journal of Innovation and Technology Management
Additive manufacturing in the wood-furniture sector: sustainability of the technology, benefits and limitations of adoption	Murmura, F. and Bravi, L.	2018	Journal of Manufacturing Technology Management
Envisioning the era of 3D printing: a conceptual model for the fashion industry	Sun, L. and Zhao, L.	2017	Fashion and Textile
Alternative production strategies based on comparison of additive and traditional manufacturing technologies	Achillas, C. et al.	2017	International Journal of Production Research
Impact of additive manufacturing on business competitiveness: a multiple case study	Niaki, M.K. and Nonino, F.	2017	Journal of Manufacturing Technology Management
The Digital Revolution, 3D Printing, and Innovation as Data	Rindfleisch, A. et al.	2017	Journal of Product Innovation Management
Adoption of 3D-printing technologies in manufacturing. A survey analysis	Schniederjan, D.G.	2017	International Journal Production Economics
Business model			

User entrepreneur business models in 3D printing	Holzmann, P. et al.	2017	Journal of Manufacturing Technology Management
Business model configuration and dynamics for technology commercialization in mature markets	Flammini, S. et al.	2017	British Food Journal
Additive manufacturing for consumer-centric business models: Implications for supply chains in consumer goods manufacturing	Bogers, M. et al.	2016	Technological Forecasting & Social Change
From rapid prototyping to home fabrication: How 3D printing is changing business model innovation	Rayna, T. and Striukova, L.	2016	Technological Forecasting & Social Change
Supply chains			
Additive manufacturing and the global factory: disruptive technologies and the location of international business	Hannibal, M., and Knight, G.	In press	International Business Review
Impact of additive manufacturing on aircraft supply chain performance: a system dynamics approach	Ghadge, A. et al.	2018	Journal of Manufacturing Technology Management
The impact of additive manufacturing on supply chains	Durach, C.F., et al.	2017	International Journal of Physical Distribution & Logistics Management
3D printing the future: scenarios for supply chains reviewed	Ryan, M.J. et al.	2017	International Journal of Physical Distribution & Logistics Management
Industry 4.0, global value chains and international business	Strange, R. and Zucchella, A.	2017	Multinational Business Review
Global value chains from a 3D printing perspective	Laplume, A. et al.	2016	Journal of International Business Studies
3D printing services: classification, supply chain implications and research agenda	Rogers, H. et al.	2016	International Journal of Physical Distribution and Logistics Management
Impact of additive manufacturing technology adoption on supply chain management processes and components	Oettmeier, K. and Hofmann, E.	2016	Journal of Manufacturing Technology Management
Sustainability			

Disruptive technology as an enabler of the circular economy: What potential does 3D printing hold?	Garmulewicz, A. et al.	2018	California Management Review
Circular economy, 3D Printing, and the biosphere rules	Unruh, G.	2018	California Management Review
Unlocking value for a circular economy through 3D printing: A research agenda	Despeisse, M. et al.	2017	Technological Forecasting & Social Change
Additive manufacturing and sustainability: an exploratory study of the advantages and challenges	Ford, S. and Despeisse, M.	2016	Journal of Cleaner Production
Additional themes			
New industrial platform and radical technology foresight: the case of 3D printing in Finland and Europe	Kaivo-oja, J. et al.	2018	International Journal of Manufacturing Technology and Management
3D printing and the third mission: the university in the materialization of intellectual capital	Birtchnell, T. et al.	2017	Technological Forecasting & Social Change
The rise of 3-D printing: the advantages of additive manufacturing over traditional manufacturing	Attaran, M.	2017	Business Horizons
The changing face of additive manufacturing	Gibson, I.	2017	Journal of Manufacturing Technology Management
Building the layers of a new manufacturing taxonomy: how 3D printing is creating a new landscape of production eco-system and competitive dynamics	Kapetaniou, C. et al.	2017	Technological Forecasting & Social Change
Implementation of rapid manufacturing for mass customisation	Deradjat, D. and Minshall, T.	2017	Journal of Manufacturing Technology Management
The Potential of Additive Manufacturing for Technology Entrepreneurship: An Integrative Technology Assessment	Gartner, J. et al.	2015	Creativity and Innovation Management
E-commerce channels for additive manufacturing: an exploratory study	Eyers, D.R. and Potter, A.T.	2015	Journal of Manufacturing Technology Management
Disruptions, decisions, and destinations: Enter the	Kietzmann, J. et al.	2015	Business Horizons

age of 3-D printing and additive manufacturing	al.		
3-D printing: The new industrial revolution	Berman, B.	2015	Business Horizons

Source: own elaboration

4. Technology Adoption and the Use of 3d Printing

A first group of two studies focused on the *antecedents of 3D printing adoption*. Schniederjans (2017) investigated the drivers of 3D printing intention to adoption, considering top management perceptions and characteristics. Combining the theoretical framework of diffusion of innovation (DOI) and unified theory of acceptance and use of technology (UTAUT), the author found that relative advantage and performance expectancy were stronger drivers of intention to adopt, but also compatibility and facilitating conditions were significantly related to adoption. Yeh and Chen (2018) too investigated the factors influencing 3D printing adoption, but they rely on the technology-organizational-environment (TOE) framework combined to cost considerations; their study show that cost and environment are the most important drivers, followed by technology and organization. It's worth nothing that different departments express different viewpoints on the second and the third most important factor: the production department puts technology at the second place, whereas the marketing and the R&D department consider the environment as the second most important factor.

A second group of studies focused on the *consequences/implications of AM adoption*, in terms of results, benefits and challenges. Two of these studies adopted a wide perspective (Niaki and Nonino, 2017; Achillas et al., 2017), whereas three of them adopted an industry-specific focus, researching for implications of 3D printing in the fashion industry (Sun and Zhao, 2017), jewelry (Marzi et al., 2018), and in the wood-furniture sector (Murmura and Bravi, 2018).

Niaki and Nonino (2017) researched about the implications of AM, in terms of business strategies and performance; they highlight that AM brought not only a process innovation, but also product and market innovations and it may improve firms' performance both increasing revenues and decreasing costs. However, from their case studies, emerged that there are some key factors driving AM performance, such as company size, time of use, aim of use, type of material and transition from conventional manufacturing techniques. Achillas et al. (2017) studied, in particular, the AM implications in terms of lead time and total production cost, in comparison to the traditional manufacturing techniques in the fabrication of end-use products. They concluded that none of the AM technologies examined is yet able to practically replace the traditional one for medium- and high production volumes; on the contrary, for low-volume production AM technologies offer significant advantages because they shorten lead times and decrease total production costs.

The paper of Sun and Zhao (2017) is a conceptual paper, regarding the impacts of 3D printing on four main areas in the fashion industry: design and product development; sourcing and manufacturing; retail, distribution and consumer; and

sustainability optimization. These impacts would lead to the development of a new paradigm integrating Direct Digital Manufacturing. Marzi et al. (2018) investigated the impact of AM on competitiveness and performance of n.8 gold jewelry Italian SMEs, considering AM adoption as a radical process innovation. Such innovation consists in new machinery – 3D printers – introduction in prototyping and/or in production processes. From the evidence of, emerged that AM can improve the firms' competitiveness, because it allows the development of product innovations with a higher value for customers, an increase in the willingness to pay and a better access to new market segments, resulting in an improvement in the firm's revenue stream. On the contrary, the costs tend to increase due to the maintenance, the staff training and the raw materials. Therefore, the increased competitiveness depends more on the revenues side than on the cost side. The third industry-focused paper (Murmura and Bravi, 2018) is an empirical study on a sample of Italian wood-furniture firms, aiming at exploring the current situation about AM adoption in a descriptive way. The main benefits and limitations of AM implementation are investigated; reduction in time to market of products and the freedom of design are the two major advantages perceived by the firms, whereas the main limits are grouped in three categories: unsuitability of technology, the necessity to have more knowledge and training, the investment needed to implement technology. It's worth noting that education and training need is a shared challenge with the two other industries (fashion and jewelry) and it is a quite common factor emerging from the limitations of AM adoption/implementation. This means that in order to reach an effective implementation of this new technology, human resources are fundamental, and they need to activate a learning process for acquiring the specific skills and the knowledge.

The last paper regarding the “Technology adoption and use” theme, is that of Rindfleisch et al. (2017), who consider 3D printing as enabler of a “full digital revolution”, because it completely eliminates the divide between the physical and the digital for a broad range of products. In other words, 3D printing allows consumers to transform digital data into physical products and vice versa, enhancing the new Innovation as data (IAD) approach. This new approach is characterized by a fundamental shift in the consumers' role in the new product development process: consumers may use digital tools, such as 3D scanners and 3D printing, to acquire and/or to generate data to create their own innovative offering. As a consequence, the relevance of firms in the new products generation will likely be challenged and a new role and new strategies have to be developed in order to contrast this declining perspective.

5. 3D Printing and Business Models

Another stream of research that is connected to the 3D printing is the related implications in terms of business models. Our investigation highlights a set of contributions, although not numerous, that deals with some relevant issues. Most of the studies can be understood as a part of the *debate on the relationship between business models change and technological innovation*. There are studies that both discuss the impact of 3D printing on the entire configuration or that consider some specific features of the business models (Flammini et al. 2017; Rayna and

Striukova 2016; Bogers et al. 2016). In their work, Rayna and Striukova (2016) investigates the impact of 3D printing on business model components and the subsequent potential degrees of radical change of the business model.

The authors examining four adoption stages of 3D printing that include “*rapid prototyping, rapid tooling, direct manufacturing and home fabrication*” (page 216) conclude that this new technology can have a disruptive potential for business models with particular regard to the last two stages. The study of Bogers et al. (2016) considering the central role that AM assign to consumers, discusses implications on business models emerging from the reconfiguration of supply chain activities. As noted by the authors in fact, the possibility given to the end-users to personally participate to the design and manufacturing of the products, should lead to a rethinking of how the company manage the supply chain, in order to be closer to the market, paving the way to the proposal of innovative business models. Flammini et al. (2017), specifically, considering the case of the food industry, pointed out how business models can support the implementation of a new technology, as 3D printing in the case study they analyzed, letting new companies to propose innovations in mature markets. A different perspective, although analyzed in only one contribution in our sample, is the study of *the role that 3D printing may have in the development of new business models by users*. As noted within the literature, one of the main characteristics of 3D printing is that of giving the possibility to final consumers and users to create and produce products at home. Holzmann et al. (2017) discusses how 3D printing may represent an opportunity for user-entrepreneurs, so taking the perspective of the users rather than that of the company for the development of innovative business models. In their contribution, the authors propose four main situations that can lead to new business models by user-entrepreneurs, resulting from the combination of two main dimensions, namely (page 79): number of potential consumers and level of costs for exploiting the opportunity.

The work examines how business model components can fit with different situations, describing the result of an empirical investigation of eight companies.

6. 3D Printing and Supply Chains

The interplay between 3D printing and supply chains seems to have received rising attention in the literature. Our sample highlights an interesting set of contributions.

Most of the studies concentrate their attention on *how 3D printing adoption will affect supply chains processes* (Ryan et al. 2017; Oettmeier and Hofmann, 2016; Rogers et al. 2016; Durach et al. 2017). Some contributions deal with the topic trying to offer a comprehensive and rather broad view. For example, Durach et al. (2017), on the basis of an empirical investigation with experts, conclude that AM could be less disruptive in terms of change for supply chains as it is expected to be from a theoretical point of view, at least in the short term. Another interesting contribution is that of Rogers et al. (2016) who discuss the service dimension inherent to a widespread adoption of 3D printing across industries, formalizing a research agenda on how this will impact the configuration of the supply chains. Other studies propose taxonomies of supply chain management areas to be

impacted by 3D printing and AM. For example, Oettmeier and Hofmann (2016) discusses how AM may impact on five main key areas and related processes (page 954): the relationships with suppliers; the management of manufacturing flows; the development of the product; the relationships with customers; the activities related to the returns of goods. There are also studies that investigate the impact of AM in specific industries, with a more technical approach (Ghadge et al. 2018).

Some contributions try to understand the *impact of 3D printing on supply chain, taking into account an international perspective* (Hannibal and Knight, 2018; Strange and Zucchella, 2017; Laplume et al., 2016). These studies specifically address how the new technology may lead to a new division of tasks among players within international supply chains. Hannibal and Knight (2018) relate the AM adoption to the global factory concept and aim at understanding how the new technology will impact on the decisions to localize production in a global scenario. The two authors starting from the hypothesized AM's feature to “*hold the potential to “de-globalize” manufacturing of goods*” (page 4) highlight how the location of supply chain activities and production may depend from fourteen factors. This set of factors includes aspects related to the industry (such as industrial standards), to the specific product (such as size, material type), to the process of production and distribution (such as complexity, logistical features) and to the consumers (such as importance of brands, aesthetics, authenticity). Similarly, Strange and Zucchella (2017) propose a conceptual interpretation on the changing global value chain perspective, although the analysis is not related specifically to 3D printing, while they consider the wider concept of Industry 4.0. In discussing potential changes that Industry 4.0 may imply, the authors argue relevant challenges on how multinational enterprises manage global value chains taking into account the three dimensions of the O.L.I. paradigm, a well-known contribution within the international business academic debate. A noteworthy article in our sample is that of Laplume et al. (2016). The contribution of the authors lies on the discussion of three main factors that impact on how multinational enterprises manage production activities at a global level, that are (page 602): factor-cost differentials; scale economies; factors that hinder global specialization. Laplume et al. (2016) discuss the additive manufacturing according to those factors and propose what are the main implications for the localization of the activities. For example, the authors wonder how some impediments, such as cost related to transportation or import barriers, may be overcome or reduced by the use of 3D printing technologies. To summarize, while in our sample the analysis of the impact on supply chain is a relevant topic in terms of number of contributions, many of them remain conceptual in nature. Moreover, the perspective, especially in those contributions that analyze 3D printing and international supply chains are mainly related to multinational enterprises, with a lack of focus on small medium companies.

7. 3D Printing and Sustainability

Four papers regard the relationship between 3D printing technology and sustainability (Garmulewicz et al., 2018; Unruh, 2018; Despeisse et al., 2017; Ford and Despeisse, 2016). All the papers are explorative in nature, and employ qualitative methodologies of analysis. In particular, three of these papers mention

explicitly the *Circular Economy*, considering 3D printing as an enabler of this particular model (Garmulewicz et al. 2018; Unruh, 2018; Despeisse et al., 2017); the characteristics of 3DP seem to align well with sustainability and circular principals, creating a strong potential for moving economy toward a more efficient mode of production and consumption. The same additive nature of the process allows material savings and the reuse of waste material.

Researchers agree that AM brings many potential sustainability benefits, such as improved resource efficiency in production and use phases; extended product life; shorter, simpler, more localized and more collaborative value chains (Ford and Despeisse, 2016). One of the main implication of AM is the design freedom it allows; by redesigning components, products and processes, it may offer some relevant sustainability improvements. Moreover, more localized manufacturing, deriving from AM implementations, may impact on logistic and transportation processes: delivery will be more concerned about digital files and basic materials, rather than complex assembled products, creating a strong potential in terms of cost savings. In particular, Garmulewicz et al. (2018) pointed out the advantages originating from the use of recycled plastics as material input for 3D printing; by matching waste sources with demand of 3D printed products at a local scale, efficiency and efficacy gains of material cycling may be derived.

If significant potential benefits exist, it is not clear how the sustainability potential of AM may turn into reality, because of some challenges (Despeisse et al., 2017; Ford and Despeisse, 2016). For example, questions arise regarding the relative resource efficiency of centralized mass production in comparison to localized small-scale production. Some pitfalls may emerge from the lack of awareness of the environmental implications of AM practices by prosumers, that is private users who produce themselves; or from the toxicity of the material used for AM. Considering that 3DP is still early in its adoption curve, this is the time to opportunely influence its development according to a sustainable perspective; policymakers and regulators could guide this implementation process toward this goal (Unruh, 2018; Garmulewicz et al., 2018; Despeisse et al., 2017).

8. Additional Themes about 3d Printing

This category includes three distinct sub-themes: (1) evolution of the industries where 3D printing technologies are adopted and impact of 3D printing on industrial processes; (2) how mass customization and 3D printing are interlinked; (3) the ‘policy’ side of 3D printing implementation and use.

As for sub-theme (1), the major question posed by Kapetaniou et al. (2018), Attaran (2017) and Gibson (2017) regards how 3D printing is affecting currently the industries and what are pros and cons of implementing and using the technology. Although those articles appear rather descriptive all of them seem to face at least two specific topics, what are the industries more willing to promote and adopt 3D printing and what are the roles played by the industrial actors as enablers of the technology. By reviewing secondary data, Kapetaniou et al. (2018) provide a taxonomy of the industries considering the use of the technology. It seems that 3D printing is a matter of ‘niche industries’ where customers/consumers are heavily involved by the suppliers along the production process (eg. jewellery,

medical and dental tools, etc.). In a similar vein, Attaran (2017) identifies specific sectors where 3D printing is already providing benefits to the users such as the Aerospace industry, and the Author also points out that 3D printing should be considered ‘complementary’ technology to the traditional manufacturing processes. In addition, it is interesting the viewpoint of Gibson (2017) who stresses that the ‘niche’ industries where major benefits of 3D printing use are expected might be classified regarding the technology complexity of the products: low-end technologies vs high-end technology.

In sample only two contributions have been focused on the mass customization phenomenon (sub-theme 2). Berman (2012) faces in a descriptive manner the issue of comparing 3D printing with mass customization. Interestingly, the author points out that from an economical perspective in both the cases there are advantages since custom products might be produced at lowest prices. But Berman (2012) also highlight that mass customization implies to integrate the supply chain much more than in the case of 3D printing due to the presence of pre-assembled modular parts that might be supplied by multiple actors. Instead, the 3D printing takes advantage of automated manufacturing that is based on the use of CAD software. The article by Deradjat and Minshall (2017) focuses on how 3D printing may or may not support the implementation of mass customization strategy in a niche industry. The output of this research consists of a model based on a set of key variables (corporate strategy, technology, operational such as the product design, organizational, and external such as the customers) which are key to consider to understand the influence of 3D printing on mass customization; the contribution of Deradjat and Minshall (2017) holds in identifying the importance of acquiring competencies in relatively short time to implement mass customization processes supported by the use of 3D printing.

The sub-theme 3 – the policy side of 3D – is taken from the perspective of what policy makers should deal with in order to facilitate the exploitation of the 3D printing technology. Birtchnell et al. (2017) point out that government, industries and universities should increase the collaborations with the specific goal of pushing further the technology on the market. The authors underline how relevant might be the bridging role of universities to favor the knowledge transfer of 3D printing between suppliers and users in a setting where policy should coordinate and support such processes. The issue of how policy might support 3D printing diffusion is the central research object of Gartner’ study et al. (2015) that carried out an interesting survey with the aim of understanding what the perceptions of policy makers in this field are. It emerges that policy makers needs to be more active in order to reduce the common sense that 3D printing is more like a dream than a real ‘revolution’ by introducing new actions to provide public resources devoted to the current innovation systems. At more general level, the article by Kietzmann et al. (2015) strengthen the importance for policy makers to deal with intellectual property as a process that might be revisited since 3D printing calls for new ways of interpreting the ownership of the goods. This means that the collaborations with prosumers would deserve more attention also on the ethical aspects regarding 3D printing. The last contribution included in this sample is the work by Kaivo-oja et al. (2018) which takes the Finnish policy in the case of 3D printing as a case study to explain what the best conditions to support the development of such technology are.

Interestingly, the authors identify ‘critical and key challenges’ providing a roadmap for the government of Finland.

9. Final Discussion and Conclusions

This study has been triggered by the idea of understanding more the 3D printing concept from a business/management perspective. In this final section of the paper we try to lift up the discussion around the five identified themes by relying on the analysis of the content and characteristics of each group.

As pointed, we have identified five major themes that seem to have attracted attention at international level. Two of them have been more investigated than others, specifically (1) technology adoption of 3D printing; (2) how 3D printing impacts on supply chain structures and processes. This result is not unexpected since both the themes often appear at the center of many debates on technologies and innovation, moreover the supply chain is particularly intriguing due to its relation to production and operations. Therefore, our study confirms the attention paid by scholars towards more ‘traditional’ topics when investigating 3D printing.

However, the challenges posed by 3D printing regarding its implementation, adoption and effects from a business perspective are rather peculiar but not really investigated. There is a dearth of empirical driven studies which may be helpful to develop in order to contribute more on how 3D printing would affect companies and innovation systems as well: in fact, most part of the analyzed studies in our sample is conceptual and they offer only general insights regarding 3D printing and the related processes.

As for the left themes (3D printing and sustainability, 3D printing and business models, and the categories emergent from the additional themes section), we noticed that the debate is even less brought to the attention of management scholars. The theme of business modelling, for instance, is kept at very general and descriptive level. On a similar vein, the relation between 3D printing and sustainability although central in the debate doesn’t always provide enough insights probably due to its youth.

To sum up, most part of the analyzed studies are opening up interesting research avenues within the 3D printing from a technical aspects. But given the limited number of insights concerning the management perspective on 3D printing, in line with Ford et al. (2016) we suggest that a better understanding of this phenomenon and implications for management could be gained from carrying out empirical research aimed at exploring the business side of 3D printing. Exploring the business side of the 3D phenomenon would entail to go beyond the technical side of the technology and afford different issues such as how 3D printing may affect the firms’ dynamic in the local and global contexts. In other words, what might be intriguing is the understanding of the inter-organizational mechanism which may help to figure out how 3D printing brings value to companies in their surrounding context.

Therefore, we suggest to go beyond the logic that 3D printing concerns some specific and often technical themes instead it should be viewed in a more systematic manner by considering the impact that 3D printing would have in respect to the internal/external processes which characterize any company.

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