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Additive manufacturing for consumer-centric business models: Implications for supply chains in consumer goods manufacturing

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ABSTRACT

Digital fabrication—including additive manufacturing (AM), rapid prototyping and 3D printing—has the potential to revolutionize the way in which products are produced and delivered to the customer. Therefore, it challenges companies to reinvent their business model—describing the logic of creating and capturing value. In this paper, we explore the implications that AM technologies have for manufacturing systems in the new business models that they enable. In particular, we consider how a consumer goods manufacturer can organize the operations of a more open business model when moving from a manufacturer-centric to a consumer-centric value logic. A major shift includes 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. We discuss some of the main implications for research and practice of consumer-centric business models and the changing decoupling point in consumer goods' manufacturing supply chains.

1. Introduction

Additive manufacturing (AM), which is also known as rapid manufacturing or 3D printing, has emerged as a new and disruptive manufacturing technology that has major implications for companies and industries at large (Phaal et al., 2011). Given that the AM industry is currently assessed at more than $3 billion, with an expected rise to $13 billion by 2018 and $21 billion by 2020 (Wohlers, 2014), AM technologies have an enormous potential, although they also imply important and necessary changes to companies' business models—their logic of creating and capturing value (Afuah, 2014; Zott et al., 2011). As a hyper-flexible technology that can provide highly customized and personalized products and production, AM provides a specific set of opportunities and challenges for developing new business models (Piller et al., 2015; Ponfoort et al., 2014). In this paper, we analyze the recent advances in AM technologies and we explore their implications for business models in the consumer goods manufacturing industry, where they have a big potential to revolutionize the way products are produced (Berman, 2012; Gibson et al., 2010; Huang et al., 2013; Tuck et al., 2007).

Manufacturers of customized products in domains as dental, biomedical, fashion and apparel have so far successfully adopted AM technologies. The hyper flexibility of AM technologies allows for customized shapes, digital interaction with consumers and direct manufacturing, which gives benefits in terms of lower costs, reduced supply chain complexity and lead times, etc. However, despite the potential, many questions pertain, for example related to the justification for mass manufacturers of commodity products to use AM technologies, the types of business models that they would have to employ to capitalize on the flexibility that AM offers, and how these changes would affect their operations and supply chain structures. Accordingly, our research question is: How do emerging AM technologies impact business model development and operations in consumer goods manufacturing?

In this paper, we explore the new possibilities and challenges that AM presents to consumer goods manufacturers' business models with a particular focus on the potential to open up to a higher degree of consumer involvement and on the associated implications for the organization of production activities. In particular, shifting productive activities from manufacturers to consumers challenges the centralized nature of production systems and thus calls for a decentralization of supply chains. We will present an inductive study that is based on the general developments within AM technologies in the context of the consumer goods manufacturing industry. Specifically, we will propose that AM technologies fundamentally change the role of the consumer in consumer goods manufacturers' business models with a particular implication being that supply chains are becoming more distributed

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and decentralized to enable more personalized production of consumer goods. Effectively, productive activities shift from the manufacturer to the consumer, which leads to a need to decentralize and decouple the organization of the manufacturer's supply chain to embrace the central role of the individual consumer in the value creation-capture process.

2. Background

There is a diversity of perspectives on the business model concept in the literature, without a wide consensus regarding its precise conceptualization (Zott et al., 2011). In general, a company's business model describes its logic of creating and capturing value (Afuah, 2014; Osterwalder and Pigneur, 2010; Zott et al., 2011). The concept arose from the emergence of the Internet, the growth of emerging markets, and the appearance of postindustrial technologies (Zott et al., 2011). Consequently, the growth of e-businesses promoted the need for a value-capturing model as a reaction to the value potential that was created (Afuah and Tucci, 2001). On a more detailed level, a business model refers to a system of interdependent activities within and across the organizational boundaries that enables the organization and its partners to create value and capture part of that value (Zott and Amit, 2010). Amit and Zott (2001) moreover present a specific framework that comprises efficiency, complementarities, lock-in, and novelty to determine the value creation logic. Given that activities within a business model can also take place across organizational boundaries, the business model determines the logic of purposively managed knowledge flows in open innovation (Chesbrough and Bogers, 2014). Open business models accordingly use the "division of innovation labor" to create greater value by leveraging more ideas, resources and other assets that are available outside of the companies' boundaries (Chesbrough, 2006; Frankenberger et al., 2013; Vanhaverbeke and Chesbrough, 2014).

Recently, AM, a hyper-flexible technology that can provide highly customized and personalized products and production, provides a new set of opportunities for developing a new logic for creating and capturing value from such products and processes (cf. Piller et al., 2015; Ponfoort et al., 2014; Wohlers, 2013, 2014). These changes imply enormous challenges—not the least for incumbent manufacturers—addressing various aspects of traditional business models, such as the value proposition, cost structure and value chain (e.g. Afuah, 2014; Chesbrough and Rosenbloom, 2002; Osterwalder and Pigneur, 2010). Given that there are different AM technologies available in the market and that traditional manufacturing technologies are still widely used, manufacturing companies need to explore or experiment with new business models based on the emerging technologies (Brunswicker et al., 2013; McGrath, 2010). These exploratory processes imply an important interaction between technology and business model innovation (cf. Baden-Fuller and Haefliger, 2013), while furthermore making the link to the organization of production, including supply chains (cf. Bogers et al., 2015; Johnson and Whang, 2002; Koren, 2010).

3. A note on research design

The empirical base consists of the general developments in AM technologies, business models, and supply chains, although we also rely on the recent experience of a large internationally-oriented manufacturer within the plastic component industry. The company has been utilizing digital fabrication for the purpose of prototyping for more than 20 years, and it has recently been working toward the adaptation of AM as consumer goods manufacturing concept. While some of the observations and analyses in this paper are based on the company's experience, our ultimate objective is to present the general case of the consumer goods manufacturing industry.

Based on the original research that we conducted, with the above-mentioned empirical base, we engaged in an inductive study in which we built on our investigation of the state-of-the-art AM technologies to derive business models that could leverage the latent value of these technologies. In this iterative process, we identified particular characteristics of the business model that could be derived from considering both the general developments in the industry and the particular developments within the focal consumer goods manufacturer. Ultimately, this led to a specification of key business model design parameters and related implications for supply chains.

4. Additive manufacturing: from production technologies to business models

Here, we describe the state of the art of AM technologies, starting with AM as a manufacturing concept, and then leading up to a description of how AM fundamentally changes the logic of how companies can create and capture value (i.e. business models).

4.1. An overview of additive manufacturing technologies

In this paper, we refer to AM as the utilization of additive technologies for the production of customer-specific consumer goods. In contrast to rapid prototyping—the use of additive technologies for the manufacturing of single or multiple prototypes—AM is in principle repeatable and scalable as a production process. AM technologies have existed since the beginning of the 1980s—initially mostly as a prototyping tool—and they have recently emerged as a viable manufacturing technology due to significant improvements in part quality, price and manufacturing process time. Principles such as "lean" and "just in time" can also be considered here in the context of full-scale small batch production, with a focus on the customer and creating value, with more or less waste ("muda") (cf. Tuck et al., 2007).

In order to understand the different AM platforms and technologies, we conducted a detailed state-of-the-art[1] analysis of AM technologies.[2] We explored the different AM technologies' characteristics, advantages and disadvantages, and their feasibility for consumer goods production. Table 1 presents the six leading technologies that we identified, while Appendix A provides a more detailed overview of each technology, its method of operation, and its current main use.

The basic characteristics of these emerging AM technologies have important implications for consumer goods production systems. Based on our analysis, we identified a number of dimensions that we consider essential to assess the feasibility of each of the AM technologies (see Appendix B for a more detailed assessment).[3] These dimensions are the components of production that must be satisfied for AM to be recognized as a feasible production concept. Table 2 shows a description of the dimensions as well as the results of the comparison of the different technologies based on these dimensions. In the table, a score of 5 represents high (i.e. optimal) results, while a score of 1 represents low (i.e. critical) results. Results are benchmarked to existing injection molding manufacturing capabilities and have been evaluated with the use of experts in AM production processes. While Appendix B provides a more detailed assessment of the AM technologies in consumer goods production systems, we will focus (below) on the overall assessment and subsequently present the implications for business models.

[1] The analysis was concluded in 2014, which is therefore the reference point for this analysis.

[2] We note that the technologies explored in this paper are polymer AM production technologies alone. Several technologies use metal as well for rapid tool manufacturing and general metal production, such as Selective Laser Melting (SLM) or Metal Selective Laser Sintering (MSLS). Other technologies use wax and ceramics as base materials. These technologies will not be explored in this paper as the focus (in the consumer goods manufacturer that serves as the empirical base) is plastic parts production for consumer goods.

[3] Our analysis is primarily based on the assessment of the potential of AM technologies for the large consumer goods manufacturer that serves as the empirical base in this paper, while it thereby, at least indirectly, also extends to a part of the consumer goods industry at large.

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