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The co-evolution of business models and eco-systems

A case study on the changing landscape within 3D-printing

Master's thesis in Management and Economics of Innovation

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ABSTRACT

3D-printer manufacturers, the business model they uses as well as the industry structure are in general severely understudied, especially when comparing to the overall interest shown in 3D-printers lately. Previous research has shown, and emphasized, the importance of considering business model innovation together with eco-system development to understand the drivers for business model innovation. This study aims to investigate the change in business models for 3D-printer manufacturers when the 3D-printer becomes increasingly used for mass-production instead of prototyping. During this study I have been embedded in a 3D-printer manufacturer in the greater Boston area to understand the internal discussion within this company which aims to launch a 3D-printer for mass-production. For understanding the general 3D-printer manufacturer I have also drawn on experts advising the company I was embedded within. I have also used secondary sources to understand the industry. The result shows that there are three components of business models in this industry; the 3D-printer, the materials, and services provided. The main difference for companies with a 3D-printer aimed for mass-production compared to those which has a 3D-printer mostly aimed for prototyping is the approach towards materials. For the materials the industry is moving towards becoming less vertical integrated where a greater emphasis is made on outside partners to produce the material used in a 3D-printer. This vertical disintegration is then affecting the business models. Therefore, I conclude that there is strong evidence for the interactive relationship between business model innovation, vertical disintegration, and eco-system development.

Keywords: Business model innovation, Business model, Vertical integration, 3D-printing industry

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Introduction

Additive manufacturing, also called 3D-printing, emerged in the 1980s when the company 3D Systems was founded. Observers have predicted that 3D-printing will disrupt various industries. However, disruption has, thus far, generally not been the case. It has been suggested that 3D-printing enables business model innovation, mainly due to shorter supply chains and mass customization (Rayna and Striukova, 2016). However, the overwhelming focus when discussing 3D-printing, and potential disruption, has been on how companies *using* 3D-printers may increase the captured value and disrupt their industry. Absent from the research is a focus on the *manufacturer* of 3D-printers. Also absent from the discussion is how the manufacturer of 3D-printers may access the increased value created when companies are using 3D-printers.

For the aforementioned users of 3D-printers, they are said to have adopted 3D-printers in four different steps: first as a means to produce prototypes, and then as a means to create molds for customized tools (Rayna and Striukova, 2016). The third step is for 3D-printers to produce the end product directly. The final adoption is localized fabrication, which has happened during the last 10 years (Rayna and Striukova, 2016). It is suggested that 3D-printers will emerge on the same trajectory as other disrupting technologies, mainly 2D-printers and home computers (Rayna and Striukova, 2016). 3D-printing is a diverse industry encompassing many different technologies and price points: a metal, industrial, printer may cost US $1 million while the simplest plastic desktop printer may cost US $500. There is also a great diversity in the size and use cases for 3D-printers, scaling from industrial to home use cases. As a result, comparing the steps of adoption and trajectory of 3D-printers with the paths of 2D-printers and home computers may blur the boundaries between business-to-consumer and business-to-business.

Since the focus has been on the adoption on 3D-printers and the users of 3D-printers the different technologies which can be used to 3D-print a object is then often glossed over. However, when analyzing the 3D-printing industry, it's necessary to understand the technology. For example, the same part may be printed using various, different, 3D-printing technologies. It is therefore necessary to understand the differences the technologies offer. 3D-printing technologies may differ on the print speed, time and cost required for post-processing, as well as the cost for printing (Gibson et al., 2015). A key difference between technologies is the material available which plays a very large role when a customer selects a technology. In addition, some companies, for example Digital Metal, 3D Systems, EOS, and GE Additive, offer automation of some or all of the process by adding robotics (Griffiths, 2018). The offerings for automation is in the very early stages. With increased automation, the need for manual labor decreases, which can further improve the viability of 3D-printing for mass manufacturing. Automation will also increase the possibility of the use of 3D-printing in industrial and mass manufacturing because of the potential of integrating a 3D-printer with other parts and processes on a manufacturing floor.

The ability to integrate a 3D-printer with other aspects of a manufacturing floor is becoming more important since 3D-printers are increasingly used for direct manufacturing, called the third step by Rayna and Striukova (2016). One of the early adopters of 3D-printing for end product manufacturing was the hearing aid industry (Sandström, 2016). One other industry which has adopted 3D-printing for large scale manufacturing is the dental aligner industry, led by Align Technologies (McCue, 2018).

To further understand the technology and the uses cases of 3D-printers, there is a need to understand the general applications when using a 3D-printer is valuable, compared to traditional manufacturing. Those applications can broadly be described as three different categories, or reasons for using 3D-printers. One is design freedom. Design freedom enables complexity of parts. 3D-printing is advantageous when a part is complex and hard to make with traditional manufacturing. Due to the design freedom inherent in 3D-printing, increased complexity does not correspond with increased cost. On the contrary, in traditional manufacturing, an increase in complexity almost always corresponds to an increase in cost. It could even be argued that complexity saves cost when 3D-printing. For example, the amount of material used is lower for a complex 3D-printed part. Another use case for 3D-printing is small series production. It is advantageous to use 3D-printing for creating a small number of parts since the set-up costs are low. Therefore, it is easier to make customized parts or prototypes. The last use case for 3D-printing is when it brings efficiency gains, for example when it is possible to produce a part entirely, termed part consolidation.

1.1 Problem-statement and research question

3D-printing is standing before a large shift in use, from being mostly deployed in prototyping and other small series production. The focus is slowly shifting towards 3D-printers being used in mass-manufacturing. This shift will entail a technology shift since the requirements by a 3D-printer and the competencies and assets of an organization is perceived to be different after this shift has occurred. It is therefore possible that this shift may produce a change in the industry, and especially a change in the composition of the industry. With a change in industry, and especially the composition of an industry, there is sometimes a shift in the business models used by companies in the industry undergoing changes. This shift is extensively covered from the point of users of 3D-printers and how this shift may change many industries. However, the focus on the manufacturers of 3D-printers and the 3D-printing industry are, generally, absent.

With the shift the 3D-printing industry most likely will experience within the near future and the possibilities for these changes to affect the manufacturing industry at large, I would argue that it is of interest to understand the ongoing changes within 3D-printing from a 3D-printer manufactures point of view. It also gives an opportunity to further explore the developments of industry structures, eco-systems and business models and how they develop interdependent of each other. It is interesting to explore and understand the reasoning for interdependent developments in business models because, as stated by Björkdahl and Holmén (2013), "More generally, we argue that the business model(s) and the eco-system of actors co-evolve but further research is needed to identify and analyse the mechanisms or sources of the changes"(p.223). Hence, this research will aim to give further clarity to the problem stated by Björkdahl and Holmén (2013)

There is, therefore, a need to understand the business models previously used by manufacturers of 3D-printers, and how those business models may fare when the 3D-printers are used for mass-manufacturing. There is a company, Inkbit, which is going to launch a 3D-printer for mass-production. Since this company is focused on launching a 3D-printer aimed for mass-manufacturing instead of prototyping and small series production it is interesting to study this company. It is interesting to study this company beacuse it would be possible to compare the findings to the industry as a whole.

This report will therefore answer the following question; How and why does the business model, and the immediate eco-system, for a 3D-printer manufacturer change when 3D-printers are used for mass-production instead of prototyping?

2

Theoretical framework

In this theoretical framework I will present literature on vertical integration and disintegration, servitization, and business models, including, business model innovation. Those three parts have all been found to be of importance when answering the question asked in this study

2.1 Vertical integration and disintegration

Starting with vertical integration and disintegration, some different reason for the occurrence of vertical disintegration have been found in the literature. Those are the technical development of products, the market size, and enablers for vertical disintegration.

Starting with technical development, industries which experience technical development tend to first be vertically integrated and then to vertically disintegrate as the technical development progresses (Christensen et al., 2002). Industries are first vertically integrated because the different subsystems which makes up a product needs to be developed interdependently to achieve the best performance (Christensen et al., 2002). Therefore, it is better for a company to be vertical integrated since it can develop the subsystem, and hence the product, without relying on a third party. However, as the technical development progresses the product tends to be 'good enough' for its purpose (Christensen et al., 2002). When the product becomes 'good enough' the need for technical development decreases and instead there is a need for process development (Christensen et al., 2002). This, in turn, decreases the interdependencies of the different subsystems which the product is built of. When the interdependencies decreases it is then possible for different companies to produce and develop only one or a few subsystems instead of the whole product which would mean that the industry becomes disintegrated (Christensen et al., 2002).

Furthermore, it has been observed that vertical integrated firms are present in small markets due to small markets not being able to support specialized firms (Stigler, 1951). Hence, Stigler (1951) observed that vertical disintegration could occur when the market was large enough to support specialized firms.

Jacobides (2004) have further examined and focused on vertical disintegration and builds upon the work of Stigler (1951), by stating that vertical disintegration does not always occur, even when the market is large enough and can support specialized firms. Jacobides (2004) then states that there are three enables for vertical disintegration, necessary conditions, enabling processes, and motivating factors. The necessary conditions, as stated by Jacobides (2004) are coordination simplification and information standardization. Coordination simplification means that interdependencies has been reduced and, hence, it is easier to organize different steps in different companies. This is consistent with the reasoning presented by Christensen et al. (2002), stating that industries could become disintegrated when a product can be broken into subsystem. Information standardization is, as the name suggest, standards which enables transactions. Enabling processes consist of, according to Jacobides (2004), intrafirm partitioning and interfirm co-specialization. Intrafirm partitioning means that companies are divided into separate divisions which may source from within but also outside the company. Interfirm co-specialization is the advantage of using other companies' capabilities as a complement to the own company's capabilities. Lastly, motivating factors, per Jacobides (2004), is gains from specialization and gains from trade. Gains from specialization is the advantages realized when separating divisions which requires different leadership styles, knowledge, and incentives. Gains from trade is the benefits received when trading with other firms compared to creating everything within the company.

2.2 Business models

In the literature there is a disagreement on the definition of a business model (Zott, Amit, and Massa, 2011). Even with this disagreement business models have been described, on the very basic level, as the way companies conduct business or the logic through which a company earns money (Zott, Amit, and Massa, 2011; Osterwalder and Pigneur, 2010). However, there are some components of a business model which are frequently recurring. Those are: value proposition, value creation, value capture, and value delivery (Rayna and Striukova, 2016; Desyllas and Sako, 2013; Osterwalder and Pigneur, 2004; Shafer et al., 2005; Chesbrough and Rosenbloom, 2002; Johnson et al., 2008)

Those components, and other building blocks where put together by Osterwalder and Pigneur (2010) in the business model canvas. In the canvas a business model can be described with nine building blocks. Those nine building blocks are; customer segments, value proposition, channels, customer relationships, revenue stream, key resources, key activities, key partnerships, and cost structure. The business models canvas describes how a company creates, delivers, and captures value.

Another consideration of a business model is how it defines the boundaries of the firm and how it defines the firms interactions with other companies. This is to some extent covered in the building blocks by Osterwalder and Pigneur (2010), and especially the key partnerships. Zott and Amit (2010) further adds to this by defining a business model "as a system of interdependent activities that transcends the focal firm and spans its boundaries" (p.216).

The discussion of business models and the boundaries it sets for a firm is connected to the very basic idea of a business model, namely how a company conduct business. The way a company performs its business will impact how it interacts with other firms, and therefore a business models is argued to include how vertically integrated a firm is (Casadesus-Masanell and Ricart, 2010; Itami and Nishino, 2010)

For this article I will combine the above, and being influenced by the definition of a business model used by Zott and Amit (2010) as well as Berglund and Sandström (2013), to define a business model as a set of activities that states how the company will create and capture value as well as defining the limitations of the firm.

However, business models are not stationary or fixed. They are instead subject to innovation, in the same realm as technology. The co-dependency of technological development with the need for business model innovation has been shown in research. For example, when a company innovates a new technology, that innovation can either fall within, and may use, the current business model of the company or the innovation may need a new business model (Chesbrough and Rosenbloom, 2002). When an innovation falls outside the current business model, it is important for the company to apply the, for the situation, correct business model. Since the business model enables the commercialization of the product (Chesbrough and Rosenbloom, 2002). This reasoning by Chesbrough and Rosenbloom (2002) is corroborated by Björkdahl (2009) which found the importance of business model innovation for a firm's ability to capture the created value from a technological change.

Even though the business model is important for a company's ability to capture value, a well-developed business model does not guarantee a competitive advantage. A business model is often easy to imitate and therefore does not, on its own, creates a sustainable competitive advantage for the firm which first launches the business models (Teece, 2010; Jacobides and Winter, 2012). Even though the single firm may not stand to benefit from the business model innovation, due to the absence of sustainable competitive advantage, the industry might undergo significant change due to the introduction of the business model (Jacobides and Winter, 2012). The possibility for a business model to significant change the industry is also dependent on where the value is captured. Björkdahl (2009) states that it can be assumed to be harder for a company to introduce a business model which tries to capture more value than previous models, especially if the customer is accustomed to receive some of the value created for free. There is, hence, a possibility to change the industry when introducing a new technology coupled with a new business model but it's much harder to shift value captured to the producing company by only introducing a new business model.

When performing business model innovation, the focus has been on the internal capabilities, resources and internal focus of the firm. Brink and Holmén (2009) states that the business models which a company adopts and uses is related to, and even constrained, by the internal capabilities of the firm. The focus on internal capabilities and challenges for business model innovation in the existing literature has been highlighted by Berglund and Sandström (2013). However, a business model defines the boundaries of a firm but also the interactions with other actors. Berglund and Sandström (2013), therefore, argues that it is vital to consider the system which the firm is operating within. This is because, there are significant interdependencies within the ecosystem of the firm. The choices of suppliers and customers are effecting the company and what kind of business model it, ultimately, will develop. The ecosystem view on business model innovation is repeated by Schneider et al. (2013) where shifting trends and shifting focus on a company's supplier and customer leads to disruption within the business model.

There is a direct connection between the boundaries of a firm and to what extent a firm can capture value from a technological development. This connection is made of the complementary assets, because the complementary assets needed to successfully commercialize a technology is key (Teece, 1986). The two different avenues a company can take is to either contract out or internalize the complementary assets needed to commercialize the product (Teece, 1986). Depending on how special those assets are to the situation, i.e. specialized complementary assets, there are different problems and consideration needed. If the company does not have the means to acquire the assets the company should enter into an agreement to get access to those assets on the market (Teece, 1986). However, depending on the level of specialization needed and therefore how much the supplier must alter the operations there is several hazards to take into consideration (Teece, 1986). Another important aspect to consider is the power the complementary assets gives to its owner. If a technology is easy to replicate and also depends highly on complementary assets which the innovator cannot easily create, much of the power is going to be in the hand of the owner of the complementary assets (Teece, 1986). With this power comes then the likelihood of capturing the most value from the technology. Some companies might become forced to give up this power and subsequently a large part of the profits if they want to stay in business. At the same time, companies might benefit immensely by acquiring assets which they cannot create in a timely and cost effective manner, for example branding (Teece, 1986).

This focus on complementary assets and whether to internalize them or contract for them is to some extent the interfirm co-specialization previously discussed by Jacobides (2004).

With this, it is possible to see the strong connection between the boundaries of the firm, the possibility for capturing value but also the possibility for creating value. Hence, there is a strong connection between the vertical integration and disintegration and the business model of a firm. Since the changes within the ecosystem drives business model innovation the changes to the vertical integration of an industry could therefore be assumed to impact the business models. Consequently, vertical integration is about what kind of capabilities the firm has and need to satisfy the customer. Similarity, the business model can be argued to combine the capabilities demanded by the customer to create value. The capabilities are also responsible for the value a specific company may capture.

2.3 Servitization

For manufacturing companies, there is a trend of offering services instead of, or as a complement to, their products (Cohen et al., 2006; Neely, 2008; Fang et al., 2008). Neely (2008), stated that approximately 60 percent of manufacturing firms in the US were, in 2008, offering some form of service, for example aftermarket service. The shift from products to product-service systems stems from a more global world. Manufacturers located in developed economies need to compete with manufacturers located in developing nations on the price offered to customers (Neely, 2008; Cohen et al., 2006). Introducing product-services instead of products also provides a total customer solution, which improves competitiveness and mitigates the risk of product commoditization (Neely, 2008; Fang et al., 2008). Companies which in the last twenty years have begun offering services includes ABB, Caterpillar, IBM, and GE (Cohen et al., 2006). One well-known case of shifting from a product-based to a service-based business model is Rolls-Royce, which offers airplane engines on a 'power by the hour' basis.

Even though the trend has been to add services to a core of product offer, or to substitute a product offer, with a service offer, the results are mixed on its impact on profitability (Kastalli and Looy, 2013). One of the challenges comes from the difficulties for a company to change direction and focus (Kastalli, Looy, and Neely, 2013). The challenges faced by manufacturing firms shifting to services, has been compared to the challenges faced by firms which adopted the Japanese manufacturing methods in the 1980s (Kastalli, Looy, and Neely, 2013). It has been suggested by, Kastalli and Looy (2013), that the challenges and risks may be mitigated by implementing an integrated product-service business model. Kastalli and Looy (2013) further states, that an integrated product-service business model will view services as a strategic complement instead of an add-on. If a firm focuses too much on products and not on the service, some salesmen might be inclined to offer services for free in order to secure the product sale (Kastalli, Looy, and Neely, 2013).

The mixed result on profitability and the challenges in implementing services will therefore have some financial implications. However, it has been noted that the financial impact of services is first negative but becomes positive once a critical mass of service sales has been reached (Fang et al., 2008; Suarez et al., 2013). To further create a good financial impact by launching services, companies should prioritize services which are closely related to the core-offering since this will translate better to good financial results (Fang et al., 2008). One explicit tactic, of offering services which are related to the core offering, is selling solutions, meaning the combination of services and products to create synergies. To avoid some of the pitfalls and challenges previous mentioned, it is suggested that firms should avoid unrelated services (Fang et al., 2008).

Another important finding, when Fang et al. (2008) evaluated the value created by firms which adopted services, is the context of the industry in which firms operates. The findings of Fang et al. (2008) suggest that in an industry with high turbulence and competition, it is more advantageous to implement services than in an industry with low turbulence and competition. The findings further suggest, that it is better to implement services in an industry which has low growth than in an industry with high growth. Fang et al. (2008) suggest that managers should avoid adding service initiatives when their core product offering is in a high growth market. The reason given is that to add services offerings and to start service initiatives, there are significant effort and resources needed. The effort and resources needed are amplified if the company is inexperienced in launching service initiatives. Those resources can be better used in capturing the growth in the core product market.

The previous discussed of complementing a core offering with services, which would mean to still sell the product. There is also a trend to move further in servitization and to offer the equipment as a service. Which means that the company is supplying an integrated services and the customer does not buy and own a product. This trend, to offer something as a service, could be attributed to the software industry (Butron et al., 2019). When selling software, moving to a service model is easier and does not incur much risk since the cost of duplicating code is very low. However, the introduction of services when selling equipment is riskier since the unit cost is significant. When introducing services there is a need to understand the pricing for that service, as for any business model it is important to understand how to price the offering.

According to Butron et al. (2019) there are two different pricing models when supplying equipment as a service, with two subcategories in each, for a total of four different models. The two different models are deemed to be outcome-based models and time-usage-based models. For the outcome-based models, it could either be tied to financial outcomes or to operational outcomes. An operational outcome model is argued to be good for machines performing predetermined, and precise assignments, for example robots which are payed per completed cycle. Financial outcome models are useful when the usage of the equipment is tightly coupled to a financial performance, for example cost savings. The time-usage-based models have the two subcategories of time-based and usage-based. For a time-based model the equipment is, as the name suggests, paid for by the time it uses. One example being Rolls-Royce and 'power by the hour', in which the payments of engines are tied to the hours flown. In the usage-based model the equipment is paid for by how much it's used, for example by kilometer driven. Butron et al. (2019) states that equipment as a service will deliver more revenue than selling the products over a 10-year lifetime of a product. In their model, the service delivers less initial revenue, for the firm supplying the service, but will overcome the product sale after six years.

However, selling the equipment on an outcome-based model requires that the supplier is able to measure the value created by the machine. It also requires an adequate sharing of the risks, for example the failure of an application which is produced by the machine. If the manufacturer of the equipment is not able to adequately measure the delivered value, the manufacturer should instead consider a time-usage-based model or abandoning equipment as a service and instead sell the machine.

3

Method

This study was done as an inductive case study on the 3D-printing industry by focusing on the 3D-printer manufacturer. The case study was conducted in two, interconnected, phases. First, during the duration of the study I was embedded in a company, Inkbit, which is launching a 3D-printer aimed to be used in mass-production. Second, I used interviews, data from the company and secondary sources to acquire data about the general 3D-printer manufacturer in addition to the data from the company I was embedded within. The techniques used for gathering data during my time embedded within Inkbit was both a complete participation study as well as a semi-concealed study.

I was continuously informed by the literature review on business models, vertical integration and servitization which expanded throughout the study. This was needed for me to understand and explain the data. Moreover, the literature on business models, and especially the literature on business model innovation highlighted some challenges or questions which previous researchers wished to explore more. Hence, it guided the research question.

In this section I will explain the method and also the reasoning for doing the case study, including explaining the two parts of the case study. I will start with explaining the method used when I was embedded at Inkbit and then explain the method used for understanding the general 3D-printer manufacturer. Those two parts will be used to construct the result and analysis of this case study.

3.1 Embedded at Inkbit

For the duration of the case study I did a complete participation observation and semi-concealed research by being embedded at Inkbit, a company which will launch a 3D-printer aimed for mass-production. Inkbit is located outside of Boston, USA. The research is defined as participant observations since I was defined by my role as, foremost, employee to Inkbit (Easterby-Smith et al., 2015). Often, complete participation implies that others are not aware of the researcher being a researcher, or that people are considering this fact irrelevant, this is called covert research (Easterby-Smith et al., 2015). During the period of the research I did not do covert research. Instead I performed a semi-concealed research which means that some, but not all, are aware of the research being performed (Easterby-Smith et al., 2015). Those aware of the research were the company executives and some of the employees. However, in meetings with outsiders, i.e. customers and suppliers to the company I did not state that I was performing research. This was done as to not take focus from the reason for the meeting and enabled me to participate in the meeting as an employee and therefore gather important data.

Most of the data from the company comes from participating in various meetings, both internal and external. External meetings consisted of meetings with customers and suppliers. Internal meetings consisted of company-wide meetings and workshops to understand the reasoning of the company. One meeting, in particular, was with a vice president of additive manufacturing at a large materials manufacturer. This person will henceforth be referred to as a VP, or a VP of a materials manufacturer.

The participation observation was done to understand the challenges facing a company introducing a 3D-printer for mass-production. This include understanding the demands for customers, the wishes from suppliers and the reasoning by management.

3.2 Understanding the general 3D-printer manufacturer

The understanding of the general 3D-printer manufacturer is tightly coupled to the participant observation study, which was done when I was embedded at Inkbit. There is a tight coupling here because data gathered during the participant observation was sometime also about a typical 3D-printer manufacturer. I also frequently asked questions to Inkbit managers to understand the general 3D-printer manufacturer.

However, the data for understanding the general 3D-printer manufacturer also consists of interviews with experienced executives, personal knowledge from the 3D-printing industry and secondary data. Starting with the interviews of experienced executives, I have done frequent interviews with two experienced executives in the 3D-printing industry. They were chosen due to their experience but also from being connected to Inkbit, meaning that I had easy access to them. The interviews were semi-structured, meaning that I as the interviewer steered the interview in a desired direction but let the interviewee discuss and explain freely within that topic. The topic for the interviews where typically the business models used by 3D-printer manufacturers, the structure of the industry and the reason for using 3D-printers.

Interviews are deemed to be good when the interviewer want to understand the world from the interviewee's perspective (Easterby-Smith et al., 2015). This was something I sought to understand due to the, what I perceive as, lacking information of business models used by 3D-printer manufacturers. It was therefore crucial to get the viewpoint from those executives.

Furthermore, secondary data on the general 3D-printer manufacturer was gathered. This secondary data consists of state-of-the-art industry reports, well known 3D-printing news agencies, company reports, company websites and news articles. There are a couple of advantages to using secondary data, among them being the ability to get historical perspective and to save time (Easterby-Smith et al., 2015). For this study the secondary data was used as a mean to corroborate the findings from the participant observation study and the interviews.

3.3 Analysis and procedure

Since I knew of Inkbit and what the company tried to do from the onset of the study it was natural to begin the study embedded at the company. This enabled me to straight away inform myself of the company, the industry, competitors, potential customers and the challenges the company was facing. This also enabled me to gather data for a prolonged period.

During the time I was embedded at Inkbit I would also, naturally, perform analysis as data was gathered. It was necessary to perform analysis alongside the data gathering for me to understand the industry and understand what knowledge I was missing and hence what new questions I needed to ask and which new secondary data to consider. From this continues analysis some trends and areas of focus was developed which guided the rest of the study.

This study has therefore been a quite deep study in understanding the 3D-printer manufacturer. Thus, it gives the study reliability and validity due to the quite limited industry considered but also the data considered, where secondary data was consulted to give a full picture of the industry. However, the generalizability of the study could be limited, meaning that it is possible for the findings of this study to solely apply for the limited case of 3D-printing and 3D-printer manufacturers. Some of the findings in this study could then benefit from being corroborated from a similar study within another industry context. However, some of the findings is specific for the study, due to uncovering the business models of the general 3D-printer manufacturer. Something I argue, in the introduction, is needed due to the absence of business models for 3D-printer manufacturers in the literature of the revolution of 3D-printers.

4

Empirical data

In this section, first I cover the general findings from the 3D-printing industry and the point of view from a general 3D-printer manufacturer. Second, I then describe Inkbit as well as report on the findings from my time embedded within the company.

4.1 The general 3D-printer manufacturer

When covering the general 3D-printer manufacturer I'm first stating the results covering the 3D-printing industry. I'm also stating the findings on how the industry is structured. Following this, I'm presenting the findings regarding the business models for a general 3D-printer manufacturer.

Starting with the beginning of 3D-printing, the foundation comes from the 1980s with the invention of stereolithography, in which a laser is used to solidify liquid polymers (Wholers, Campbell, and Caffrey, 2016). In the 1990s other technologies were invented, among them FDM, a material extrusion technology, by Stratasys (Wholers, Campbell, and Caffrey, 2016).

From this start the industry has evolved and nowadays experts within the industry say that the 3D-printing sector mainly consists of four actor or roles a company may take; materials manufacturers, 3D-printer manufacturers, service bureaus, and OEM-users of 3D-printing systems. The actors taking the roles can all be different or an actor can assume several roles, meaning that there are some different forms of vertical integration.

To further explain the possibilities of vertical integration, there is a need to state the findings regarding a printer and the subsystems it consists of. Therefore, a general 3D-printer can be explained through a triad, in which the different corners signify each component of a 3D-printer. Those components have been understood to be software, hardware, and materials. They are connected by the process of 3D-printing. The outline of this theory, which has been presented by a 3D-printing executive, can be seen in figure 4.1.

The reasoning for the expert to include materials as a subsystem to the 3D-printer is

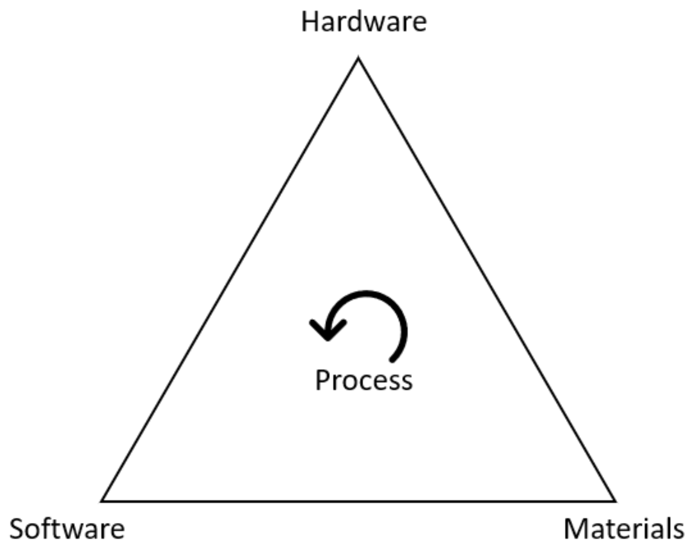

Figure 4.1: Components of 3D-printing

because, according to him and other experts, the modus operandi in the industry is for manufactures of 3D-printers to develop proprietary materials for their proprietary printers. A 3D-printer manufacturer will, in the general case, develop the materials that the printer uses in-house. The production of the material, however, can be done by either the 3D-printer manufacturer itself or a contract manufacturer. Regardless of what company manufactures the materials, it is sold by the 3D-printer manufacturer. For 3D Systems in 2019, the highest gross margin was achieved by the materials business with a gross margin of 68.8 %, the second highest was achieved by the services division with a gross margin of 50.4 %, lastly the lowest gross margin was in the products division with 17.9 %.

3D System is mentioned previously as well as Stratasys because they are the two largest 3D-printing companies in the world, both by number of 3D-printers sold and revenue. They are listed on stock exchanges and thus publish key financial data. The revenue for Stratasys and 3D Systems can be seen in table 4.1 and table 4.2, respectively. For Stratasys 'Products' includes both sales of 3D-printers and consumable materials. Consumables materials refer to materials used in their printers (Stratasys LTD, 2020). Services refer to both the service bureau as well as maintenance contracts (Stratasys LTD, 2020).

For 3D Systems products refer to the sale of 3D-printers, materials refer to the materials used by customers in the 3D-printers, and services relates to 3D Systems' service bureau as well as other services (3D Systems Corporation, 2020). To enable a comparison between 3D Systems and Stratasys, products and materials were combined for 3D Systems in the end of table 4.2

Table 4.1: Stratasys Revenue and Gross Profit

Year ended December 31, US $ in millions			
	2019	2018	2017
Products	430.7	456.5	474.3
Gross profit	248.3	252.9	255.3
Gross profit margin, %	57.6	55.4	53.8
Services	205.3	206.7	194.1
Gross profit	65.4	72.3	67.5
Gross profit margin, %	31.8	35.0	34.8

Table 4.2: 3D Systems Revenue and Gross Profit

Year ended December 31, US $ in millions			
	2019	2018	2017
Products	215.5	259.1	210.3
Gross profit	38.5	79.9	52.6
Gross profit margin, %	17.9	30.8	25.0
Materials	169.1	170.1	168.8
Gross profit	116.2	119.5	123.0
Gross profit margin, %	68.8	70.3	72.9
Services	244.5	258.4	266.9
Gross profit	123.3	125.0	129.2
Gross profit margin, %	50.4	48.4	48.4
Products and materials	384.6	420.2	379.8
Gross profit	154.8	199.4	175.6
Gross profit margin, %	40.2	47.5	46.3

4.1.1 Business models in 3D-printing

According to an interview with an experienced salesman in the industry the traditional business model within 3D-printing is the one launched by 3D Systems. The salesman calls the business model the ’3D Systems Model’. This model consists of three aspects; selling printers, selling materials and providing services. Services includes both services for the installed base of printers but also printing parts akin to a service bureau. This model has been used by 3D Systems since its inception. According to senior executives within 3D-printing, this model has been the status quo model for almost all companies in the industry. The term ’the 3D Systems model’ was repeated, independently, by a VP of a materials manufacturer. They also corroborated the business model of 3D-printing manufactures as being selling 3D-printers, selling and developing materials, and offering services both as a service bureau and servicing the 3D-printers.

With this being the traditional business model used by most manufacturers of 3D-printers, findings within the three different components will be presented: 3D-printers, services, and materials.

3D-printers

The traditional business model used for supplying 3D-printers in the 3D-printing industry consists of selling 3D-printers. This has been mentioned by all sources. However, two newly founded companies, Carbon3D and Wematter, supply 3D-printers through a subscription model instead of selling the 3D-printers (Carbon 3D, n.d.; Wematter, n.d.). This is the only business model offered by those companies, meaning that it is not possible to buy the 3D-printer from them, even if a customer wants to.

This business model by Carbon3D is mentioned in an interview with a 3D-printing expert, where Carbon3D is said to be the first 3D-printing company in the US to launch a subscription-based business model instead of outright selling 3D-printers. The expert builds upon this and states that two other companies, HP and Desktop Metal, are following Carbon3D by launching a subscription-based model for some of their 3D-printers. Carbon3D's business model is to supply a 3D-printer where the customer pays a fixed amount per year with a minimum contract length of at least three years. HP's model is for the customer to pay per successful print.

The expert continues to state that Carbon3D's business model is subject to criticism. In Carbon3D's case, the business model is an 'all or nothing', meaning that the customer cannot choose between receiving the printer and pay a subscription or to purchase it. The only option available is subscription. The salesman suggests that customers want the choices depending on what fits their operations best. Another reason that Carbon3D's model has gotten criticism is that it does not allow customers to amortize the cost of 3D-printers and to then use the 3D-printers without the cost showing in the income statement.

The differences between a subscription-based business model and selling the products where further highlighted by a former executive at a 3D-printer manufacture. He said that they tried the subscription business model but ultimately chose a transaction-based business model. Furthermore, he said that there are a couple of 'pros and cons' with the different approaches. The drawbacks of selling the products include the risk of not capturing the value created by the end user of the 3D-printers. However, the positive implications of selling 3D-printers are two important ones. First, the risk, and cost, of building the 3D-printer is adequately shared with the customer, since a large part of the cost is recouped by the sale of the 3D-printer. Second, the company selling the 3D-printer gets paid regardless of the outcome of the applications the 3D-printer is intended for. In a service-based business model the 3D-printer manufacturer is dependent on a successful application since the 3D-printer will not be used, and hence paid, without a successful application. According to another interviewee, one difference between a product-based business model and a subscription business model is the financial implications. In the subscription case the manufacturer needs to bear the costs upfront and then recoup the costs over time. While in the product case, the manufacturer recoups the costs when the 3D-printer is paid in full upfront.

Materials

When it comes to the material used in a 3D-printer there is a difference between metal and plastic. The metal material is produced by a materials manufacturer. Metal 3D-printer manufacturers are thus not focused on developing materials, instead they are focused on developing printers which are able to handle the different standardized materials available. For the development of plastic materials, it is instead common for the 3D-printer manufacturer to develop the materials used in its printers. The formulation, meaning the mixing or manufacturing from standard components, of the material is often performed by the 3D-printer manufacturer. Hence, different components are sourced from various manufacturers but they are combined by the 3D-printer manufacturers. The manufacturers which produce the various components of the material does not participate in the value chain apart from supplying the ingredients for the final formulation.

One interviewee says that when the 3D-printer manufacturer produces the material they are able to enjoy high margins. He further states that a typical margin is around 70 percent but that margins above 90 percent are not unheard of. Those margins are noticed by materials manufacturers and, according to a VP at a large materials company, they are looking at these margins and want a part of it. According to the VP “he does not want to be a contract manufacturer and only get a part of the margin”, instead the materials manufacturer would like to be more involved and receive a larger part of the margin.

It has been reported by multiple sources, interviews as well as reports, that the price of polymers for 3D-printing are significantly higher than for injection molding. Wholers, Campbell, Diegel, et al. (2020) indicates that polymers for 3D-printing price is in the range between $40 to $250 per kilogram while the range for polymers for injection molding is between $2 and $10. One interview said that Objet, a company that merged with Stratasys, started to sell a printer for a high price and subsequently lowered the price when the demand was lackluster. However, Objet did not lower the price of materials, which was “more costly than blood”. The demand continued to be lackluster and according to the interviewee Objet failed to make money on the material. The interviewee elaborates that the high material price was the reason for the failed launch. It has been stated, both in meetings and by Wholers, Campbell, Diegel, et al. (2020), that the high price of materials is because the 3D-printer manufacturer views the materials as a needed complement and an avenue to earn money. The material is a recurring revenue which 3D-printer manufacturers are reluctant to give up.

Services

Generally, there are two different service types performed by 3D-printing companies. The first is the in aftermarket, which includes installation and maintenance. This is performed by almost all 3D-printer manufacturers and is called the modus operandi by a former executive. The second service type could be called education of customers. This service is required from the standpoint of the 3D-printer manufacturer since the customer needs to be educated on how to use the printer. There is also a need to understand what the customer needs the printer for. Since 3D-printers, in general, are novel technology, the customer needs to be educated. Different companies have been using different tactics to overcome the knowledge barrier and to educate their customers.

A subset of the 3D-printer manufacturers are providing an additional set of services, among them 3D Systems and Stratasys. They have internal service bureaus which are contributing to their revenue on a stand along basis. This means that those two companies have internal service bureaus with the explicit goal of earning money by selling printed parts. This is the same model employed by external service bureaus, for example Protolabs. 3D Systems and Stratasys are partly using internal service bureaus to educate customers, however it is not the norm in the industry.

Another subset of 3D-printer manufacturers, among them GE Additive, EOS, and Strataysys, are offering yet another service which is an internal consultancy. This service is providing the customer with a full solution to understand and deploy the 3D-printers for the customer's need. Helping the customer fully use the capabilities of 3D-printers.

One last service, sparsely used by 3D-printer manufacturers, is contract manufacturing. A contract manufacturer means a company which is focused on one industry, for example medical, with the goal of being an expert within that industry. The company provides insightful advice and services to customers looking to use 3D-printers for the specific area.

4.2 Inkbit

As previously described, Inkbit is located in the Boston area and was founded in 2017. The company will launch a 3D-printer which builds upon the proven technology of material jetting and adds a vision system to this technology. By introducing a vision system, it is possible to remove the mechanical flattening mechanism. A mechanical flattening mechanism is present in all present 3D-printers. The device is used to correct random errors occurring by flattening the part before a subsequent layer is printer. By flattening each layer, the surface is optimal for the subsequent layer, which is needed to achieve a good quality for the part printed. The company is able to use the vision system to instead correct the random errors by software. It is then possible to speed up the print process, limit the waste of material, and use materials previously unusable.

The new types of materials which may be used are materials which solidifies continuously, even when not exposed to UV-light. Those materials are unusable with a mechanical flattening device since they would continue to solidify on top of the device which would quickly damage the 3D-printer. By enabling a larger set of materials than other 3D-printers it permits usage of materials with better properties than before, for example epoxies which are known for their durability.

The possibility of printing fast is due to a combination of the proven technology of material jetting and the vision system. Material jetting enables a specific build speed in one dimension, the height, regardless of the size of the other two dimensions. The benefit from material jetting is enhanced by the machine vision, since it is faster to correct random errors with a vision system than with a mechanical flattening device. The printer can, hence, be used for high throughput applications which, in turn, enables the printer to be used in mass manufacturing.

During my time at the company there were ongoing business development activities focusing on finding applications for which the printer is suitable. In connection with finding the right application for the printer there were also discussions regarding the business model through which the company would capture the value created by the printer. When discussing the business model and value capture, the aspects of vertical integration was also highlighted.

The discussion regarding the business models and the aspects of vertical integration can be centered on the three different aspects previously explained, meaning the 3D-printer, the materials, and services.

4.2.1 3D-printer

The discussion regarding the business model for delivering 3D-printers have been centered on whether to sell the 3D-printers or to supply them through any other means. For example, the idea of a manufacturing line as a service has been talked about. If the company is going to sell the 3D-printer, the price is envisioned to be $500,000. However, when potential customers to Inkbit are questioned regarding buying a 3D-printer, they are often appalled by the price. The company thinks that customers do not understand the product or the value of it, causing the negative reaction to the price. The customers further state that they are having a hard time justifying a purchase due to uncertainties regarding the reliability of the 3D-printer. These uncertainties come from the unfamiliarity of the printer.

4.2.2 Materials

For the company, the material is highly important. Managers at Inkbit suggest that the material is a very important aspect of 3D-printing because the material enables applications and use cases. This is also expressed by potential customers which highlight the need for the optimal material properties. The customers further explain that without the right material properties there is no need for the printer. However, the requirement of the exact properties is different depending on the industry the specific customer is in. For customers in highly regulated industries, for example medical devices, certain properties and materials may be required or prohibited to match what they have approval for. For industrial applications, or non-regulated consumer products, there is fewer specific demands.

Furthermore, from the company executive's experience, service bureaus do not like Carbon3D's printers but are forced to use them in cases when the material supplied by Carbon3D is the only material which will be sufficient.

From a business model and vertical integration perspective the company is focused on developing its own materials to sell to customers. The internal discussions are centered on who will manufacture, develop, and profit from the material. The company is very interested in the money which can be made from the materials. This comes from the understanding from the broader 3D-printing industry in which manufacturers of 3D-printers are able to enjoy high margins from selling materials. It is also discussed and understood that when targeting mass-production the amount of material used will be vastly more than if the printer is used for prototyping. The company then sees more value in the materials than in the 3D-printer due to the amount of material used. However, it has also been suggested by both the company, materials manufacturers, and customers that if large customers with established supply chains and policies would adopt 3D-printing they would like to be able to source materials from multiple entities. It has then been discussed within the company to collaborate with materials manufacturers. The discussion about collaboration is often about how the company can earn money from this. Frequently discussed topics are licensing and co-branding. For licensing the company envision that they would receive a licensing fee for making the material compatible with the 3D-printer. For co-branding the company envision a 'powered by' type of co-branding to make use of the materials manufacturers established brands. According to the reasoning within the company this would help minimizing some of the risks felt by potential customers in the ability to source the material.

4.2.3 Services

Firstly, the company is not thinking about outsourcing the maintenance of the 3D-printers. Instead the company values the customer relationship that maintenance contracts would enable. Customer relationships are valued when launching a new product due to the need of learning about its customers. Also, the company values the recurring revenue from maintenance and other service contracts highly.

Another service the company is contemplating is charging for printed parts. The reasoning behind this is to capture the value created by the 3D-printer. Another reason is to understand for what parts the customer is looking to print with the 3D-printer. For one potential customer this model was constructed to understand the value created by the 3D-printer and understand how the company could capture the value. The model showed that it would cost approximately 20 dollars for the company to produce a specific part for the potential customer. The cost is calculated based on the needs for a production facility at Inkbit and cost of the materials. This specific part would replace a part currently manufactured with traditional manufacturing technologies. Inkbit has been informed that the current cost of producing the specific part is 60 dollars. The value created from 3D-printing is the difference, between 20 and 60 dollars. The debate is then how this value is distributed between the companies and how the 3D-printer manufacturer can benefit the most.

5

Discussion

As has been discussed in the introduction, this study aims to answer the question; How and why does the business model, and the immediate eco-system, for a 3D-printer manufacturer change when 3D-printers are used for mass-production instead of prototyping?

To answer this question, I'm going to discuss the findings and connect those to the various aspects of the literature. To adequately answer the questions there is a need to establish and discuss the business models and level of integration for the general 3D-printing manufacturer and Inkbit separately. After those two sections I will then answer the research questions by discussion and establishes the changes between the two and why this evolution has come about.

5.1 The general 3D-printing manufacturer

The results show a tendency for 3D-printer manufacturers to sell the 3D-printers. The results also show that some companies have embarked upon a venue of business model innovation. There is a need to establish the true nature of the business models applied to deliver 3D-printers to discuss some general trends. Given what the literature says about business models, and especially the literature on servitization in manufacturing, it is possible to established that the main business model used by 3D-printing manufactures is a product-service system. It is also possible to establish that 3D-printer manufacturers are centering on the product and then complementing the product with various services, for example maintenance services. Hence the business model used is a product-oriented model. All covered companies, except for HP, are providing the 3D-printers by selling the 3D-printers. Even though Carbon3D and Wematter claim to have invented a new business model by subscription it is possible to deduct that this is not a business model innovation in the sense of product-as-a-service as explained by Butron et al. (2019). From Butron et al. (2019), there are four different models for providing a product-as-a-service. Wematter and Carbon3D are not providing their 3D-printers according to any of those models, instead the 3D-printers are provided for a fixed yearly cost. This is not an outcome-based model since there is no outcome tied to the price. It is also not a time-usage-based model since the price is not fluctuating based on the time used since the 3D-printers are provided on a fixed yearly price. Instead it is possible to say that this is merely aggressively pursuing a singular financial business model, and one which is well proven by manufacturers in different industries. It is therefore not a business model innovation, meaning that they still provide a product. Hence, it is possible to state that all 3D-printing companies are providing all or some of their printers as products, even though HP is the sole example of a company selling printers and also providing printers-as-a-service.

The results also show that the general 3D-printer manufacturer is providing different types of services. The general 3D-printer manufacturer provides services related to the aftermarket, for example maintenance contracts. There are, however, also companies that are providing other services. Those services are printing parts and consultancies. Those companies are in the minority. Thus, it is possible to deduct that the general 3D-printer manufacturer is providing services and then limited to aftermarket services.

The results further show that the general 3D-printer manufacturer is developing and selling materials. This is especially prevalent for manufacturers which provide polymer-based system. This is due to the non-existing standards within polymers. Instead, new polymers are being developed to be used in the company specific 3D-printer.

Hence, for the general 3D-printing manufacturer the business model can be explained as selling 3D-printers, providing services and manufacturing the material. Its therefore possible to state that, the general 3D-printer manufacturer is backwards but not forwards integrated since they are manufacturing the material but not performing anything their customers are doing. However, for the subset of the market which provides additional services, they are both backwards and forwards integrated. Other manufacturers of 3D-printers have decided not to pursue the forward integration and instead have been selling printers to external service bureaus, for example Protolabs.

There is then a need to discuss and understand why this business model and company structure is the dominant one. There is a high possibility that this comes from an uncertainty of where the value is captured. Starting with the 3D-printers, the uncertainty of where the value is captured could be attributed to the versatile nature of a 3D-printer. There is a significant difference in the value captured by the 3D-printer manufacturer and its customer depending on the application printed. When a 3D-printer then is used for prototypes this could be argued to insert further uncertainty and increase the need for vertical integration. It then comes down to choosing the right pricing, or business model, depending on the application. For a versatile product like a 3D-printer it is inherently hard. Especially in the traditionally use case for 3D-printing, which is mostly centered on prototyping. For prototyping almost every part printed is different and the use of the 3D-printer is not predictable. To then choose a business model dependent on use or calculated based on the end applications, for example financial savings, could be detrimental for the manufacturer of 3D-printers.

This could be detrimental because the risk assumed by the company using the printer for prototyping is limited because the company only pays for when the machine is used and since the machine is used infrequent there is no continuous payment. The risk is, therefore, almost entirely carried by the 3D-printer manufacturer. The risk can instead be shifted to a more adequately sharing between the parties by the customer purchasing the 3D-printer. With the purchase of the 3D-printer the customer also has an incentive to use the 3D-printer, since the cost of use, once bought, is small. The usage of the 3D-printer would further deliver value to its manufacturer since when used the manufacturer realizes the 3D-printer's strengths and weaknesses. Hence, there is an argument for the status quo in the industry, to have been the adequate business model when selling to companies using the printers for multiple uses, for example external service bureaus. From a risk and learning perspective it also seems to be an adequate model when selling to companies using the printers for prototyping. Drawing from the conclusions of Fang et al. (2008), it would also be correct assessment to focus on the product in the case of 3D-printing since the industry is still an industry of high growth and turbulence as various new companies are entering the space. Hence, the versatile nature of the 3D-printer leads to an uncertainty in if the manufacturer is capturing an adequate value or if the customer is capturing the most value. This then leads to both the printer being sold and to some manufacturer to forward integrate.

To further understand the choice of the business models and vertical integration there is a need to discuss the services offered by 3D-printer manufacturers. Here it's also interesting to consider the vertical integration performed by a subset of the manufacturers through the establishment of internal service bureaus. When talking about the service offerings provided there is a need to repeat that printers are being sold. This is important because it established that the companies are using a product-oriented offering, meaning that the product is complemented by the service. The services offered by most of the 3D-printer manufacturers are complementing the 3D-printer, for example maintenance, installation, and education for users. The service offering provided by the subset of the market is, however, not complementary to the product offering. This service offering consists of 3D-printer manufacturers setting up internal service bureaus to serve, for example, customers which do not need or cannot afford a 3D-printer in-house. This service is directly competing with the sales of printers since an external service bureau would be able to service those customers instead. An external service bureau could then become the supplier to the customer while the 3D-printer manufacturer supplies 3D-printers and materials to the external service bureau. Introducing an external service bureau, compared to the 3D-printer manufacturer also supplying this service, introduces another actor into the supply chain. The introduction of an addition actor will either increase the price to the end-customer or lower the margins for the 3D-printer manufacturer since the external service bureau needs margins as well. Depending on the end applications this could be doable if the savings and/or the value created by using 3D-printing ensure healthy margins to all actors. Per Fang et al. (2008), companies should avoid services which is not complementing the product. Hence, it could be easy to state that the non-complementary offerings should be discontinued. Unfortunately, it's not that easy.

To really understand the reason for a 3D-printer manufacturer to compete with a main customer segment, service bureaus, there is a need to understand *why* the 3D-printer manufacturer would need an internal service bureau. 3D-printing consists of many different technologies which brings different strengths. The different technologies are also able to excel at different applications. This together with 3D-printing being largely an immature industry creates a need for educating a potential customer. The internal service bureau is then used to ease a customer into 3D-printing by lowering the costs of using 3D-printing. The reason being that a customer could be reluctant to order a 3D-printer before understanding the technology. One strategy is then to have the customer pay per part which is directly competing with an external service bureau.

However, there is still a need for the 3D-printer manufacturer to have a couple of 3D-printers producing parts internally. This will increase the knowledge about the 3D-printer for the manufacturer and will in-turn help customers fully utilize the 3D-printer. It is also reasoned to be necessary for the 3D-printing manufacturer to learn about the 3D-printer, to improve the 3D-printer and to understand how to design for the 3D-printer. Having 3D-printers internally is therefore of high value for the 3D-printer manufacturer.

Another reason for 3D Systems and Stratasys to compete with customers with their internal services bureaus comes from the uncertainty in the value captured by the different actors in the value chain. For example, a service bureau has the opportunity to produce parts of different value, and different value added by the usage of 3D-printing. This can be highlighted by an example of three different parts. First is a part which costs roughly half to produce with 3D-printing compared with traditional manufacturing. Second is a part which is just slightly more cost effective to produce with 3D-printing than traditional manufacturing. Third is a part which cost only a fraction to produce with 3D-printing compared to other manufacturing methods. If those parts are sold for approximately the same as the traditional manufactured ones the value will be distributed different depending on the part being produced. For the first part the value is captured roughly equal between an external service bureau and the 3D-printer manufacturer. For the second part the 3D-printer manufacturer captures most of the value while the opposite is through for the last part. Even if the different parts have roughly the same value, the value captured is vastly different for the service bureau and the 3D-printer manufacturer. This different value captured and the uncertainty in which actor captures the value is then used as a reason to implement an internal service bureau.

However, since the 3D-printer manufacturers are product-centric companies and hence have the selling and delivering of 3D-printers in focus, an internal service bureau could be seen as unrelated. As has been shown by Fang et al. (2008), a company should avoid selling unrelated services due to the negative impacts this may create. But, as previously stated, there is a need to educate the customer and for the manufacturer to understand the 3D-printer. The internal service bureau is used for capturing value, educating and understanding customers. Hence, it could be argued to be a necessary service provided by the 3D-printer manufacturer. There is then a need to compare this to the more comprehensive service provided by some manufacturers, namely the consulting service. From a value creating perspective this service aims to add value by advising the customer how to best use 3D-printers in their operations. It also aims to educate and understand the customer. In that sense the consulting service is similar to the internal service bureau. A main differences is that the internal services bureau aims to capture value through production of parts while the consultancy aims to create and capture value in the education and understanding of customers. In the consultancy service there is no obvious value capture mechanism for what the customer does once 3D-printing has been adopted. Hence, both those two different services aims to capture value when educating customers. The general 3D-printing manufacturer is also educating and understanding customers through printing parts but there is not such a profound emphasis on capturing the value created since they are not, generally, charging for parts.

The last vehicle, through which polymer focused 3D-printer manufacturers are capturing value, is the materials business. As seen in the data, all companies are vertically integrated backwards in the sense that they are developing and manufacturing the materials. As can be seen for Stratasys and 3D Systems, the materials are where those companies are realizing the highest margins. It could hence be argued that the 3D-printing manufacturer are using the materials to capture most of the value. Or put differently, the majority of the value is captured through the material and not the 3D-printer. The importance for the material is also stressed through the different materials available and what they offer. Hence, a large reason for choosing a specific 3D-printer could be due to the material offered. Another reason for the 3D-printer manufacturer to develop and manufacture the materials comes from the immaturity of the market and what a 3D-printer is used for. Since 3D-printer are mainly used for prototyping the volume of material needed is minuscule compared to the volume needed in mass-production. Therefore, it could simply be that large materials manufacturers do not highly value the 3D-printing industry when it's used for prototyping and the materials volume is low. Hence, the 3D-printer manufacturer could be forced to manufacture the material themselves.

The reasoning surrounding the strategy regarding the vertical integration for the materials is twofold. First, it's the need to develop own materials when launching a new printer as a mean to prove the printer but also for differentiating the company compared to competitors. Hence, the company vertically integrates to gain competitive advantages. Second, the company is able to capture value through the materials which cannot be captured through other means. The high margins from a material business is most likely connected to the use of the 3D-printer, which is prototyping. When the 3D-printer is used for prototyping the price of the materials is not a prime cost driver, as in mass-production. Therefore, it's possible for the companies to demand a high price and earn high margins. However, the price cannot be too high. This is exemplified with the Object printer which failed due to the high materials price.

The decision regarding the materials and the vertical integration hence rest on the same notion of value capture as 3D-printers and services. This is coupled to the uncertainty in the industry of where the value will be captured and hence the companies are using vertical integration to understand where the value is captured but also to capture as much value as possible.

In summary; the reasoning behind selling printers, offering services, and manufacturing materials comes from the uncertainty felt by 3D-printer manufacturers of where the value is created in the value chain. Hence, they decide to integrate vertically, the majority only backward while some also integrate forward.

5.2 Inkbit

The discussion within Inkbit has, as for the general 3D-printer manufacturer, been focused on 3D-printers, services, and materials. However, the discussion within the company has been focused on the integrated system and the goal of launching a 3D-printer for mass-production. The focus of the discussion has not, primarily, been on the different parts of the offering. At this point in time, the discussion is centered on what it will mean for the company to launch a printer for mass-production. One aspect immediately realized by the company is the importance of the material. Both from what a good material will enable for the parts being produced in the 3D-printer but also the opportunity a material business entails due to the volumes of material used in mass-production. Hence, there is a discussion not regarding the specific parts of the offering but more on the system and where the value is created. The company also envision that the main revenue will not be achieved through selling 3D-printers, instead the main revenues will be from materials when the 3D-printer is used. For the company, it's therefore of uttermost importance to understand the right approach towards materials. This importance is further highlighted by the awakening of the large materials manufacturing and their interest in polymers. This is shown from the materials VP where they want to get a part of the margin and supply materials for mass-production. It becomes interesting for the materials manufacturer when 3D-printing is being used for mass-production since the volumes is more akin with the volumes produced for other manufacturing processes. It's further interesting for the materials manufacturer since the companies using 3D-printers for mass-production wants security in the supply chain, as shown by potential customers to the company. The value added by the materials manufacturer is therefore both the volume it's able to produce but also the reliability of a supply chain.

Since the company has been focused on the value capturing of the system, meaning the combination offered to customers, it is natural that it has not been a large focus on the 3D-printer. Especially since the company believes that most of the value captured will come from the materials. However, the discussions regarding the 3D-printer have been centered on selling the 3D-printer. This idea comes from the status quo in the general printing industry. I.e. the company sees what has been working for other companies and follows this. As stated by Butron et al. (2019), when the company does not know the value created, or cannot measure the value, a time/usage-based model might be useful. It could also be useful to provide the equipment as a product, i.e. selling the 3D-printer. When entering a new industry or a new usage, as will be happening with large-scale manufacturing it can be assumed that the 3D-printer manufacturer cannot, at least from the beginning, easily measure the value created. Hence, when first entering the segment of large-scale manufacturing and there is a need to learn the market it is adequate to sell the 3D-printers. Therefore, the discussion on selling the 3D-printers would be the correct assessment.

Services have not been discussed at the company to a great instant. It is a foregone conclusion that the company will provide spare parts, maintenance and other traditional aftermarket services. Reiterating the statements from Fang et al. (2008), those services can be classified as supporting services and should hence be focused upon. The company has also been discussing the possibility of printing parts for customers. This would, according to Fang et al. (2008), be an unrelated service and hence not to be focused upon. However, the reason for the company to adopt a service bureau, or to charge for parts, is to capture value and to validate the technology. The discussion is once again focused on value capture and where the value will be captured in the chain. The company reasons that if much value is captured in the printing business, it could be a correct integration.

Hence, the discussion within the company is focused on value captured and the company think they understand that most of the value will be in the materials. The questions is then, how will they capture this value?

5.3 Similarities and differences

When exploring the similarities and differences between the general 3D-printer manufacturer and Inkbit it's important to acknowledge the different use cases the supplied 3D-printer is used, or is aimed to be used, for. This difference is that the 3D-printer supplied by the general 3D-printer manufacturer is traditionally used for prototyping while the 3D-printer from Inkbit is intended for mass-manufacturing. In prototyping the versatility for the 3D-printer will be called upon which means that it can be hard for a manufacturer to understand what the printer is used for and what value is created. This is manifested in the uncertainty felt by 3D-printer manufacturers and how they will capture the value. This has resulted in vertical integration. Similarly, Inkbit is also unsure how they may capture the value through the 3D-printer. This has resulted in both the general 3D-printer manufacturer and Inkbit to favor selling printers.

However, even though the outcome is the same, i.e. selling printers, the reasoning for that outcome is different. For Inkbit the decision for selling printers comes from not possessing enough information. Hence, it cannot, at the moment, introduce another business model for providing the printers. It may be possible in the future with better understanding of the usage of the printer. For the general 3D-printer manufacturer the decision to sell printers comes from the difficulties in understanding and measuring the usage of the printer since for prototyping the parts will, naturally, differ from time to time. Hence, the similarities could, perhaps, become differences as Inkbit understand how the printer is used in specific mass-production settings.

From a service perspective the similarities are in the supporting services offered. It is a foregone conclusion that typical aftermarket services will be offered. This most likely comes from the overall trend, as has been extensively covered, that manufacturing firms are offering services. There is not a large difference between the overall trend in manufacturing and the developments seen by 3D-printer manufacturers. There are, also, some similarities between Inkbit and a subset of the 3D-printing manufacturers in the sense that they are both offering to sell parts instead of 3D-printers. For both cases this can be tracked back to the uncertainty of where the value will be captured.

Hence, for both services and printers there are currently significant similarities in the business model and the vertical integration.

The major difference between the general 3D-printer manufacturer and Inkbit is in the approach towards the materials. While the general 3D-printer manufacturer is vertical integrated, Inkbit is considering a disintegrated model. For Inkbit this consideration is impacted by the wish from potential customers to source from multiple entities as well as the appetite from materials manufacturers to join the market.

For the general 3D-printer manufacturer and when the 3D-printer is used for prototyping large materials manufacturers has not, to the same extent, indicated an interest to join the market and the value chain. Customers using 3D-printers for prototyping is also not, to the same extent, looking for the reliability in the supply chain and a strong material brand since the volumes used in prototyping is much smaller. The supply chain is also less important since the 3D-printer is not used for mass-production, hence, the parts produced by the printer is not, to the same extent, part of a larger operation which will suffer great financial consequences if delayed.

To further explain the differences there is a need to understand the relationship between materials and printers better. As previously stated, for polymers the material is in most cases developed in tandem with the printer, or the material is developed for a specific printer, since it is not always possible to understand if a standard material will work on a specific printer. Hence, it is possible to consider the material and the printer as one system experiencing technical development. This is also consistent with the presentation of 3D-printing by an executive in figure 4.1, where materials are explained as an integrated part of 3D-printing. Materials are in that explanation given the same importance as hardware and software which highlights its importance in the offering to the customer. Drawing upon Christensen et al. (2002), it would then make sense for the company to be vertically integrated to develop the most technical advanced system which delivers the material properties required by the customers. The materials properties are one limitation of 3D-printing and, hence, it then makes sense for a company to be vertical integrated to deliver the highest possible performance.

However, when launching a 3D-printer for mass-production the material needs to deliver the material properties required for an end-product. If the material is good enough for the end-product there is then no need for a focused effort to develop the best material possible. Again, going back to Christensen et al. (2002), the system is good enough and could, therefore, be broken into subsystem and hence it facilitates vertical disintegration. The development seen in Inkbit, which instead empathizes co-branding and licensing fees, is then a natural step. To only use Christensen et al. (2002) to explain the happening would be an oversimplification, as argued by Jacobides (2004). By using Jacobides (2004), and especially coordination simplification and interfirm co-specialization it is possible to further explain the difference between Inkbit and the general 3D-printer manufacturer. As stated in the theory, the coordination simplification is related to the reasoning presented by Christensen et al. (2002). This reasoning states that when a technology becomes good enough it can be broken into sub-systems and different companies may become specialized in performing a subset of the final product. In the case of a 3D-printer for mass-production, when the material is good enough and the printer is good enough it is easier to separate the material from the 3D-printer development. Hence, there is a coordination simplification between materials manufacturers and the 3D-printer manufacturer.

Interfirm co-specialization, as presented by Jacobides (2004), plays a role in the vertically disintegration considered by Inkbit since the customer is demanding capabilities which the materials manufacturer has. The capabilities are mainly a reliable supply chain, a recognized brand, and familiarity to the customer. Those capabilities would be very costly and time consuming for Inkbit to develop. Instead, those capabilities could be delivered through vertical disintegration and interfirm co-specialization. Those capabilities are also what Teece (1986) would describe as complementary assets, or specialized complementary assets. As stated, it would be time consuming and costly for a company to acquire the assets needed to address the customers' demand for entering mass production. It is therefore a good idea to contract for those assets. It is also good to contract for those assets since there is little specialization needed for those assets to satisfy the customer, and hence the possible hazards are lower. At the same time, it's important to understand the power structure between those who control the specialized assets and the 3D-printer manufacturer who contracts for them. It's important because it will ultimately define the level of value capture possible for each actor.

The materials manufacturer has become interested in 3D-printing due to the high margins enjoyed by 3D-printer manufacturers. With the emergence of 3D-printers for mass-production, as seen with Inkbit it is possible that the materials manufacturer sees the market as attractive due to the volumes it would demand. Hence, it would also be possible to draw upon the theory by Stigler (1951) to explain these emerging interests where a large market may enable firms to become specialized.

One other reason for the general 3D-printer manufacturer to integrate backwards could be the uncertainty of where the most value will be created and captured. This uncertainty then leads to integration since the general 3D-printer manufacturer uses it as a hedge. In comparison, Inkbit realizes that the most value will be in the materials since the volume will dwarf the value in the 3D-printers. However, due to the already established materials manufacturers and the demand from customers, the company is forced to disintegrated and outsource.

The previous discussion has focused on the differences and similarities within the vertical integration for Inkbit and the general 3D-printing industry. As is argued in the theory, there is an intimate connection between the vertical configuration of an industry and the business model. One reason for the vertical disintegration and hence, the need for business model innovation, is that the material manufacturer is looking to take an active part in the value chain. This is a stark contrast to the previous case where materials manufacturers only were suppliers and didn't take any part in the value chain. This position of the material manufacturer is made possible by the demands of the customer. The customer is demanding capabilities possessed by the material manufacturer, in the form of a strong brand, reliable supply chain and familiarity for the customer. This enables the material manufacturer to enter the value chain since it would be nigh impossible for the 3D-printer manufacturer to acquire those capabilities in a timely manner. Since these capabilities are demanded by customer which are deploying 3D-printers for mass-manufacturing, the change is driven by factors outside the company. With those capabilities already possessed by companies in adjacent industries it's easy for the materials manufacturer to enter the industry and deliver the value demanded by the customer. Thus, it is not far-fetched to assume that the business model of the industry will be changed.

Hence, the primarily driver for the business model innovation for the 3D-printer manufacturer supplying customers within mass-manufacturing is what the customer demands. Therefore, the reason for the business model innovation is not controlled by the 3D-printer manufacturer. Instead, the manufacturer is forced to change the business model if it wishes to capture some of the value created by the capabilities demanded by the customer. With the company being dependent on the ecosystem and the industry which it's present within, this gives further proof to the reasoning presented by Berglund and Sandström (2013) as well as Schneider et al. (2013).

6

Conclusion

The similarities between the general 3D-printer manufacturer and Inkbit is the uncertainty of where the value will be captured. Both actors have therefore thought about vertically integrating to maximize the odds of the 3D-printer manufacturer capturing the value.

However, differences exits in the backward integration. While the general 3D-printer manufacturer is integrated backward, meaning they are developing and selling their own material, this is not the planned strategy for Inkbit. Instead Inkbit envision collaborations and partnerships with large materials manufacturers. This is driven by the materials manufacturers as well as customers. Materials manufacturers want a piece of the margins and customers want a strong brand with a reliable supply chain. The volume used in mass-production will also be significantly larger than in prototyping and hence there is a need to partner with manufactures with strong materials capabilities. This partnership could also facilitate value capturing, even though it would be to a lesser extent than if the company produced the material itself.

For the general 3D-printer manufacturer targeting prototyping there is also a reason for vertically integrating forward, i.e. producing parts, because it is hard to understand the value created when making prototypes since every part is different. For Inkbit, it could be easier to measure the value for each manufacturing process since the parts produced could be assumed to be more well defined and not subject to much change in a mass-production setting. This could then facilitate business model innovation, as suggested by Butron et al. (2019), towards services. It would then also be easier to understand where the value is created and captured, which could lead the company to produce part, if that is more advantageous.

The differences in the business model and the vertical integration is also due to the demands by the customer, which is certain capabilities which the 3D-printing company does not have. The changes are further due to materials manufacturers entering the value chain. Hence, the result of this article is in line with the reasoning of Berglund and Sandström (2013) and Schneider et al. (2013) where the business model is co-developed with the industry's ecosystem.

This paper adds to the understanding of drivers for business model innovation within changing industry. In particular for 3D-printer manufacturers where the main drivers for business model innovation when targeting mass-production instead of prototypes are customer demand and the entering of materials manufacturers to the value chain.

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