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Emerging Technologies and Their Influence on Business Model Dynamics: Case Studies of 3D Printing in the Food Industry

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To Silvana and Lucio, who have been my greatest source of inspiration

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Abstract

The commercialisation process of a technological innovation is a complex process that has mainly been studied within emerging industries. However, there are fewer studies on business models to commercialise emerging technologies in established markets, although frequently mature industries represent core sectors in the whole economy. Within this context, business models and their innovation can be of strategic importance for new ventures to commercialise their innovations and achieve competitive advantages.

After an extensive review of the literature, this thesis offers an understanding on how business models are framed in the commercialisation processes of a new technology (i.e. 3D printing) in an established industry (i.e. the food industry). The literature highlighted that the role of collaboration, as well as the innovation of the business model, can be of great importance in the ability of new ventures to commercialise their products and services.

A conceptual framework was developed on the relevant themes that emerged in the review of the literature. It combines: 1) the technology commercialisation and 2) the commercialisation strategy literatures; 3) the (collaborative) business models literature as well as 4) the issues encountered in business model innovation literature. This framework was initially developed as an *a priori* set of constructs to act as guidance for the study. The framework was then reconfigured according to the empirical findings that emerged from the cross-case study analysis of 13 emerging technology-based organisations (i.e. 3D printing organisations) operating in an established market (i.e. the food industry).

Through this research journey, a number of patterns emerged with regard to the links between strategic choices and specific business model solutions, the business model archetypes and the influence of the new technology on the business models, and the role of collaborations in the above mentioned contexts. Further patterns emerged concerning the business model innovation processes of emerging technologies organisations and their evolution mechanisms (i.e. triggers and degree of innovativeness). These results provide useful insights not only for academics, but also for practitioners who require an overview on how business models are framed and developed in the commercialisation of emerging technologies in established industries.

Abstract (Italian)

Il processo di commercializzazione di un'innovazione tecnologica è un processo complesso, che è stato principalmente studiato all'interno di industrie emergenti. Tuttavia, non sono ancora molti gli studi che affrontano i modelli di business adottati da aziende innovative per la commercializzazione di tecnologie emergenti in mercati consolidati, sebbene molto di frequente, industrie mature rappresentino settori strategici per l'intera economia. In questo contesto, lo studio dei modelli di business e la loro innovatività può essere di importanza strategica per nuove imprese che vogliano commercializzare le loro innovazioni per perseguire vantaggi competitivi.

Questa tesi, dopo aver presentato un'ampia panoramica della letteratura esistente sulla tematica, offre una possibile comprensione di come i modelli di business vengano definiti nei processi di commercializzazione di una nuova tecnologia (i.e. 3D Printing) in un determinato tipo di industria matura (i.e. industria alimentare). La letteratura ha inoltre messo in luce il ruolo delle collaborazioni così come quello dell'innovazione nei modelli di business, come elementi di rilevanza cruciale nel supportare aziende innovative nei processi di commercializzazione delle loro tecnologie.

Nella presente tesi è stato sviluppato un '*framework'* concettuale sulle tematiche rilevanti emerse nel corso dell'analisi della letteratura. Tale '*framework'* associa: 1) la letteratura sui sistemi di commercializzazione delle tecnologie, 2) e sulle strategie di commercializzazione; 3) la letteratura riguardante i modelli (collaborativi) di business, nonchè quella relativa 4) alle aree rilevanti nella letteratura sulle innovazioni nei modelli di business. Questo '*framework'* è stato inizialmente sviluppato come insieme di costrutti stabilito in un modello *a priori* utilizzato come guida per lo sviluppo dello stesso lavoro di ricerca. Successivamente questo '*framework'* è stato riconfigurato alla luce dei risultati empirici emersi dall'analisi di 13 casi studio.

Attraverso questo percorso di ricerca sono emersi una serie di *patterns* sia per quanto attiene le connessioni tra scelte strategiche e modelli di business, sia per quanto riguarda gli archetipi di modelli di business e l'influenza delle nuove tecnologie su questi ultimi, che per quanto concerne il ruolo delle collaborazioni in entrambe le circostanze sopra delineate. Ulteriori *patterns* sono stati individuati sia circa i processi di innovazione nei modelli di business che nei loro meccanismi evolutivi (i.e. ragioni di cambiamento e grado di innovatività). Questi risultati forniscono spunti di riflessione utili non solo in ambito accademico, ma anche in ambito professionale per coloro che vogliano avere una panoramica di come i modelli di business di imprese tecnologiche vengono sviluppati per commercializzare le loro tecnologie in un mercato consolidato.

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Glossary

3D: three-dimensional

3DF: three-dimensional food

3DFP: three-dimensional food printing

3DP: three-dimensional printing

AM: additive manufacturing

BM: business model

BMD: business model design

BMI: business model innovation

BMR: business model reconfiguration

CEO: chief executive officer

e-commerce: electronic commerce

e.g.: exempli gratia

et al.: et alii

FLM: food layered manufacturing

i.e.: id est

ICT: information and communication technology

IP: intellectual property

n.: number

OBM: open business model

OI: open innovation

pp.: page

R&D: research and development

TCS: technology commercialisation strategy

Tech. comm.: technology commercialisation

Chapter 1 Introduction

1.1 Topic overview

Emerging technologies such as digital manufacturing technologies play a more and more relevant role in many sectors of our economy. More specifically, additive manufacturing (AM) technologies, offer firms new and unexploited possibilities to create and capture value (De Jong & De Bruijn, 2013; Ford, et al., 2016; Rayna & Striukova, 2016b). AM as a generic technology (i.e. a technology with many possible applications) has been used across several different industries, both emerging and established. Among the latter, AM is expected to enable more customer-centric supply chains (Bogers, et al., 2016). AM is expected to have a disruptive impact on established industries, and therefore give origin to new types of business models. Given the new possibilities that AM can provide, it seems conceivable that AM could be utilised by industries in which the digital manufacturing processes can help to meet the challenges of the emergent market needs and social trends (Bogers, et al., 2016; De Jong & De Bruijn, 2013). These specifically concern customers' nutritional health needs and taste preferences (Sun, Peng, Zhou, et al., 2015). The food industry can represent a suitable example of an established industry typically characterised by high barriers to entry, incremental innovations and customers' resilience to change. Within this context, AM seems a suitable technology to contribute to breaking these barriers. Over the last decade, the food industry has been changing. The food business sector is currently becoming more consumer-oriented, and this means that constant developments are required to meet customers' expectations. At the same time, firms face shortened life cycles of products, more cost-effective markets, and competition from private labels (Bigliardi & Galati, 2013; Manzini, et al., 2016). To face all these challenges and to remain competitive, firms in the food industry need to become more and more innovative. In this sense, the innovation process can be facilitated both by innovation in the business models, as well as by developing collaborations with partners.

The commercialisation processes concern the strategies that firms decide to develop in order to enter a specific market, and the business models they choose that are more suitable to capture value from the innovation. Business models explain the target market and the appropriate value proposition, the resources needed and the placement of a firm in a value chain. All these elements play a significant role in the creation of competitive advantages (Casadesus-Masanell & Ricart, 2010).

Firms that want to commercialise new technologies face complexity, and to get through this, they have to identify possible ways of collaboration. Therefore, collaborations are not only a means to innovation, but they also offer tools for the commercialisation of innovations (e.g. other products, technologies or services).

As well as collaboration, another element that enables firms to reach a competitive advantage is the innovation in the business model itself (Massa and Tucci, 2013). Therefore, a business model can also

be considered by entrepreneurs as a source of innovation, and a firm can cyclically design and reconfigure its business model to gain and then maintain its viability and uniqueness (Cortimiglia et al., 2016). This process becomes crucial when firms want to bring a technological innovation to the market.

1.2 Research objectives

In the previous section the importance of technology commercialisation, strategy, (collaborative) business model and business model innovations (BMI) emerged, in determining the organisation's ability to bring its innovation into the market. Even though these aspects have different origins because they are rooted in separate branches of the literature (innovation, strategy and entrepreneurship), however they are inter-related phenomena, so far still mainly considered separately.
In addition, the literature highlights that the commercialisation of emerging technologies within established industries is currently understudied (Jia, et al., 2016; Probert et al., 2013). Overall empirical studies are needed, especially on emerging technologies/applications ventures (Bogers, et al., 2016; Cortimiglia, et al., 2016; Dmitriev et al., 2014; Ford, et al., 2016; Lubik & Garnsey, 2015). This research contributes to extend the knowledge in the theory, by linking technology commercialisation and strategy literature to the (collaborative, i.e. open) business model and business model innovation literature. To pursue this theoretical aim, one main research question has emerged:

How are business models framed in the commercialisation processes of a new technology in an established industry?

In order to operationalise this overall aim, it has been divided into two expanded research aims, which are detailing a static and a dynamic perspective for this study.

Given the great importance of collaboration for new ventures in the commercialisation process of their innovations, to answer to the first expanded research question (see below), two main objectives have been identified: 1) identify the links between strategic choices and specific business model solutions within the collaboration frame, and 2) identify the business model archetypes and their revolutionary potential within the collaboration frame.

1) Static RQ: What types of business models emerge when firms commercialise a new technology in an established industry?

After gaining a better understanding of the typologies of business models, that organisations are adopting to commercialise their innovations, it is then possible to identify how the business models of

these organisations have developed over time by scoping two objectives: 1) identify the patterns in the process of business model innovation; and 2) identify the triggers and the degree of innovativeness associated with different types of BM changes. Thus, the second expanded research question can be addressed:

2) Dynamic RQ: What are the BMI dynamics in the commercialisation process of an emerging technology in an established industry?

1.3 Research approach

In order to answer to the above research aims, this study analyses an explorative phenomenon to develop theory based on an empirically-driven data collection. In doing so, this thesis aims to contribute to extend the nascent studies on business models in the commercialisation of a new technology in an established industry. In this context, particular attention is payed to the role of collaboration, as well as to the dynamics of the evolution of the business models.

The context of this research is the applications of 3D printing in the food industry, known as 3D food printing (3DFP). The reason behind this choice is that 3DFP is an emerging application of a radical generic technology, known as additive manufacturing (AM), within a well-established industry which is typically resilient to change. This characteristic suits the focus of the study. Furthermore, since AM has been developing for more than 20 years and 3DFP for more than ten years, this technology has a sufficient history to provide informative data.

The extensive literature revision on technology commercialisation (e.g. Datta et al., 2015), (collaborative) business models (e.g. Cortimiglia et al., 2015; Vahnaverbeke and Chesbrough, 2014; Bogers et al., 2016a;b) and business model innovation (e.g. Massa and Tucci, 2013; Casprini et al., 2014; Dmitriev., 2014; Cavalcante et al., 2011; Rayna and Striukova, 2016b), was used to identify the research gaps and build an *a priori* framework. It has acted as a guideline for the study. A deep research on the 3DFP ecosystems was carried out to identify a sample of thirteen case studies, in order to understand how the organisations under study framed and developed their business models for the commercialisation of their innovations. More specifically, a cross-case study method was identified to be the most suitable method to better understand the phenomenon under study, as it focuses on a current phenomenon that is exploratory in nature (Yin, 2009; Eisenhardt 1989).

1.4 Thesis structure

This thesis is divided into seven chapters. The chapters are composed by an introduction, a main body and a summary. Each chapter is linked to the other developing a consistent flow of the research work up to its conclusion.

The study starts with a brief introduction which highlights the objectives, the research approach and the general structure of the thesis.

In chapter two the relevant literature that will help to increase understanding of the topic under observation is outlined and analysed. After the chapter introduction, the first section of this chapter draws an overview of the technology commercialisation concept and its process. This section continues by focusing on the strategic and ecosystem perspectives of technology commercialisation within mature industries. The chapter continues by shedding light on the topic of business models for technology commercialisation, detailing the role of open business models and the business models for digital technologies. The following section looks at the business model innovation process, honing in the business model innovation triggers and degree of innovativeness. Synthetising the above bodies of literature analysed, an *a priori* framework is detailed in the fifth section of the study. The sixth and seventh section of the chapter focus on the context of the thesis, and thus detail an overview of the food industry as well as the 3D printing technologies in food.

In chapter three is designed and detailed the methodology that has been adopted for the present work. First, the research aims and objectives are identified. The philosophical position and theoretical foundations are then outlined. In section three, the research methodology is detailed while the next section focuses on the cases studies, outlining the data collection method, how the case studies were selected, the data presentations and their analysis.

In chapter four, the history of the thirteen case studies is detailed. Chapter five outlines the findings, it cross-examines the empirical evidences derived from the vertical case study analysis. In chapter six, the findings are compared and contrasted with the literature analysed to generate a discussion of the work.

In chapter seven, the theoretical contributions of the work are detailed and a reconfigured version of the framework detailed in chapter two is drawn. The other sections highlight the contributions to practice, along with the limitations and possible future research paths.

Chapter 2 Literature Review

2.1 Chapter introduction

The commercialisation of technological innovation is "the firm's capacity to bring a technological innovation to market and to reach some of the mainstream, beyond the initial adopters" (Datta, et al., 2015). This capacity is often the prerogative of new firms that try to establish themselves in new or existing markets by exploiting their technological knowledge. The commercialisation processes concern the strategies that firms decide to develop in order to enter a specific market, and the business models they choose that are more suitable to capture value from the innovation (Lubik & Garnsey, 2015). Business models explain the target market and the appropriate value proposition, the resources needed and the placement of a firm in a value chain. All these elements paly a significant role in the creation of competitive advantages (Casadesus-Masanell & Ricart, 2010).

Firms that are commercialising new technologies face complexity. The technologies' development and commercialisation is often impossible in isolation (Maine & Garnsey, 2006). Hence, firms need to identify collaborative ways to work with the ecosystem of partners, either to manage innovations through open innovation (OI) activities (Chesbrough, 2003), or to manage the commercialisation process itself, through open business models (OBM) (Vanhaverbeke & Chesbrough, 2014). As such, collaboration is not just needed for innovation, but also to provide the complementarities (the complementary elements) for the commercialisation of an innovation (e.g. other products, technologies or services). Whitin this context, the management of collaborations becomes of strategic importance for firms to gain competitive advantages (Spithoven, et al., 2013). Along with collaborations, another element considered of strategic importance in enabling firms to achieve competitive advantages is the innovation in the BM itself (BMI) (Massa & Tucci, 2013). Hence, the business model innovation is often seen by entrepreneurs as a source of innovation, whereby a firm can design and reconfigure its BM in order to obtain and then maintain its viability and its uniqueness (Cortimiglia, et al., 2016). This is particularly true when firms aiming to commercialise their technological innovation need to develop and reconfigure a suitable BM for their innovations.

These topics have all been sources of discussion in the literature. However, due to their roots in different theoretical streams (i.e. strategy, innovation and entrepreneurship traditions), these themes are so far still mainly considered separately. Therefore, there is a need for further studies in interplaying these literature streams. A particular context in which more research is needed is the commercialisation of emerging technologies within established industries (Probert et al., 2013). These industries, like for instance the food industry, are often characterised by a well-established dominant design, great fragmentation, high resilience to change and low-tech innovation rates (Manzini, et al., 2016). At the same time, these industries represent core sectors in the world economy. Firms within this context need to constantly innovate to adapt to market needs which are increasingly focused on product

personalisation (Bigliardi & Galati, 2013a). There are emerging technologies, such as AM (or 3D printing), which are suitable to enable a firm to provide personalised products. However, new ventures that aim to commercialise these innovative solutions in the food industry often need to manage high uncertainty and complexity that can be reduced through both collaboration (Vanhaverbeke & Chesbrough, 2014) as well as through BMI (Massa & Tucci, 2013).

This chapter reviews the relevant literature and aims to link the above theoretical concepts in order to derive an *a priori construct* (i.e. framework) to acts as a guidance in the study to understand how business models are framed in the commercialisation processes of a new technology in an established industry. The *a priori construct* that emerges in reviewing the literature is based on the following key areas: 1) the key phases of a technological innovation commercialisation process from the strategy, the ecosystem (collaboration) and the business model perspective are provided by the technology commercialisation literature; 2) business models (BM), the main dimensions of which are derived from the BM literature; and 3) the issues encountered in business model innovation in relation to technological innovation commercialisation, which are extracted from the BM innovation literature.

The chapter is structured as follows: Section 2.2 describes the technology commercialisation process. Section 2.3 presents the business model concept for technology commercialisation. Section 2.4 discusses the business model innovation concept, and section 2.5 presents the theoretical framework and its implications. The context of this study is detailed in sections 2.6 and 2.7. In section 2.6, an overview of the food industry is outlined, while section 2.7 focuses on the technology (i.e. 3D food printing technologies).

2.2 The commercialisation of emerging technologies

Innovation is a core determinant for a company's development and competitiveness (Bigliardi & Galati, 2013b). It can be considered as an all-comprehensive concept that explains how an idea is brought to market. Many innovations are driven by the emergence of new technologies. Freeman (1982) sees the development of technological innovations as a process that matches the technology with the market.
Along these lines, Datta et al. (2015) define innovation as "the firm's capacity to bring a technological innovation to market and reach some of the mainstream, beyond the initial adopters". This capacity is often the prerogative of new firms that try to establish themselves in new or existing markets by exploiting their technological knowledge.
Hence, in the exploitation of innovation, a crucial role is played by the figure of the entrepreneur. His/her role is to identify and exploit potential opportunities and turn them into innovations. This exploitation process is known as the technology commercialisation process.

2.2.1 Technology commercialisation: process

The technology commercialisation process has been widely studied. However, two main perspectives dominate the studies in the field. On the one hand, scholars see technology commercialisation as part of the innovation process (Burgelman, et al., 2004). On the other hand, this process is seen as part of the diffusion of innovation in the market (e.g. Nambisan & Sawhney, 2007; Nerkar & Shane, 2003). Regardless of which commercialisation process perspective is followed, there are three main actors that develop and commercialise innovations. These are: established companies, new ventures, universities and research institutions. These actors can either develop the technology and then market it, or they can do just one part of the development and leave the complementarities to someone else (e.g. a research institution can develop a technology, and can then license it to a large firm, which can then embed it into a new product to then launch it into the market) (Kirchberger & Pohl, 2016).

Within the innovation management perspective, Datta et al. (2015) presented a literature review on the commercialisation processes of innovations and the most common related entrepreneurial activities needed. The authors identified six main steps that lead the technological innovations getting into the market. These are based on three main phases of the innovation process: *ideation, development and deployment* (Mitchell, 1989; Teece, 1986; Teece, et al., 1997) (see figure 1).

'Ideation' consists of the discovery, the idea generation and the consistent market recognition. In this phase, Datta et al.(2015) highlighted two main steps that an entrepreneur should follow: the identification of the innovation source (e.g. alliances, organisational creativity, technology clusters) and the identification of its type (e.g. radical or incremental, product or process). 'Development' has parallels with the development of the innovation and its transformation into goods. In this phase, the steps followed by an entrepreneur, are 1) the decisions on the strategies needed for entry in the market (e.g. market entry strategies, competence analysis), and 2) the process of protecting the innovation (e.g. intellectual properties, trademarks, copyrights). The last phase, 'Deployment', concerns the launch of the product into the market (e.g. collaboration (ecosystem) definition, customer segment identification, marketing and launching strategies), by the exploitation of the firm's strategy through the definition of a business model, which explains the target market and the appropriate value proposition, the resources needed, and the placement of a firm in a value chain (Teece, 2010). Once the innovation is deployed, it diffuses through the purchase of the product or service by the customer.

According to Rogers' (1962) diffusion of innovation theory, the innovation-diffusion is "the process in which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 2003, pp. 5). According to Rogers' (1962) theory, if an entrepreneur aims to reach a wide spread diffusion of his/hers innovation, he/she needs to market the innovation differently,

using distinct communication channels, depending upon to the different social groups of adopters. Thus, Rogers (1962) identified five distinct social groups of adopters according to their speed in adopting an innovation (i.e. "innovativeness"): innovators, early adopters, early majority, late majority and laggards. More specifically, *innovators* represent the smallest part of the social system, as high risk takers, who have the role of bringing the innovations to the mainstream of the social system. The *early adopters* are the part of the social system made up of 'opinion leaders' who "put their stamp of approval on a new idea by adopting it" (Rogers, 2003, pp. 283). Then, there are the *early majority* who have less of a leadership role and tend to take slightly more time to adopt an innovation than the early adopter, however, they have a great social network, which is important for the diffusion of the innovations. Therefore, both early adopters and the early majority contribute in bringing innovations into the social mainstream. The *late majority* are the members of the social system who wait to adopt an innovation until it has been widely adopted by the majority of their peers. Finally, the *laggards* are the most sceptical part of the social population in adopting an innovation. Often they all take part in a community of other laggard peers. This group of adopters will wait to adopt an innovation until they have seen the proof of the success of the innovation.

Following an innovation management perspective, the emphasis of the subsequent sections is placed on the 'Development' and on the 'Deployment' commercialisation phases.

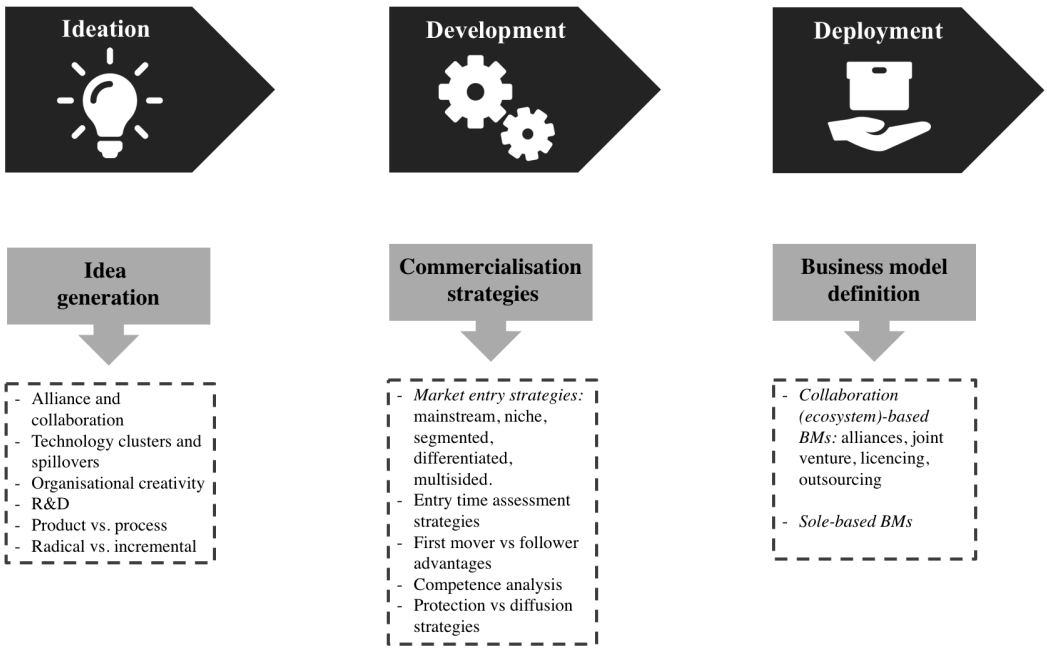


Figure 1 The commercialisation process of a technological innovation
Source: adapted from (Casadesus-Masanell & Ricart, 2010; Datta, et al., 2015; Osterwalder & Pigneur, 2010). Icons sources: Ideation - Gregor Cresnar; Development and Deployment - Freepik

2.2.2 Technology commercialisation: strategies

Whilst the 'Ideation' concerns the ideas generation phase of a technology development, the 'Development' is the phase in which the commercialisation strategies are defined. In terms of outcomes, the definition of the latter is a complex process that requires companies to identify the most suitable commercialisation strategy for their innovation. The process of defining the strategy can follow two main decision logic paths; causal or effectual. Respectively, the first one is more consistent with a logic of exploitation (i.e. prediction) and the other one with a logic of exploration (i.e. control) (Sarasvathy, 2001).

The strategy literature suggests contrasting commercialisation strategies for new technologies. Hence, as highlighted by Osterwalder & Pigneur (2010), there are several types of market choices from which an entrepreneur can choose, such as: mass, niche, segmented, diversified and multi-sided. As initially highlighted in the studies on disruptive innovation, large firms can encounter difficulties in taking up opportunities where the markets are not yet completely formed. Instead, these situations can be more suitable for small ventures that can easily achieve their competitive advantage without the pressure of incumbents (Christensen, 1997). Along these lines, Davidow (1986) suggests that niche strategies are preferred by high tech-based new ventures that aim to commercialise innovation based on technologies with the potential to be exploited within the next 10 years (emerging technologies (Keenan, 2003)). Hence, according to Christensen & Rosenbloom (1995), by pursuing a niche strategy, new ventures can better defend themselves from incumbent competition. Nerkar & Shane (2003) take the opposite perspective, and recommend that new ventures develop intellectual properties in a way that could suit a wide range of the market. However, new ventures are often limited by financial constraints that do not allow them to pursue commercialisation across several different markets (Maine & Garnsey, 2006). At the same time, Maine et al. (2012) suggest that a suitable trade-off strategy for new ventures could be to select some target markets, where the technology can be applied, and exploit innovations among the ones selected. Later, Lubik & Garnsey (2015) suggest that radical, generic technology-based ventures should select mainstream markets to get in, rather than niche markets, due to the presence of incumbent firms that can provide the resources needed by the new venture. Specifically referring to established industries, Grant (2016) suggests that firms should exploit innovations through differentiation strategies, such as embracing a new customer segment and augmenting the product offer with more additional related products and or services. Another approach that can be adopted by firms operating in mature industries is to innovate in the realisation of more customised solutions and the use of creativity to face traditional situations. The choice of the most suitable exploitation strategy is linked to the resources and capabilities of the innovator firm (Grant, 2016).

Among the possible risks for the commercialisation of a technology, some concern the commercialisation of other complementarities that can take place in the present or in the future. Independent from their experience, structural constraints, as well as cognitive biases are elements that contribute to the complexity in the technology commercialisation that firms have to cope with, which can lead to high level of uncertainty.

For established organisations, some uncertainties can be represented by the risks of remaining stuck in their usual ways of approaching the new challenges. For new ventures difficulties lie in being able to choose among the great number of market options available (Maine et al., 2012), and in the considerable challenge that they face to gain access to the resources that are useful for their creations. All these uncertainties mean the firms have different visions of their future, some see a clear-enough future, others a range of futures, a set of alternative futures or true ambiguity (Courtney et al., 1997).
Hence, technology-based new ventures, which are typically characterised by scarce resources and capabilities, are keen to reduce the risks generated by uncertainties through strategies that rely on the support of other players (e.g. outsourcing, alliances, and joint ventures - i.e. collaborations) (Maine & Garnsey, 2006). Collaborations with other organisations can help new ventures share risks and therefore reduce the complexity (Chesbrough, 2003). Hence, Marx et al. (2014) and later Marx and Hsu (2015) identified that new ventures who aim to commercialise their technologies, but lack resources and capabilities, can pursue their ideal strategy by adopting interim co-operative strategies to access the needed complementarities. This consists of developing a temporary, not ideal, sub-strategy, such as launching the product briefly on the market to test the technology and get proof of it. Once the firm has proved the technology, it can aim to build partnerships with incumbents in the market. By doing so, the firm can achieve its ideal strategy. As such, the strategy can be exploited in the 'Deployment' phase (Casadesus-Masanell & Ricart, 2010). Here, the ecosystem of partners (e.g. suppliers, complementors, downstream players, end–customers, governmental institutions, policy - Adner & Kapoor, 2010) is outlined in the business model, sometimes even before the technology reaches its maturity, (Lubik & Garnsey, 2015).

Gap n. 1: Although the understanding of strategies and BMs is growing, there is still the need to understand the links between strategic choices and specific BM solutions in the technology commercialisation, in particular in established industries (Baden-Fuller & Haefliger, 2013; Datta et al., 2015; Probert et al., 2013; Spieth, et al., 2016).

2.2.3 Technology commercialisation: collaborations (ecosystem)

Firms can successfully commercialise their innovation if the process is managed across an entire group (ecosystem) of innovation participants orchestrating "value constellations" with partners that have different competences through alliances, joint ventures, licensing agreements and other kinds of relations (Vanhaverbeke & Cloodt, 2006). The joint collaboration of the ecosystems of actors allows the whole constellation to create and capture value from the commercialisation of their innovations (Vanhaverbeke & Cloodt, 2006). Adner (2006) highlights the companies' need of inter-firm coordination and collaboration within their specific market and environment to face the complexity of innovation exploitation. Ecosystems are made of "collaborative arrangements through which firms combine their individual offerings into a coherent, customer-facing solution" (Adner, 2006, p. 2).
Adner & Kapoor (2010) show their generic conceptualisation of an ecosystem (see figure 2), according to which the outputs produced by the upstream supplier are the inputs for the focal firm. The focal firm processes them to create its product/service, that will then serve as an input for the customer. The model also includes the possibility that the customer may need other complements to the product/service offered by the focal firm to be able to use it. Hence, the market/s selection impacts on the position occupied by a firm in the supply chain, on its potential partner/s, suppliers, co-producers as well as competitors.

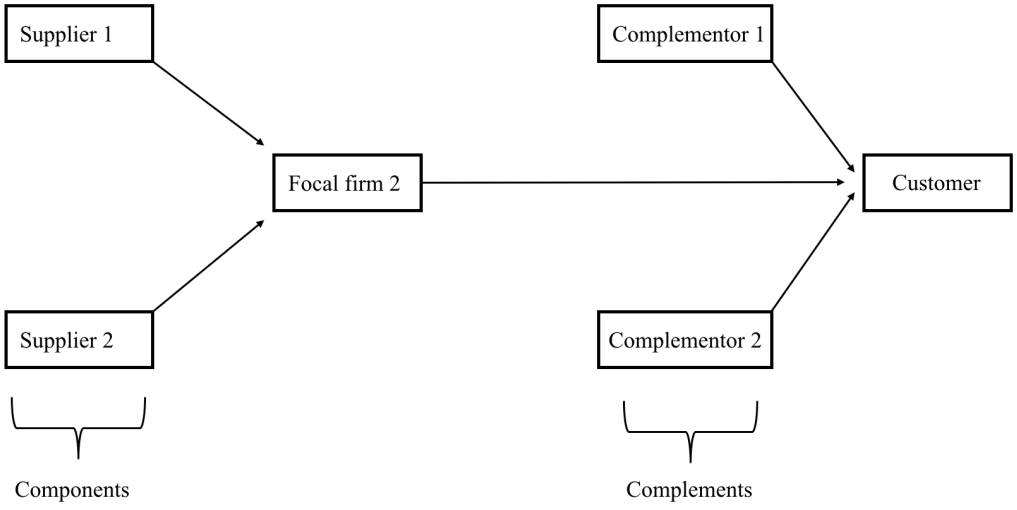


Figure 2 Generic conceptualisation of an ecosystem
Source: (Adner & Kapoor, 2010, PP. 309)

Hence, firms can create more value through partner collaborations than in isolation (Adner & Kapoor, 2006; Williamson & De Meyer, 2012). In the collaboration, each partner becomes involved by sharing specific competencies and becoming dependent on the other partners (Clarysse et al., 2014). As such, both cooperative and competitive tensions (Moore, 1993; Nalebuff & Brandenburger, 1997) might occur amongst partners. The central firm in an ecosystem acts as the keystone (Iansiti & Levien, 2004), it is responsible for the direction of the network and its management, which is achieved by pursuing several open innovation activities (e.g. Faems, Van Looy, & Debackere, 2005; Phelps, 2010). In this way, the management of collaborations through inbound and outbound open innovation processes (i.e. "open innovation as a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization's business model" - (Chesbrough & Bogers, 2014)) becomes of strategic importance for firms to gain competitive advantage (Spithoven et al., 2013). Through collaborations, firms can identify new ways not only to develop innovation, but also to generate value by commercialising the innovation in partnership with others (i.e. through an open business model – further detailed in section 2.3.3) (Vanhaverbeke & Chesbrough, 2014). Along these lines, Adner (2012) highlighted that "firms shift from using supply chains to offer better products to embracing partnerships and collaboration to offer better solutions". With this shift, these innovation-based firms are finding new ways to build and commercialise their products, by increasingly leveraging co-creation processes (i.e. an "active, creative and social collaboration process between producers (retailers) and customers (users), facilitated by the company" Piller, et al., 2010; Rayna & Striukova, 2015). All these processes are defined in the business models (BMs).

Gap n. 2: Even though the understanding of collaborations is growing, there is still need for further studies devoted to understanding how collaborative approaches (OI/OBM) support the commercialisation of emerging technologies (Bogers, et al., 2016a).

2.3 Technology commercialisation: business model

By increasingly building and managing collaborations with external partners, innovating firms are finding new ways to build and commercialise their products by leveraging these processes (Rayna & Striukova, 2015). A business model that allows an organisation to exploit its technological innovation (Chesbrough & Rosenbloom, 2002; Cortimiglia et al., 2016) represents its implemented strategy (Casadesus-Masanell & Ricart, 2010). The BM is hence a helpful unit of analysis for the study of innovation commercialisation approaches.

2.3.1 Theoretical grounding: strategy, entrepreneurship and innovation management

The concept of business model is considered to have a multi-dimensional nature; therefore, scholars look at it from different perspectives. According to Demil et al. (2015) the business model concept is intended to explore "how firms do business at the system level" (Zott, et al., 2011). Hence, the authors see the BM not as a unique construct, but as a set of aspects determining a phenomenon. According to Demil et al. (2015)**,** the business model concept finds its place between strategy and entrepreneurship studies. In addition to this perspective, Spieth et al. (2016) also highlighted the innovation management literature to explain the BM concept. Consequently, the BM can be considered at the intersection of the strategic, entrepreneurship and innovation management literatures.

Among the strategy scholars, the BM is operationalised as a unit of analysis at the system level. The scholars in the field look at the BM as a construct to understand how specific mechanisms of creating and capturing value can support an organisation's ability to achieve competitive advantages (Spieth et al., 2016; Zott et al., 2011). In this case, scholars see the business model as the reflection of the firm's planned strategy. For instance, Zott and Amit (2008) consider the BM as the organisational frame in which are indicated the firm's mechanisms to create and capture value. Along this line, Casadesus-Masanell and Ricart (2010) intend the BM as the logic through which the firm operates to create and capture value.

The entrepreneurship literature examines the BM as a framework to be used by new ventures to structure the business activity in the fundraising process (Spieth et al., 2016). Demil et al. (2015) detail that entrepreneurship scholars focus their attention on the link between entrepreneurs and opportunities to explain the value creation mechanisms through the "discovery, creation and exploitation of opportunities".

The innovation management scholars focus on the function of the BM as a construct to organise an organisation's resources, capabilities and activities in order to create, capture and deliver value (Teece, 2010). Here business models are useful to identify the market strategy (Chesbrough & Rosenbloom, 2002).

To meet the purpose of the present study (i.e. understand how BMs are framed in the commercialisation processes of a new technology in an established industry), none of the three perspectives is excluded from the analysis.

2.3.2 The concept of the business model and business models archetypes

The concept of the business model started to spread with the diffusion of the information and communication technologies and the emergence of internet companies (DaSilva & Trkman, 2014). Along with its diffusion among practitioners, scholars have started analysing the BM concept since the early 2000s, and the literature on BM has since then been growing fast and has produced a wide range of definitions (see for instance table 1).

Source	BM Definition	BM Building Blocks	BM Framework
(Amit and Zott, 2001) (Zott, et al., 2011)	The business model depicts "the content, structure, and governance of transactions designed so as to create value through the exploitation of business opportunities". - The business model is "a system of interdependent activities that transcends the focal firm and spans its boundaries"	Transaction content, transaction structure, transaction governance	Firm-centric - Network-centric
(Henry Chesbrough & Rosenbloom, 2002)	The business model is "the heuristic logic that connects technical potential with the realization of economic value".	Value proposition, market segment, revenue generation mechanisms, value chain, complementary assets, cost structure and profit potential of the offering, position of the firm within the value network of suppliers and customers, competitive strategy	Network-centric
(Magretta, 2002)	Business models are "stories that explain how enterprises work. A good business model answers Peter Drucker's age-old questions: Who is the customer? And what does the customer value? It also answers the fundamental questions every manager must ask: How do we make money in this business? What is the underlying economic logic that explains how we can deliver value to customers at an appropriate cost?"	Customer, customer value proposition, value delivery method, economic logic that supports delivery of value to the customer at an appropriate cost	Firm-centric
(Morris, et al., 2005)	A business model is a "concise representation of how an interrelated set of decision variables in the areas of venture strategy, architecture, and economics are addressed to create sustainable competitive advantage in defined markets"	Value proposition, customer, internal processes/competencies, external positioning, economic model, and personal/investor factors.	Firm-centric
(Johnson, et al., 2008)	Business models "consist of four interlocking elements, that, taken together, create and deliver value".	Customer value proposition, profit formula, key resources, and key processes	Firm-centric
(Santos & Spector, 2009)	"A business model is a configuration of activities and of the organizational units that perform those activities both within and outside the firm designed to create value in the production (and delivery) of a specific product/market set."	Set of activities, set of organisational units, linkages (physical transactions and human relationships), governance mechanisms	Network-centric
(David J. Teece, 2010)	"A business model articulates the logic, the data and other evidence that support a value proposition for the customer, and a viable structure of revenues and costs for the enterprise delivering that value".	Market segment, value proposition, mechanism to capture value, isolating mechanism	Firm-centric
(Osterwalder & Pigneur, 2010)	"A business model describes the rationale of how an organization creates, delivers, and captures value".	Customer segment, value propositions, channels of distribution, customer relationships, revenue streams, key	Network-centric

		resources, key activities, key network partnerships, cost structure	
(Casadesus-Masanell & Ricart, 2010)	" Business model refers to the logic of the firm, the way it operates and how it creates value for its stakeholders."	A BM include two different sets of elements: (a) the concrete choices (compensation practices, procurement contracts, location of facilities, assets employed, extent of vertical integration, and sales and marketing initiatives) made by management about how the organisation must operate, and (b) the consequences of these choices. Three types of choices: policies, assets and governance structures.	Firm-centric
(Mason & Spring, 2011)	"The business modeling process can be understood to be both influencing and being influenced by not only internal actors within the firm developing the business model, but also by external actors within the business network – because of this complexity it seems unlikely that a linear sequence of activities could ever exist".	Technology, market offering, network architecture	Network-centric
(Baden-Fuller & Haefliger, 2013)	The business model is "a system that solves the problem of identifying who is (or are) the customer(s), engaging with their needs, delivering satisfaction, and monetising the value".	Customers, customer engagement, value delivery and linkages, monetisation.	Network-centric
(Massa & Tucci, 2013)	Business model is "the rationale of how an organization [..] creates, delivers, and captures value [..] in relationship with a network of exchange partners (Zott et al., 2011)"	Value creation, value delivery, value proposition, value capture and value network	Network centric
(Cortimiglia et al., 2016)	"A BM is a unit of analysis that explains, from a system-level perspective, how activities conducted by a firm and external stakeholders create, deliver, and appropriate value (Zott et al., 2011)".	Value networking, value creation, value proposition, value delivery, and value appropriation.	Network-centric
(Wirtz, et al., 2016)	"A business model is a simplified and aggregated representation of the relevant activities of a company. It describes how marketable information, products and/or services are generated by means of a company's value-added component."	Strategic, customer & market as well as value creation components	Network-centric
(Rayna & Striukova, 2016b)	"The ability and the extent to which the firm is able to create and capture value is defined by its business model (Øiestad and Bugge, 2014) ".	Value proposition (product offering, service offering, pricing model), value creation (core competences, key resources, governance, complementary assets, value networks), value delivery (distribution channels, target market segments), value capture (revenue model, cost structure, profit allocation), and value communication (communication channels, ethos and story).	Network-centric

Table 1 Business model definitions and dimensions

Two main approaches to study BMs exist: *firm-centric* (Magretta, 2002) and *network-centric* (Chesbrough & Rosenbloom, 2002)(see table 1). The two schools differ in that a *firm-centric* approach is mostly concerned with the company's BM from an internal point of view. In other words, this vision considers the BM only within the firm's boundaries. Therefore, a firm-centric approach includes only the aspects of 1) value proposition, 2) value delivery, 3) value creation and 4) value capture. Conversely,

the network-centric view of the BM also includes 5) a network component in the BM, where the network can at the same time be a source of ideas, value creation, value delivery and value capture (figure 3). This second perspective is consistent with an *open* firm's strategy, which has the advantage of increasing a firm's responsiveness to external influences (Vanhaverbeke & Roijakkers, 2013). It reflects how the firm collaborates with its ecosystem to develop and capture value: "the BM may be conceptualised as depicting the rationale of how an organization [..] creates, delivers, and captures value (economic, social, or other forms of value) in relationship with a network of exchange partners" (Massa & Tucci, 2013).

The definition of BM adopted in this study follows the view highlighted by Cortimiglia, et al. (2016), who developed a network-centric vision on BM, widely diffused both among scholars as well as practitioners. Hence, as definition of BM, the authors adopted the one from (Zott et al., 2011), which is widely adopted among scholars. Furthermore, Cortimiglia et al. (2016) outlined a conceptual framework that includes in its five main BM dimensions also the nine dimensions detailed by Osterwalder and Pigneur (2010), whose BM definition is highly diffused across practitioners. Hence, the BM construct that has been adopted contains the following five dimensions (see below). For the purpose of this work, the definition of BM that has been adopted also includes elements derived from Rayna and Striukova (2016a), Vanhaverbeke and Chesbrough (2014) and Baden-Fuller and Haefliger, (2013):

1) *Value proposition (VP)*: A description of the main purpose of the products or services offered by a firm to its customers. It indicates the mission and the vision of the project (Cortimiglia et al., 2016; Osterwalder & Pigneur, 2010). This dimension also includes the segment of customers targeted by the firm (Baden-Fuller & Mangematin, 2013; Cortimiglia et al., 2016), as well as the type of value that it aims to bring to the customers (i.e. newness, performance, customisation, pursuing the objective, design, brand/status, cost reduction, risk reduction, accessibility, convenience/usability) (Osterwalder and Pigneur, 2010).

2) *Value delivery (VD)*: This BM dimension indicates how the organisation reaches its customers. This building block thus can be included in the relationships that the organisation builds with its customers (i.e. personal assistance, dedicated personal assistance, self-service, automated service, communities, co-creation) and the distribution channels (direct sales force, direct web sales, indirect own shop, partner store, wholesaler) (Cortimiglia et al., 2016; Osterwalder & Pigneur, 2010). This BM dimension can also include the communication channels (Rayna & Striukova, 2016a).

3) *Value creation (VCr):* This building block is linked to the ability of the company to create value through key resources and competences. It reflects the key activities and resources that indicate how a product/service is developed to create value for customers (Cortimiglia et al., 2016; Enkel, Gassmann, & Chesbrough, 2009; Osterwalder & Pigneur, 2010).

4) *Value capture (VCa)*: This building block represents the ability of the business to capture revenue through monetisation (Baden-Fuller & Mangematin, 2013). Therefore, it includes the business's costs and its related revenue stream (Cortimiglia et al., 2016; Osterwalder & Pigneur, 2010).
5) *Value network (VN)*: This building block is consistent with how a firm collaborates and interacts with the stakeholders of its ecosystem to enhance the commercialisation process of the firm's product/ service (Vanhaverbeke & Chesbrough, 2014). This category also includes the competences that come from (the) outside the organisation. Therefore, this BM dimension includes the relationship with partners (Cortimiglia et al., 2016; Osterwalder & Pigneur, 2010) and suppliers (i.e. hierarchical or networked) (Baden-Fuller & Haefliger, 2013).

These BM's building blocks are summarised in figure 3.

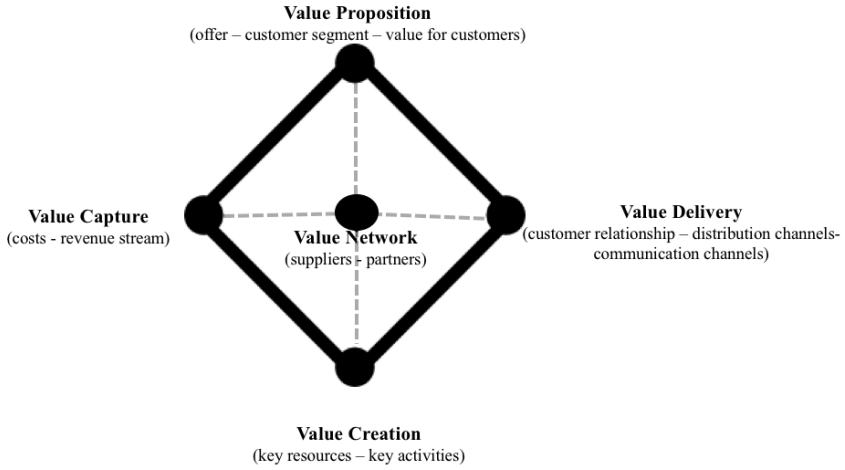


Figure 3 Network-centric business model
Icon source: adapted from GraphicsBay

The BM's dimensions, grouped through a series of common patterns, generate an archetype (Zott et al., 2011). This can be considered as a general projection of a BM (Massa & Tucci, 2013). Among scholars, many categorisations of these archetypes exist. For instance, Cabage & Zhang (2013) identified seven business model archetypes for online businesses, based on the general value proposition offered by the firm to its customers (e.g. product, service, distribution, product-service, etc.). Gassmann, et al. (2014) identified 55 BM archetype patterns to enable organisations to innovate their BMs. A known literature example of a BM archetype is the case of the 'razor and blade BM', which relies on "selling cheap razors to make customers buy its rather expensive blades" (Zott & Amit, 2010).

Organisations adopt BMs with different shapes and forms, starting from a general archetype. BMs that are characterised by their dependency on the ecosystem of partners are known as open business models.

2.3.3 An open approach to business models for technology commercialisation

In ecosystems, firms integrate their individual technologies, products and services to develop and deliver a coherent solution for a particular market (Adner, 2006; Adner & Kapoor, 2010). Each organisation holds a particular part of the final solution, which together with the other complementary parts, delivers the value to customers (Christensen & Rosenbloom, 1995; Clarysse et al., 2014). Therefore, through ecosystems, firms manage to create value beyond what a single firm could do in isolation (Adner, 2006).

The ecosystems typically do not follow a linear value creation process where each partner is only linked to the linear supply chain - upstream and downstream (Iansiti & Levien, 2004). Rather, the network also consists of horizontal links amongst organisations (Moore, 1993). The participants in the ecosystem are mutually dependent on each other (Clarysse et al., 2014), although they might all play different roles. Accordingly, *open business model* (OBM) has been defined by Weiblen (2014) as a construct in which the collaboration with the ecosystems of partners is central in the mechanisms through which the focal firm creates and captures value. Frankenberger et al. (2014) present an inbound vision of OBM. Hence, the authors see OBMs as the value of integrating ideas, resources and capabilities from the external environment into the focal firm's BM.

Vanhaverbeke & Chesbrough, (2014, pp. 54) defined OBM as "the situations where the innovating company relies on its partners' competencies to jointly create value for customers and share that value according to agreements they have negotiated prior to the collaboration." The authors see the open business model as a model to organise innovation. The concept levers the division of labour as the source of value creation (i.e. firms can rely on external collaboration to facilitate their innovation commercialisation process), and looks at the ability of the firm to capture value by using resources, knowledge and capabilities, not only within the firm's boundaries but also outside them.
Table 2 reports a classification of OI/OBM done by Vanhaverbeke & Chesbrough, (2014, pp. 54) in which different open innovation approaches are combined (i.e. how the innovation is developed) with the level of openness of the BM.

Business Models Outcomes → *Open Innovation process ↓*	**STAND ALONE BM**	**LINKED BM**
INBOUND	**3**. Look for **other people's knowledge to develop a product/service** which is offered without the help of others. (e.g. a product provider, works with partners to develop its innovation, but commercialises it internally)	**6.** Look for **others knowledge** to develop a **new BM.** (e.g. end customers provide the design of the product they want from the manufacturer, who realise them)
OUTBOUND	**2. Offer internal knowledge to others for them to develop a new product/service** which is commercialised without the help of others. (e.g. a consultancy activity, where the firm provides its internal knowledge to others, so they can develop their own innovation)	**5. Offer internal knowledge** to develop a **new BM.** (e.g. a software provider that provides its product tailored to be embedded in the client's/partner's final product)
(NONE) CLOSED	**1**. **Develop and commercialise a new product/service** with internal **own knowledge** without the need of complementary offers. (e.g. R&D and commercialisation is generated internally)	**4. Launch of a product/service internally** conceived whose **value is obtained** via the **complementarities offered by others.** (e.g. a product ideator, who needs the help of the partners to commercialise it)

Table 2 Classification of combinations of open innovation and open business models
Souce: adapted from Vanhaverbeke and Chesbrough's (2014)

According to Vanhaverbeke and Chesbrough's (2014) view (table 2), while OI activities help in the product/service development by combining flows of knowledge (internal – external), this, can either needs an external input (collaborations) for the commercialisation of the innovation (6), or not. In this latter case, the innovating firm can commercialise independently from the innovator partners (3). A specular opposed situation happens when the focal firm releases its internal knowledge to others, contributing in the development of other BMs (5). Similarly, there is the situation in which the focal firm provides its internal knowledge to a third party to develop innovation, but does not, however, contribute in the development of the third-party BM (2). The classification also foresees the closed innovation situations for both innovation and BM (1) or only for innovation (4).

2.3.4 Business models for the commercialisation of emerging technologies

By exploiting new digital technologies, such as additive manufacturing (AM), firms can consider the possibility to open up their boundaries (Thiesse et al, 2015). This might support, both OI to involve a range of partners in the co-creation of products and new (O)BMs to capture value from innovation

(Rayna & Striukova, 2016b). The affordability of AM could offer ventures a variety of options; ranging from the development of new strategies and new possibilities for firms to create new industries, to the development of new potentialities to meet some of the needs of unsatisfied customers of existing industries (De Jong & De Bruijn, 2013). In the existing literature, some scholars have highlighted some of the potentialities of AM enabling BM solutions (e.g. Bogers, et al., 2016; Holzmann, et al., 2015; Jia et al., 2016; Rayna & Striukova, 2014, 2016b). Figure 4 describes a generic value chain for AM, whereby the technical elements (e.g. designer provider, material provider, process technology provider, digital ICT provider, knowledge provider), once they are aligned, can deliver the industrial system (AM-value chains). Every actor that commercialises innovation in an industry needs to put together a value chain, and emphasise, through the BM, how the elements are assembled (with closed or network-based (O)BMs) to deliver value, and how organisations, that take part in the value chain, are going to participate in the process.

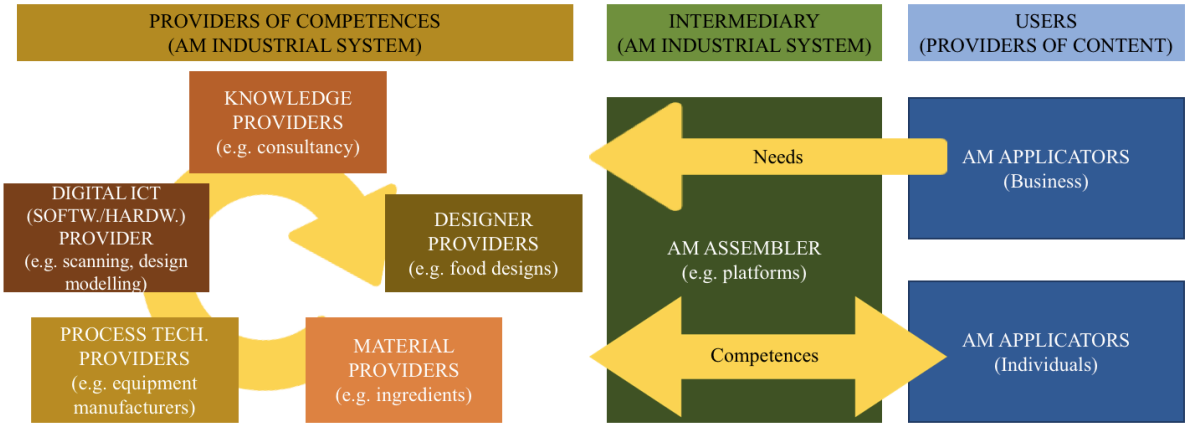


Figure 4 AM value chain.
Source: adapted from (Piller, et al. 2015)

Bogers et al. (2016) and Piller et al. (2015) pointed out the opportunities for the customers to become an integrated part of the value chain with the provision of competences (e.g. design and personalised designs or personalised combinations of needs) in order to make the BM work. Bogers et al. (2016) underline how AM can help industries to move towards more decentralised supply chains in which the consumers become active players in the promotion of the manufacturer. Jia et al. (2016) outline two supply-chain centric BM options, including a retailer supply-chain centric BM in the food industry, in which the retailer is the focal firm and it produces the 3D printed food products using a 3D printer. Here customers can become active players by going to the retialer's shop and creating/designing their own personalised 3D food printed items. Rayna and Striukova (2016b) suggest a range of BM options including these customer-centred-BMs amongst the most radical.

Gap n. 3: However, there is a theoretical understanding of the AM supply chains and of some possible BMs, there is still the need to understand what types of BMs (open or closed BM - Vanhaverbeke and Chesbrough 2014) emerge as a result of the availability of particular technologies (Bogers et al., 2016b; Ford et al., 2016).

2.4 Business model innovation for technology commercialisation

To navigate the complexity of the environment and successfully commercialise innovation, ventures need to be able to change and adapt their strategies and reflect these in their BMs.
Thus, innovations do not happen only at the technology/service level, but also often occur at the BM level as starting point for innovating a firm's strategy. Hence, the *business model innovation* (BMI) can be seen as a comprehensive unit of analysis that allows managers/entrepreneurs to consider at the same time the most relevant endogenous and exogenous factors that would enable their organisation to achieve competitive advantages and better performances (Datta et al., 2015; Velu, 2015) In fact, Schneider and Spieth (2013) argue that BMI has a positive influence on the firm's ability to react to the continuous changes in the markets. Several scholars consider it a dynamic capability (Spieth et al., 2016). Mason and Spring (2011) see organisations, business networks and markets as embedded systems that influence each other's business models. Also Simmons et al. (2013) see BM development within a dynamic evolutionary perspective. Hence, the business model concept can be seen not only as an enabler for innovation, but also as the subject of the innovation itself (Mitchell & Coles, 2003; Zott et al., 2011). Many studies have been produced on BMI since the beginning of the millennium, however, the literature on this topic can be further expanded (Frankenberger et al., 2014; Velu, 2015). Like for the BM, there is not a unique definition for BMI, but several scholars understand it as an instrument to understand a firm's evolution, change and transformation (e.g. Chesbrough, 2010; Cortimiglia et al., 2016; Demil & Lecocq, 2010; Dmitriev, et al., 2014; Hock, 2015; Johnson et al., 2008).

2.4.1 Business model innovation: process

In general, it is agreed that the BMI process is cyclical (Chesbrough and Rosenbloom, 2002; Teece, 2010; Demil and Lecocq, 2010; Osterwalder and Pigneur, 2010; Chesbrough, 2010; Achtenhagen et al., 2013; Simmons et al., 2013; Dmitriev et al., 2014; Lubik and Garnsey, 2015) and involves two main phases, *BM design* and *BM reconfiguration* (Massa & Tucci, 2013).With similar meanings, Cortimiglia et al. (2016) refer to *BM design*, and *BM development* respectively. BM design (BMD) is usually associated with the designing process for creating new business models. Whilst the BM reconfiguration (BMR) is a process for already existing firms that aim to change their actual business model. These two approaches toward BMI are rooted in two different streams of the literature. On the one hand, the BMI

processes related to the design of new business models for the commercialisation of innovations by new ventures are conducible to the innovation management literature as well as to the entrepreneurship literature. On the other hand, the BMI processes concerning the reconfigurations of the BMs of already existing firms, usually of a large size, are conducible to the strategy literature (Cortimiglia et al., 2016; Massa & Tucci, 2013).

Dmitriev et al., (2014) see BMI as a complex system of interactions that leads to a new BM, through a series of virtuous cycles, and *via* a "continuous process of conceptualising value and organising for value creation". Some scholars have also focused their attention on BM change in relation to the commercialisation of technological innovation (e.g. Cavalcante, et al., 2011; Dmitriev et al., 2014; Lubik & Garnsey, 2015). In this context, often the processes of innovating the BM takes place through a 'trial and error' learning process (Lubik & Garnsey, 2015; Sosna, et al., 2010). Sosna, et al. (2010) observed that the 'trial and error' learning approach is a strategic development mechanism adopted by organisations to innovate their BMs.

The literature has highlighted several ways in which the BM can change over the time. For instance, Cavalcante et al. (2011) conceptualised a process-based framework, integrating it with the role of individual agency. In their work, the authors identified four main typologies of business model change (i.e. BM creation, BM extension, BM revision and BM termination), and then linked those typologies to the degree of innovation. Amit & Zott, (2012) indicated three main ways in which a BM can change, namely "by adding novel activities, by linking activities in novel ways – or by changing one or more parties that perform any of the activities". Aversa, et al., (2015) detected six possible BM modular operators (i.e. splitting, substitution, augmenting, inverting excluding and porting) that are generated at the single BM dimension level. Casprini, et al. (2014) outlined three main BM evolution types that have been observed when organisations apply high technologies within the mature sector of cultural heritage. These are: (i) firms shift from one BM archetype to a completely different one over time; ii) firms briefly change their BM over time, but then go back to the original BM; and iii) organisations do not change their BM over time.

Each BMI cycle (Design and Reconfiguration) is instigated by certain 'triggers' that lead to a new BM with a certain degree of innovativeness (Dmitriev et al., 2014).

Gap n. 4: Although the literature on BMI is growing, it is still at a nascent stage and further studies are needed, especially in understanding the patterns in the BMI process (Achtenhagen, et al., 2013; Cavalcante et al., 2011)

2.4.2 Business model innovation: triggers and degree of innovativeness

Some studies analyse the factors that can trigger the BMI process. For Johnson et al., (2008) a BMI happens after gaining new knowledge, and therefore by redefining the customer value proposition. Following the lines highlighted by Demil & Lecocq (2010) and later by Dmitriev et al. (2014), the BM cycles can be triggered by several factors. Overall, the cycles can be started by the interaction between and within the BM components, and the interactions that occur within the firm's capabilities, as well as the inputs that can come from the external environment and the specific context (Demil & Lecocq, 2010). Triggers can be divided into three macro categories: external, internal and contextual. For instance, internal triggers can be related to the effects of decisions that can affect the organisational system (e.g. a decision related to outsourcing part of the production) (Demil & Lecocq, 2010). The changes to the BM can also be triggered by external factors such as a geographical expansion, changes in demand, technological advancements, and country-dependent environmental issues (Dmitriev et al. 2014). Ultimately, the dynamism of a BM can be launched by contextual factors. Within this context Dmitriev et al. (2014) show the examples of: the individual in the organization, the market segment, the nature of an invention and the degree of radicalness.

When the BMI process cycles finish, a new BM emerges. This is the outcome, which is either 'very new' or 'a bit new.' Hence, as for technologies, the level of changes in the BM can present a radical and incremental nature. The difference between the two types of BMI is the degree of change of a BMI: the more disruptive the change, the more radical the BM (Velu, 2015). Bucherer et al. (2012) detail the degree of innovativeness of a firm's BM according to the radical and incremental dimensions associated with the impact on the market versus industry breakthroughs. For the authors, an incremental BMI occurs when there is a new BM, but it does not present a substantial breakthrough in the market/industry, while a radical BMI happens when the BM reflects significant discontinuities in market and industry. Rayna & Striukova (2014; 2016b) 'dig deeper' into the studies on the degree of innovativeness of the BM by highlighting two main perspectives of BMI literature: *internal* (inside) and *external* (outside). In the *internal* view of BMI (e.g.Brink & Holmén, 2009; Demil & Lecocq, 2010), the radicalness of the BMI can be reflected in the degree of change that happens within a firm's structure (e.g. how many BM dimensions change at the same time and the related degree of change). While the *external* view of BMI (e.g. Johnson et al., 2008) perceives the disruptiveness of the BMI according to its effects on the external environment (i.e. customers, market and industry). Rayna & Striukova (2014; 2016b) developed a framework (i.e. inside-outside BMI framework) that merges the two perspectives to understand the interdependencies between radical/incremental changes in the BM and the sustaining or disruptive impact on the market/industry (see figure 5). In this way, it is possible to detect not only the cases in which to a great change in the BM corresponds to a disruptive impact on the market (i.e. the dotted arrow that connects the radical part of the framework with the disruptive

one), but also the cases in which, even though there is a great change in the BM, this is not reflected by a great impact on the market (i.e. the dotted arrow that connects the radical part of the framework to the sustaining one) (Rayna & Striukova, 2014; 2016b). The framework shows also the opposite scenario, whereby incremental innovations in the BM can lead either to a sustained impact on the market (i.e. the dotted arrow from the incremental side of the framework to the sustaining one) or to great disruptiveness in the market (i.e. the dotted arrow from the incremental part of the framework up to the disruptive one). The framework shows that in between of the main axes there are several possible scenarios of combinations between the internal changes in the BMs and their impact on customers, market and industry.

Some studies have highlighted that the BM evolution should be recognisable by the growth of the revenues, as well as the costs. At least some changes have to occur in the structure of these indicators, as stated by Demil & Lecocq (2010).

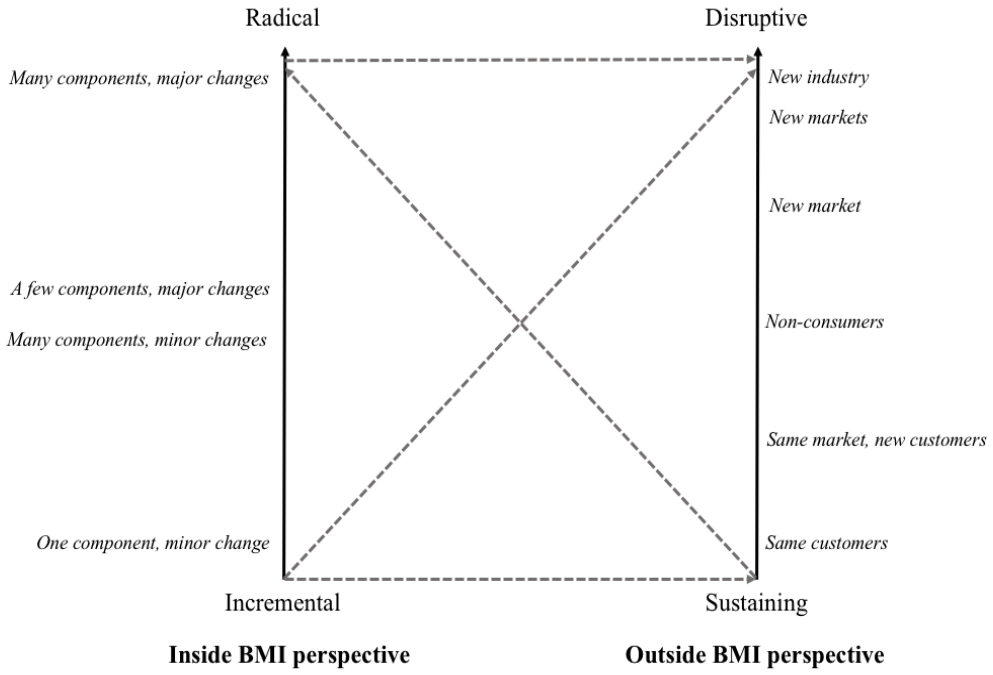


Figure 5 Inside-outside BMI framework
Source: Rayna & Striukova, (2016b, pp. 223)

Gap n. 5: Further studies on BMI are needed also on understanding how the BM evolves (e.g. triggers and degree of innovativeness), especially concerning the commercialisation of emerging technologies in established industries (Dmitriev et al., 2014).

2.5 Business model and its dynamics: a priori framework in the commercialisation of technological innovation

An a *priori* framework (i.e. set of constructs) that synthesises the technology commercialisation (strategy and (O)BM) and the business model innovation (process, triggers and degree of innovativeness) of an innovation is derived from the literature. It is reported in figure 6. The explanation of the framework is described in the following section.

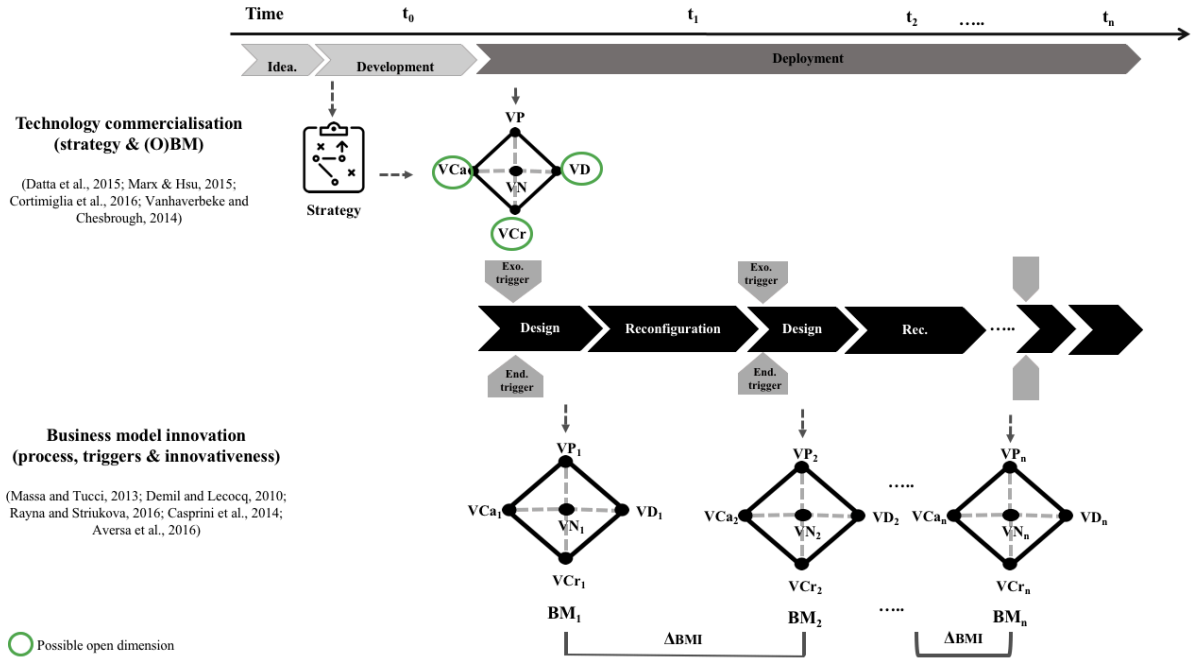


Figure 6 A priori framework: business model and BM innovation in the technology commercialisation process
Icons sources: strategy – Zlatko Najdenovski; BM - adapted from GraphicsBay

In the case of emerging technologies, the commercialisation process can be complex due to high technology and market uncertainty (Maine & Garnsey, 2006). The process becomes even more complex if it focuses on emerging technologies entering into established industries, due to the high barriers to entry and to the market saturation (Manzini et al., 2016). Usually, emerging technologies are developed by new ventures (Maine et al., 2012) that have to choose their commercialisation strategies. For instance, new ventures developing the technology should choose their market. The most diffused options in the literature are niche (Davidow, 1986) or diversification (Nerkar & Shane, 2003) market strategies. This phase belongs to the 'Development' stage of the technology commercialisation process.

The exploitation of the strategies is realised in the formation of a BM within the 'Deployment' commercialisation phase (Datta et al., 2015). To reduce the market and technology risks, and therefore

the overall uncertainty, firms usually rely on collaborations, either to innovate (OI) and/or to commercialise (OBM). In this latter case, they assume a network-centric BM perspective with five BM dimensions (Cortimiglia et al., 2016). According to the OI/OBM literature, three of these BM dimensions can be open (VD, VCr and VCa) (Vanhaverbeke & Chesbrough, 2014).
As several other scholars have shown, the BMI can be seen in a cyclical manner (see for instance: Achtenhagen et al., 2013; Chesbrough, 2010; Chesbrough & Rosenbloom, 2002; Demil & Lecocq, 2010; Dmitriev et al., 2014; Frankenberger et al., 2013; Lubik & Garnsey, 2015; Osterwalder & Pigneur, 2010; Simmons et al., 2013; Teece, 2010).
The BMI process belongs to the 'Deployment' phase of the technology commercialisation process (Datta et al., 2015), where each cycle is triggered by exogenous or endogenous factors. Exogenous triggers can be brought back to all the factors that lead, for instance, to a new market opportunity and to technological advancements, for endogenous triggers it is possible to refer to all the factors related to a cognitive perspective (Hock, 2015).

Building on other scholars' work (e.g. Cavalcante et al., 2011; Demil & Lecocq, 2010; Rayna & Striukova, 2016b; Velu, 2015), one or more triggers in the framework initiate a BM cycle, and influence one or more of the BM dimensions, leading to a new BM (BMn) whose degree of innovation (ΔBM) will vary from incremental to radical (hence Incremental < ΔBM < Radical). The more dimensions (VCa, VCr, VN, VP, VD) change in a BM and the more these changes impact the whole BM, the higher is the degree of novelty (radicalness) of the new BM (BMn+1). However, a high degree of radicalness of the BM does not necessarily translate to a great impact (disruptiveness) on the market and vice versa, a small degree of radicalness in the BMI can generate a disruptive impact on the market (Rayna & Striukova, 2016b). The process of BMI can be seen as an iterative process either of BMD and sequentially of BMR, or as a process of BMD and separately of BMR (Massa & Tucci, 2013). This process is continuative through the life of the firm, although there might be a time lapse between cycles (Dmitriev et al., 2014). Once the BMI process ends, it results in a new BM that can assume various typologies and shapes (e.g. Aversa et al., 2015; Casprini et al., 2014; Cavalcante et al., 2011).
Due to the complexity of the commercialisation of emerging technologies-based venture, firms can go through many cycles of development of their business model within the entire innovation process. As recently suggested by Lubik & Garnsey, (2015), emerging-technologies-based ventures usually go through a 'trial-and-error' processes of learning to develop their business model. These companies can encounter many triggers points that can start constant cycles of adjustments.

This *a priori construct* was outlined as a guideline for the study in order to understand how BMs are framed in the commercialisation processes of a new technology in an established industry. A suitable context for this can be represented by 3D printing technologies in the food industry. The following sections (2.6 and 2.7) outline an overview of the two contexts.

2.6 Food industry overview

The food industry is of key importance for the global economy. As a matter of fact, the food industry generates more than four trillion US dollars in annual retail sales (Global Food Industry, 2016). Its value chain includes a series of actors ranging from: suppliers of input materials, primary food producers, manufacturers and food processors, distributors, marketers (e.g. restaurant, food service providers, food retailers) (Diamond et al., 2014). Along with the multiple actors of the supply chain, the overall general food ecosystem is also characterised by the intersections with linked supply chains relevant in the global economy, such as the food kitchen appliance. In fact, the food kitchen appliance world market size in 2015 was about $178 billion. It was the largest regional industry in the United States in 2015. And its market share in Europe is expected to grow (Global market insights, 2016).

In Europe the food industry represents the largest manufacturing sector, not only in terms of turnover (i.e. €1,244 billion), but also in terms of employment (i.e. 4.2 million people) and value added (i.e. 1.8% of the European value added) (Food Drink Europe, 2015). In the UK, the turnover generated by the food industry is about 80 billion GBP (Innovate UK, 2016). In the United States, among the most profitable industries that are highlighted are food consumer products (e.g. General Mills, PepsiCo), food services (e.g. Starbucks, McDonald's), food and drug stores (e.g. Walgreens, CVS) and food production (e.g. Tyson Foods, Smithfield Foods) (Grant, 2016).

The food industry is characterised by a high level of heterogeneity in the types of enterprises, in the types of production, and in their retail and distribution organisations (Pellegrini et al., 2014). This industry is also characterised by complex supply chains, in which there are multiple actors of linked supply chains. For instance, food and food kitchen appliance industries can collaborate and interlink in the process of developing and commercialising new products and technologies (Bigliardi & Galati, 2013b). This context evidences the rising needs to collaborate with the other actors of linked ecosystems, especially as the food industry is mostly composed of small and medium ventures (Bigliardi & Galati, 2013b).
Small and medium enterprises (SMEs) represent 99.1% of the food and drink firms in Europe. These firms employ about 63% of the overall food industry, they produce 48.1% of the value added produced by the food industry, and generate 49.6% of the turnover (Food Drink Europe, 2015).

Although the food industry represents such a huge pillar in the European, as well as in the global economy, it is usually considered a low-tech industry, where the majority of innovations are incremental rather than radical, with an intense use of trade secrets and low investment in research and development (Bigliardi & Galati, 2013a; Garcia Martinez, 2013; Manzini, et al., 2016). Investment in research and

development (R&D) is about €2,6 billion and the sustained level of R&D investment is 0.27% (Food Drink Europe, 2015).
Manzini et al. (2016) suggest that the constraints on this type of innovation are rooted in the demand side of the market. Customers tend to be risk adverse and initially resistant to changes. In the last decade, this scenario has been changing; the food business sector is currently becoming more consumer-oriented, and this means that constant developments are required to meet the customers' expectations. At the same time, firms face shortened product life cycles, more cost-effective markets, and private labels competition. In such a complex structure, firms often apply price competition strategies, which typically involve cuts in product differentiation (Bigliardi & Galati, 2013a; Manzini et al., 2016).

To face all these challenges and to remain competitive, the firms in the food industry need to innovate constantly. These innovations can come from inside the firm's boundaries as well as from outside (Garcia Martinez, 2013). Along these lines, Bigliardi & Galati (2013b) have outlined three main models through which the food organisations innovate and then commercialise their innovations:

1) 'Sharing is winning model': this model is characterised by collaboration activities between partners, suppliers and collaborations within the upstream elements of the value chain, to create value for the customers.
2) 'The food-machinery framework': much of the model relies on collaboration between partners to develop a new manufacturing process, which is not including the end customers.
3) 'The Want, Find, Get, Manage' model: the focal food firm identifies the external knowledge needed and finds the right partners able to provide them, so that the focal firm can acquire this knowledge, involving even end customers.

Within the technological innovation perspective, the advent of the information and communication technologies (ICT) as well as the constant technological advancements can positively and greatly influence the food and its related industries (Manzini et al., 2016).

2.7 3D printing technologies in the food industry

Among the latest technological innovations in the food industry, Deloitte (2015) highlighted that Food Layered Manufacturing (FLM) or known also as 3D food printing (3DFP), as an emerging radical technology application can bring several benefits in terms of product customisation, as well as the benefits of product differentiations and increasing direct relationships with consumers.

Usually, a technology is considered radical when it is novel, unique and has the potential to influence future innovations. A technology with these characteristics can lead to new products or services that

bring radical changes from several perspectives, such as: better product performance, lower production costs, generating new markets, changing existing market settings, inducing changes in customers' behavior, and changes in firms' business models (Dahlin & Behrens, 2005; Dewar & Dutton, 1986; Lettl, et al., 2005; Utterback, 1994). In line with this last definition, 3DFP application can bring radical changes in the production of customised food items.

Effectively, nowadays the production of food-customised products are mostly in the hands of single artisans, and this means that the production costs for these kinds of goods are high, and the quantity that can be produced is limited. 3DFP technology, by implementing the mass customisation and mass manufacturing of goods, could allow production costs to be reduced, and it could increment the performance levels, as well as create novel and unique products (Sun, et al., 2015a; Sun, et al., 2015b). There are several technologies that can allow the 3D production of food as shown in table 3 by Sun et al. (2015a) and Sun et al. (2015b).

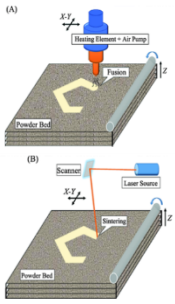
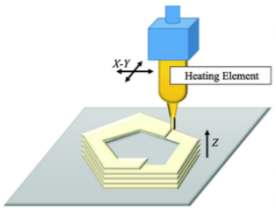
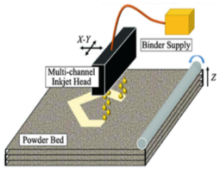
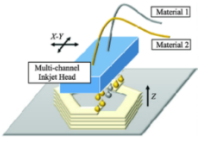
Technology	Characteristics	Use examples	Representation
Selective sintering technology: *(A) Laser* *(B) Hot Air*	1. A first layer of fresh powder is spread. 2. A sintering source that can either be a laser (A) or hot air (B) will move along the X-Y axes. 3. This will allow the fusing of the powder particles and the forming of a solid layer. 4. The above process is repeated until the end product is created.	Sugar and sugar-rich powders	
Hot-melt extrusion	1. A melted semi-solid thermoplastic food material is made from a hot-melt extrusion head. 2. Then the melted semi-solid thermoplastic food material is deposited onto a substrate. 3. The food material is melted slightly above its melting point, so it can easily solidify.	Personalised chocolate products	
Powder bed binder jetting	1. Here, each powder layer is distributed through the fabrication platform. 2. Then the liquid binder is sprayed to build a two-powder layer at the same time.	Sugar and other flavours to build sculptural design food.	
Inkjet printing	1. Here the inkjet printing dispenser drops the products on the fabrication platform and builds the product by creating layers through the drops.	3D food edible products: cookies, cakes, pizza's base.	

Table 3: 3DFP technologies
Source: adapted from Sun et al. (2015a; 2015b). Images are taken from Sun et al. (2015b).

Through material-modulation 3DFP can be also disruptive in the type of products that can be generated, since this technology can allow the creation of completely new food products that are also unique and can have an influence on future innovation. Through 3DFP applications, it would also be possible to radically change the nutrition sector by allowing the production of specific, personalised items through the novel and unique recombination of food ingredients that suit customised food needs. 3DFP can indeed be considered radical from different perspectives, depending on its applications.

Along with its benefits, 3DFP also presents some limitations, such as the requirement for special equipment, the long time needs of building the most advanced 3DFP technologies, and the limited and highly specific materials that are required (Wegrzyn et al., 2012). According to Wegrzyn et al. (2012), 3DFP would be most suitable as a radical emerging technology application devoted to producing a high value in niche manufacturing markets. The latest Deloitte report (2015) on 3DFP supports this thesis. In their work, Wegrzyn et al. (2012) identified and classified the main food layered manufacturing applications into four macro areas:

Personalised Nutrition: the idea behind this approach is consistent with the needs of personalised food, and is useful to overcome several individuals' special food requirements, in particular for categories of consumers such as the elderly, pregnant women, athletes, astronauts or young and innovative people (Sun, et al., 2015b).

Customised food Design: the aim of this approach is to allow consumers to customise their food products. Here consumers can digitally design and experiment with food forms and flavours.

Personal Food Factory: this approach is still consistent with the customised food design; it extends the latter into the domestic space. The main purpose is to allow customers to design and print their own food products and components.

Food Fabricator: this application is mostly oriented towards research experimentation. By looking at material-modulation, multi-scale production and design flexibility, a food fabricator can lead to the development of new food materials.

2.8 Summary of the literature review

The relevant literature for this study is summarised in this chapter. The technology commercialisation process and its relations with commercialisation strategies (development phase) and business model definition (deployment phase) was detailed. Both the commercialisation strategies and the BMs were observed with a lens on the role of collaboration (ecosystems – open business model). Then the BM was analysed from the dynamic perspective of the BMI process, triggers and degree of innovativeness.

From the outcome of the literature review, a conceptual framework was derived. To conclude, the focus was aimed towards the context of the study: the food industry and 3DFP technologies.

Chapter 3 Methodology

3.1 Chapter introduction

This chapter discusses how the present research was developed. First, the objectives of this research are presented, along with the related philosophical position adopted in the analysis. The research design and analysis are then detailed and explained.

3.2 Research background

3.2.1 Research objectives and research questions

The literature reviewed in the previous chapter reveals the importance of technology commercialisation, strategy, (open) business models and business model innovations, in determining the organisation's ability to bring its innovation, either as a technology and/or as a service, into the market. These themes have all been debated in literature. However, due to their origins rooted in different theoretical backgrounds (i.e. strategy, innovation and entrepreneurship traditions), these themes so far have been considered separately, but they can also be considered as inter-related.

In addition to this, the literature discloses that several studies focus their attention on the commercialisation mechanisms of new ventures in emerging markets, but less research is oriented toward emerging technology-based organisations in established markets, this despite mature industries frequently representing core sectors within the whole economy (Jia, et al., 2016; Probert et al., 2013).

Overall empirical studies are needed, especially on emerging technologies/applications-based ventures (Bogers, et al., 2016; Cortimiglia, et al., 2016; Dmitriev et al., 2014; Ford, et al., 2016; Lubik & Garnsey, 2015). This research aims to contribute to extending the theoretical knowledge, by linking technology commercialisation and strategy literature to the OBM and BMI literatures. To do so, one main theoretical aim emerged:

How are business models framed in the commercialisation processes of a new technology in an established industry?

The above research question led to defining the most suitable methodology to exploit the present research (Yin, 2009). To operationalise the main aim of this study, it has been divided into two expanded aims that detail the static and the dynamic perspectives of the study outlined in the *a priori* framework:

1) Static RQ: What types of business models emerge when firms commercialise a new technology in an established industry?

2) Dynamic RQ: What are the BMI dynamics in the commercialisation process of an emerging technology in an established industry?

The aims of the study are pursued through four research objectives that outline the gaps identified in the literature, as shown in table 4. Emphasis is placed on the role of collaborations as well as on the dynamics of evolutions of the business models in the commercialisation of emerging technologies in established industries.

Aim	***Expanded aims***	***Objectives***	***Sections***
How are business models framed in the commercialisation processes of a new technology in an established industry?	*1) Static RQ:* What types of business models emerge when firms commercialise a new technology in an established industry?	Ia. Identify the links between strategic choices and specific business model solutions within the collaboration frame	Ia. Literature gaps: 2.2.2 + 2.2.3 Methodology: 3.4.5 Findings: 5.2.1 Discussion: 6.1.1
		Ib. Identify the business model archetypes and their revolutionary potential within the collaboration frame	Ib. Literature gaps: 2.2.3 +2.3.4 Methodology: 3.4.5 Findings: 5.2.2 Discussion: 6.1.2
	2) Dynamic RQ: What are the BMI dynamics in the commercialisation process of an emerging technology in an established industry?	IIa. Identify the patterns in the process of BMI	IIa. Literature gaps: 2.4.1 Methodology: 3.4.5 Findings: 5.3.1 Discussion: 6.2.1
		IIb. Identify the triggers and the degree of innovativeness associated with different types of BM changes	IIb. Literature gaps: 2.4.2 Methodology: 3.4.5 Findings: 5.3.2 Discussion: 6.2.2

Table 4 Research aims and objectives

By looking at the two particular aspects of the research aim (i.e. static and dynamic) of BM formation, this study contributes to identify patterns and evidences for the commercialisation processes of emerging technologies/applications in established industries and their interactions within the ecosystems. The outcomes derived by answering the research aims were also used to reconfigure the *a priori* framework outlined in the literature.

3.2.2 Philosophical position

This thesis adopts as philosophical position a relativist ontological approach to the nature of reality, along with a constructivism (known also as interpretativism) epistemological perspective. These philosophical positions are linked to one another. The aim is to achieve a general understanding of

phenomena through the interpretation of reality. This process is influenced by the subjective perspective of the subjects that are experiencing it. A grounded approach is a research method through which theory and data are linked by triangulations and comparison, in order to build theory (Eisenhardt, 1989). As the ontological and epistemological approach are relativism and constructivism, the adoption of a grounded approach is suitable for building theory (Easterby-Smith, et al., 2015).

3.2.3 Theoretical foundation

Every consistent research work should provide a certain kind of original contribution to the specific field of research. According to Easterby-Smith et al. (2015), there are three main forms of contribution: substantive, theoretical and methodological. Among the three, the theoretical contribution represents the most relevant one. The main objective of theory building is to develop a conceptual framework that connects empirical data with concepts already theorised in the literature (Snow & Thomas, 1994). Whetten (1989) highlighted four main elements needed to build theory, which consist of indicating what the factors are that explain the phenomena under study. It is desirable to include more factors than necessary in the initial mapping of the concepts, acknowledging that often during the analysis, ideas can be refined several times. The other element concerns the ability of the scholar to explain how the factors selected for the study are interrelated. Finally, the scholar should justify the reasons for having selected those factors and their interrelations.

In the literature, there is an open dilemma on what comes first, data or theory. Hence, it is not possible to collect data without initial constructs and, at the same time, it is not possible to develop a framework without data (Remenyi, 1996). Eisenhardt (1989) suggests developing some "*a priori constructs*", as one of the firsts steps in theory building, that can help the scholar to shape the initial research constructs. According to the author, the development of these preliminary constructs allows the scholar to measure the theoretical constructs in a more accurate way.

Consistently with the main research aim highlighted in the previous section, this research has developed a set of *a priori constructs* Eisenhardt, (1989), summarised in the form of a framework. It has been used to shape the initial research design in order to enable a suitable empirical ground for theory building.

3.3 Research methodology

3.3.1 Methodology selection

This study focuses on the applications of 3D printing for food preparation, known as 3D food printing (3DFP) or Food Layered Manufacturing. The reason behind this choice is that 3DFP is an emerging application of a radical generic technology (additive manufacturing – AM: "a process of joining materials to make objects from 3D model data, usually layer upon layer" (ASTM International, 2013 p.2)) within a well-established industry, typically resilient to change. This characteristic suits the focus of the study. Additionally, since 3D printing is a technology with a long history of development (Rayna & Striukova, 2016) and 3DFP applications have been researched for more than ten years (Wegrzyn et al. 2012), this application of 3D printing technologies has a sufficient history to provide informative data.

According to Yin (2009), the aim identified from the literature (i.e. understand how business models are framed in the commercialisation processes of a new technology in an established industry) can be linked to a complex, current phenomenon that is exploratory in nature.
In this case, Yin (2009) suggests that the case study analysis within a grounded approach is the most suitable methodology.
More specifically, a cross-case study method is helpful to better understand the phenomenon under study when little is known about it (Eisenhardt, 1989; Siggelkow, 2007) .
Following the guidance offered from the literature, in this research work, a cross–case analysis was conducted.

As for precedent studies in the field under observation (e.g. Dmitriev et al., 2014), a multiple case study approach was used to link theory with practice (Casprini, et al., 2014; Cortimiglia, et al., 2016; Lubik & Garnsey, 2015). Hence, in-depth semi-structured interviews were conducted with at least one informant per firm, asking the informants about past (retrospective perspective) and present (current perspective) events, observing the suitability of the *a priori* framework (see section 2.5). The interviews were supported by archival data analysis that included organizations' documents, web news about the firm and the firm's website.

3.3.2 Theory building from case studies

Several scholars have contributed in advancing the theory building process for qualitative research (Eisenhardt, 1989; Eisenhardt & Graebner, 2007; Mayan, 2009; Miles & Huberman, 1994; Yin, 2009).

In 1989, Eisenhardt developed a roadmap for theory building from case study research (pp. 533). This same roadmap has been followed and adapted within the present research, as shown in table 5.

Step	Activity	Research approach
Getting started	*Definition of research question* *Possibly a priori constructs* *Neither theory nor hypotheses*	The research questions have been highlighted in section 3.2.1 according to the gaps that emerged in chapter 2. In section 2.5 of chapter 2, a set of *a priori contructs* in the form of a framework was developed to help structure the research design. No hypotheses were made at this stage.
Selecting cases	*Specified population* *Theoretical, not random, sampling*	The population specification and the sampling selection criteria were not done randomly and the explanation for their selection is reported in section 3.4.2.
Crafting instruments and protocols	*Multiple data collection methods* *Qualitative and quantitative data combined* *Multiple investigators*	As shown in section 3.4.1 the data collection was twofold: direct interviews and archival data. Given the research questions and the exploratory nature of the study, the present research adopted only qualitative data. The analysis has been carried out by one investigator, as a Ph.D. research is per se an individual research project supervised by supervisor/s.
Entering the field	*Overlap data collection and analysis, including field notes* *Flexible and opportunistic data collection methods*	Data collection and data analysis did overlap sometimes. Usually, notes were also taken during, and/or after the direct interview. A flexible approach in data collection was adopted. Case studies run simultaneously.
Analysing data	*Within-case analysis* *Cross-case pattern searching using divergent techniques*	As shown in chapter 4, each case was vertically analysed to detect the important information about it. As shown in chapter 5, a cross-case study analysis was outlined to identify patterns among the cases, according to the objectives of the research.
Shaping hypotheses	*Iterative tabulation of evidence for each construct* *Replication, not sampling, logic across cases*	In chapter 4, the relevant elements for the research (i.e. the BMs and their evolution over time) were put into tables and figures for each case. Then, to answer the research objectives, the cross-cases were

	Search evidence with conflicting literature	summarised in tables (see chapter 5). The structure of the case study was designed to enable its potential replicability. The conflicting literature is presented in chapter 2 and further discussed in chapter 6.
Enfolding literature	*Comparison with conflicting literature* *Comparision with similar literature*	The findings (chapter 5) were both compared and contrasted with the existing literature in chapter 6, in order to identify elements of contribution to the field (chapter 7).
Reaching closure	*Theoretical saturation when possible*	Even though a good spectrum of cases was found to give purposive inputs to the research, the theoretical saturation is very hard to reach in a project, such as in the present one, as it is characterised by a limited time horizion.

Table 5 Process of theory building from case study
Source: adapted from Eisenhardt, 1989

3.4 Case studies: design and analysis

3.4.1 Data collection

To collect the data, the general indications given by Yin (2009) in the development of the case study protocol, were followed and adapted to the present study.

To capture the dynamicity of the BM development, a twofold perspective on the temporal line was adopted. Hence, to capture the information about past events, a retrospective perspective was used; asking the informant the story of the project since its beginnings (for early stage projects) and/or the story since the beginning of the activities related to 3D food printing. To capture the present events, the current BM and its possible development was also observed and asked about.

To capture the events, each case under study was followed for one-year (October 2015 – October 2016) during which the data was collected following the guidelines given by Eisenhardt, (1989) and Yin (2009):

- Before each interview, the secondary information on the organisations was analysed (e.g. news interviews, project/firm's own website), so that, during the interview, it was possible to make

an informal comparison between the information the informant was providing and the external information available about the organisation's activity and evolution.

- The informants were interviewed either face-to-face or via the telephone. Each interview lasted about 45 minutes. All the interviews were conducted by myself. Each interview was tape recorded and later transcribed.
- The data were gathered by asking questions consistent with the story of the organisation, its evolution, the shape of each organisation's business model, its constituent elements and the the commercialisation process. The interviewees were left free to speak and to concentrate on what they felt to be most important. However, an outline with the main information needed was double-checked by the interviewer before closing the interview.
- In support of the primary data (i.e. in-depth, semi-structured interviews), notes were also usually taken during and/or after the direct interview. Further collection of archival data (organisation website and pieces of news collected from the internet) was done.

A second, less structured wave of data collection started from April and lasted until October 2016 and consisted of a set of follow-up discussions with the interviewees met in the previous phase. This second wave of interviews was done by 1) looking for updates in the news on the internet as well as on the organizations' websites, 2) re-contacting the interviewees with the request for clarification and further details. In this second wave, data were collected either by direct interviews, presentations of the organizations' developments or through exchanging written material.

Between the two waves of data collection, a total of about 870 minutes of interviews (about 15 hours) was tape-recorded, transcribed and analysed.
By detailing the histories of the sample of organizations' business model development, the present analysis has, by nature, a longitudinal dimension (Thomson, 2007). So, it is possible to refer to this study as a qualitative multiple-case study analysis that contains longitudinal elements.

Each interview was recorded with the approval of the informant. From the transcriptions of the interviews, the history of each case was derived and sent to the informants for revision. The case studies interpretation has been done to the best of my knowledge and understanding as of November 2016. Any information that the informants asked to be removed from the analysis sent them was taken out of the text, making sure that the omitted information did not compromise the reliability of the organization's histories detailed for the purpose of the analysis. Even though most organisations gave their consent to use their names, all the sample has been anonymized, in consideration of the few who did not. Hence label names were used (e.g. A, B, C, D etc. etc.) to represent each case study.

3.4.2 Case study selection

In order to study how business models are framed in the commercialisation processes of a new technology in an established market, different companies were interviewed. This perspective allows to better understand their industry ecosystem. Additionally, in this way it was possible to obtain knowledge from informants that view the phenomenon under study from diverse perspectives (Eisenhardt & Graebner, 2007). The company selection follows the example given by Eisenhardt, (1989) on the work of Harris and Sutton (1986), who were interested in building a model applicable to different organisations.

The subjects selected as informants were: founders, technology ideators or managers.
To select the cases I have observed the overall 3D-food-printing-ecosystem from a 3D printing website (3D Printing Industry blog - http://3dprintingindustry.com/food/), which is the most up-to-date repository of information about 3D printing. It also has a specific section on food printing, curated since the 2nd May 2012. This blog was chosen as it currently represents, to the best of my knowledge, the most updated blog in the field under observation. Additional to the 3D printing blog, other possible cases were identified by surfing on the Internet in general and, in particular, on the website of 3DigitalCooks, another website specialised in 3D food printing. From the analysis of the 3DFP ecosystem about 50 organisations were identified that were operating in the field. To allow the application of the "variety and contrast" principle (Eisenhardt, 1989), the identified population was divided according to the different 3D-food-printing applications observed in the ecosystem. Five main applications emerged: personal nutrition, customised food design, personal food factory, food fabricators and 3DFP related services. The first four 3DFP applications identified align with the one detected by Wegrzyn et al. (2012). In addition to their study, from the observation of the ecosystem, I have observed the 3DFP application of '3DFP related services'.

From the larger potential sample that emerged in the analysis of the 3DFP ecosystem, 13 organisations were interviewed. The case selection was based on the "variety and contrast" principle. I sought the cases that allowed to better understand the development of BMs to commercialise companies' products or services within an ecosystem perspective (Eisenhardt, 1989). Except in one case, where only one organisation could be identified in a category, at least two organisations were selected for each 3DFP application category.

Table 6 provides a first general overview of the sample of organizations selected for the study.

Sample	Born/or started activities in 3DFP activity	Type of Organisation	Technology Commercialisation Stage	Product/service (less relevant in brackets)	3DFP Activity
A	2009	Start-up	Deployment	Consultancy services and distribution for 3D printing in food and education.	3DFP related services
B	2011	R&D firm	Development	Develop 3D food printer that produces full personalised products. Knowledge/consultancy on 3D food shaping and 3D food printing personalisation.	Personalised nutrition
C	2014	Start-up	Development	Customised 3D printed confectionery.	Customised Food Design
D	2012	Start-up	Deployment	3D food printing appliance for professional and home kitchen use.	Personal Food Factory
E	2014	Start-up	Deployment	3D food printing appliance/ingredients/recipes for home kitchen use. (knowledge services on 3D food printing)	Personal Food Factory
F	2015	Start-up	Deployment	Customised 3D printing confectionery (3D printer/ingredients and recipes system for professional uses)	Customised Food Design
G	2011	University	Development	3D printing appliance to exploit alternative nutritional sources.	Food Fabricator
H	2013	Start-up	Deployment	Customisable 3DP software.	3DFP related services
I	2014	Start-up	Deployment	Customised 3D printed confectionery. (knowledge services on 3D food printing)	Customised Food Design
J	2012	Small-Medium Enterprise	Development	(ingredients adaptable to 3D food printing) (consultancy to professionals of how to cook with special food ingredients) Knowledge of how to mass-personalise nutrition through 3D printing technologies.	Personalised nutrition

K	2013	Start-up	Deployment	Consultancy on 3D food printing & open knowledge diffusion.	3DFP related services
L	2016	Start-up	Deployment	3DFP-based food provider (restaurant) & platform for several 3DP industries.	3DFP related services
M	2014	Start-up	Deployment	3D food printing appliance/ingredients/recipes for professional and home use. (knowledge services on 3D food printing)	Personal Food Factory

Table 6 Overview of sample

The histories of these organisations are detailed in the following chapter. The cases were compared and contrasted within the findings (chapter 5) and then linked to the literature in the discussion (chapter 6).

3.4.3 Data presentation

The histories of the case studies are detailed in chapter four, while the cross-case study analysis is drawn in chapter five. Then, the data are compared and contrasted with the existing literature in chapter six. In chapter four, the case studies were reported in a descriptive way according to their business model development chronology. The information detailed in each case (e.g. the technology commercialisation strategies (e.g. Datta, et al. 2015; Grant, 2016; Osterwalder & Pigneur, 2010) – business model (e.g. Cortimiglia et al., 2016; F. Piller et al., 2015) – business model development process (e.g. Demil & Lecocq, 2010; Dmitriev et al., 2014; Massa & Tucci, 2013)) was employed to identify patterns across business model strategies adopted for technology commercialisation, as well as across the business model innovation processes. The data emerging from the case studies represent a stepping stone to theory building and to implement the set of *a priori constructs* (i.e. the initial framework) developed in chapter 2 (section 2.5).

The structure in which each case is presented in chapter 4 follows the two main component parts of the initial conceptual framework (i.e. the technology commercialisation and business model innovation). The structure in which the cross-case analysis (findings - chapter five) is presented follows the two expanded aims and their related research objectives. This latter structure was also used in the discussion chapter (chapter six) to present the comparison of the empirical evidences with the literature. Presenting the analysis consistently allows to reduce the biases that could emerge in the reader (Miles & Huberman, 1994).

The cases are reported following the interview order. In this way, it is possible to observe the knowledge development gained study by study. The first case study (i.e. *A*) was used as an experimental case (i.e.

pilot case), to initially test and tailor the information needed for the data analysis. The last case study, *M*, was conducted as a key example of a company that is already commercialising its technology on the market. With regard to *M,* even though it is a young case study, it already has detailed news on the firm due to the fact that the case was conducted using mainly secondary sources (e.g. conference talk, web news, firm's website, firm's platform, and an online video interview) and written response from the organisation on the data interpretation and clarifications. This is the only case that provides a contrast with the other case studies, as they were developed through interviews and archival data sources.

3.4.4 Unit of analysis

The unit of analysis used to detail the narratives of the sample is the business model, developed by organisations in the commercialisation of their product and/or services. The business model orchestrates a series of mechanisms of internal as well as external resources and activities that allows an organisation to create, deliver and capture value (Zott, et al., 2011). In doing so, the BM offers a general comprehensive view of an organisation within its ecosystem of partners. As the main aim of this research is to understand how BMs are framed in the commercialisation processes of highly sophisticated technologies in an established industry, BMs represent an appropriate unit of analysis to achieve this aim.

3.4.5 Data analysis

The data analysis was conducted by performing latent content analysis, mainly following the indications highlighted by Mayan (2009). Each case study was analysed and interpreted through seven main phases that were developed in an iterative way. To begin with 1) all the data, primary and secondary, were coded. This process was iterated several times, until a clear account of the BM cycles emerged. More specifically, two main datasets were developed (the first to understand the overall history of the project and the second to enable a deeper understanding of it), that went through several sub-iterations. Within the datasets 2) the data were categorised and 3) tabulated in chronological order, following the development of each business model cycle 4) broader themes were derived (Mayan, 2009; Miles & Huberman, 1994).

The details of the development of the firsts four phases are outlined below.

After a first literature review, a first draft of the interview outline was detailed. The interview outline was then applied on the experimental case study. As outcomes of the information emerged from the experimental interview and from the literature review, a first dataset scheme emerged. This dataset has three level of analysis: single dimension, categories, theme.

This first dataset version collected information concerning:

- The business model changes information (e.g. the BM starting date, the status, the archetype, type of technology commercialisation strategy).
- The dynamics underpinning a change within the BM, so the logic underpinning the change (causal or effectual), the triggers (exogenous or endogenous) and the type of change (BM design or BM reconfiguration).
- The business model structure with its building blocks (value proposition, value creation, value network and value capture).

The sample of organizations were first analysed through this scheme. And, through this it was possible to capture the history of the organisations.

From the implementation of the literature review and from the information emerged from the first round of data analysis, this has allowed to build a revised in dataset scheme. This dataset scheme is more detailed than the first, to allow a deeper understanding of each case history. Hence, the new dataset scheme was built by integrating and implementing the first information on the case studies. The dataset has maintained the three level of analysis: single dimension, categories, theme. Before getting a final version of the dataset, it has been tested and adjusted with the experimental case study.

This dataset collects information concerning:

- General information about the case (e.g. background, industry specifics, the position within the supply chain, and the information on the technology application).
- The market entry issues and the organisations' ecosystem general structure have been also included in the dataset.
- The business model changes information (e.g. the BM type, the BM cycle, the BM starting date, the status and the archetype).
- The technology commercialisation specifics (e.g. the channels and the development stage of each project).
- The dynamics underpinning a change within the BM: the logic underpinning the change (causal or effectual), the triggers (exogenous or endogenous), the type of change (BM design or BM reconfiguration) the strategy (explorative or exploitative).
- The business model structure with its building blocks: value proposition (e.g. product/service offer, target market and value created for customers), value delivery (e.g. customers' channels, customer relationship and sales channels), value capture (e.g. revenue and costs streams), value creation (e.g. key resource and activities [identified according to the general AM supply chain,

section 2.3.4]). Consistent with the open innovation and open business model literature (chapter 2), the presence of a value network (e.g. partners/ suppliers) was held to indicate the openness of each BM building block.

- The type of innovations within the BM (e.g. the source, the origin, the demand and the type).
- The degree of openness of the organisations, was outlined by identifying the open innovation tools applied as well as the open business model strategies applied by the organizations.
- The overall strategies adopted (e.g. short and long term strategies, strategies to reduce uncertainty, strategy adopted to profit from innovation and exploit it).

As suggested by Whetten, (1989) the dataset contained more broader information than the actually adopted in the final analysis. Hence, among all the information included in the dataset I used those that were revealed to be more suitable for the purposes of the present study.

5) To develop the vertical analysis of each case (shown in chapter 4), some categories from the dataset were selected. These categories are related to the technology commercialisation strategies, the BM development process, the degree of openness of the BMs, the BM building blocks and their constituent elements.

More specifically, each case has been vertically described, highlighting the organisation's technology commercialisation strategies and the BM development history. At the end of each case analysis, the BMs' evolutions and the related triggers of each case are summarised in a figure (i.e. case name sequence of business models and change triggers). Then, the BM cycles of each case are summarised following the figure outlined in table 7. Consistent with the open BM literature (see chapter 2, section 2.3.3), the presence of a value network was held to indicate the openness of the model (Vanhaverbeke & Chesbrough, 2014). As such, it is indicated whether a BM dimension is enhanced by the influence of the network of collaborations. If so, this proves that BM building block is open, otherwise it is closed.

The description of the BM shown in table 7 was used to make the following considerations:

- If the value proposition (VP) depends on partners, it is considered open (e.g. unique project proposal made with one or more partner).
- If in value delivery (VD), the organisation enables co-creation activities with customers (e.g. crowdfunding), then this BM dimension is considered open.
- The value creation (VCr) (i.e. key activities and resources) is considered "*controlled*" (i.e. closed) when the organisation establishes a hierarchical relationship with suppliers/partners and or customers. The VCr is considered "*not controlled*" (i.e. open) when a firm establishes a networked relationship, either on the supplier or on the customer side (i.e. customers become part of the production value chain).

- If the value is captured (VCa) through a revenue shared system, this building block is considered open, if transactional exchanges of products/services/components occur, the VCa is considered closed.

	VALUE PROPOSITION *Description of the main purpose of the products or services offered by a firm to its customers.*			**VALUE DELIVERY** *The way an organisation reaches its customers.*			**VALUE CREATION** *Core resources, activities and knowledge that indicate if and how a product/service is developed to create value for customers*		**VALUE CAPTURE** *The ability of the organisation to capture revenue from monetisation, after the detraction of costs*	
	Offer *(Cortimiglia et al., 2016; Osterwalder & Pigneur, 2010)*	***Customer segment*** *(Baden-Fuller and Mangematin, 2013)*	***Value created for customers*** *(Osterwalder & Pigneur, 2010)*	***Communication Channels*** *(Rayna & Striukova, 2016a)*	***Sales Channels*** *(Osterwalder & Pigneur, 2010)*	***Customer relationship*** *(Osterwalder & Pigneur, 2010)*	***Key resources / activities*** *(Cortimiglia et al., 2016; Piller et al., 2015)*	***Supplier / partner structure*** *(Vanhaverbeke & Chesbrough, 2014)*	***Revenue stream*** *(Cortimiglia et al., 2016)*	***Cost structure*** *(Cortimiglia et al., 2016)*
BM	Products / services offered by an organisation *(partners dependency)* *(e.g. 3DF printer)*	Segment of customer/s targeted by an organisation *(e.g. professional kitchen users)*	Products/services offers core competitive advantages for customers: - Newness - Performance -Customisation - Getting the job done - Design - Brand / status - Price - Cost reduction - Risk reduction - Accessibility - Convenience / Usability *(e.g. Performance, Customization, Design)*	The channels through which an organisation communicate, and promote it products/services to customers *(e.g. website, social media, culinary events)*	Direct: Sales - web sales Indirect: Own Store - Partner Store – Wholesaler *(e.g. web sales)*	Personal assistance Dedicated personal assistance Self-service Automated Service Communities Co-creation *(co-creation)* *(e.g. self-service)*	Design provider *(controlled or not controlled)* Material provider *(controlled or not controlled)* Process technology provider *(controlled or not controlled)* Digital ICT provider *(controlled or not controlled)* Knowledge provider *(controlled or not controlled)* *(e.g. 3DF printer, controlled – software not controlled)*	Hierarchical or Networked *(i.e. controlled or not controlled)*	The revenue mechanisms through which an organisation makes money (transactional or revenue shared) *(revenue shared)* *(e.g. pay per asset sold – IP licensing - transactional)*	Costs that an organisation sustain to develop and commercialise their products/services *(e.g. Raw material, human resources, time)*

Table 7 BM general structure

6) After the analysis of the history of the case studies, patterns and mechanisms were looked for across the sample to draw a cross-cases analysis, detailed in chapter 5.

The cross-case analysis is organized according to the two expanded research aims (i.e. understand the types of BM and the BMI dynamics in the commercialisation of new technologies in an established industry). To operationalise the research-expanded aims, the analysis is further detailed according to the research objectives (i.e. identify the links between strategic choices and specific business model solutions within the collaboration frame, identify the business model archetypes and their revolutionary potential within the collaboration frame; identify patterns in the process of BMI; identify triggers and degree of innovativeness associated to different types of BM changes)

1) *Static RQ:* To understand what types of BMs emerge when firms commercialise a new technology in an established industry, two strategic perspectives were considered; short term and long term. The *short term* perspective was analysed considering the main actual business model related to 3DFP activities. The *long term* perspective was analysed considering the future BMs. In some cases, interviewees were aware of the future BM (chapter 4), while it was not the case for others. In the latter case, the BMs was deduced from the overall technology commercialisation strategy adopted by the organisation under study. To facilitate the reader, the BM tags (e.g. BM 1a, BM 1b), defined in chapter 4, corresponding to the short term or to the long term BMs, are indicated in the various tables developed. In case of missing long-term BM tags, the code "technology commercialisation strategies" (sometimes abbreviated as: TCS), was used in the tables.

    - *Objective Ia)* To analyse the commercialisation strategies (i.e. identify the links between strategic choices and specific business model solutions within the collaboration frame), a comparison was made between the market strategies (niche, diversification, mainstream - (Osterwalder & Pigneur, 2010)), the decision logics (i.e. causal or effectual - (Sarasvathy, 2001)) and the approach to market uncertainty (i.e. clear enough future, alternative futures, range of futures, true ambiguity - (Courtney et al., 1997)). The links between the strategic choices emerged and the BM solutions were analysed with a collaborative perspective (OI/OBM classification by Vanhaverbeke & Chesbrough (2014)).
    - *Objective Ib)* To analyse the types of BM archetypes and the impact of the technology on BM solutions (i.e. identify the business model archetypes and their revolutionary potential within the collaboration frame), the types of BM archetypes derived were detected according to the current main business model offer (i.e. value proposition). The identification of the BM archetypes is based on a similar logic to the one adopted by Cabage & Zhang (2013). These BM archetypes were analysed both according to the BM typologies of BMs already present in the food industry (Bigliardi & Galati, 2013b) and to the OI/ OBM classification done by Vanhaverbeke & Chesbrough (2014,pp 54). Furthermore, it has been

highlighted where the BMs, among the various BM dimensions, are open and where they are closed. This analysis has also outlined the reasons why organisations use(d) a specific BM.

2) *Dynamic RQ:* To understand what the BMI dynamics are in the commercialisation process of an emerging technology in an established industry, each BM developed by the organisations over time was considered.
    - *Objective IIa)* To analyse the patterns in the BMI processes (i.e. identify patterns in the process of BMI of a new technology in an established industry) adopted by the organisations under study, the types of BMI processes (i.e. design or reconfiguration - Cortimiglia et al., 2016; Massa & Tucci, 2013) that the organisations went through over time, along with the types of BM change archetypes that emerged according to the BM changes in the VP (Trimi and Berbegal-Mirabent, 2012) were observed.
    - *Objective IIb)* To identify how the BMs evolved over the time (i.e. identify what the triggers and the degree of innovativeness associated to different types of BM changes are in the commercialisation process of a new technology in an established industry), the triggers were observed (Casprini et al., 2014; Demil & Lecocq, 2010; Johnson, et al., 2008; Martins, et al., 2015), as was the degree of innovativeness (Rayna & Striukova, 2016b) associated with the changes in the BMs. To detect the latter I have based my observations according to the Rayna & Striukova, (2016b) inside-outside BMI framework.

7) The cases analysed were triangulated with the literature (Yin, 2009). From there, it was possible to build the considerations of the study, as outlined in chapter 6. The evidence from the observations of the cases was also used to further develop the conceptual framework (chapter 7).

3.5 Summary of methodology

The present chapter detailed the philosophical position (i.e. relativist ontological vision along with constructive epistemology approach) and the research designed (i.e. qualitative multiple cross-case analysis with longitudinal elements) to answer the main research gap (i.e. link technology commercialisation and strategy literature to the OBM and BMI literatures). To scope the research aim (i.e. how business models are framed in the commercialisation processes of a new technology in an established industry), two main research-expanded aims (i.e. understand the types of BM and the BMI dynamics in the commercialisation of new technologies in an established industry) and the related objectives, emerged (paragraph 3.2.1).

The chapter further details how the data were collected (i.e. in-depth, semi-structured interviews and secondary data) as well as the sample selected (i.e. thirteen cases selected from the 3DFP ecosystem, applying the variety and contrast principle). The structure of the data presentation is then detailed. Finally, the unit of analysis (i.e. the business model) and the data analysis process (i.e. grounded approach for latent content analysis) are highlighted.

Chapter 4 Case Studies

4.1 Chapter introduction

This chapter details the thirteen case studies collected during the course of this research. The case studies have been reported in a descriptive way following each case studies business model development history.

Each case is presented following the structure highlighted in the methodology chapter in the data presentation paragraph (i.e. the two main component parts [technology commercialisation and business model innovation] of the conceptual framework (chapter two, section 2.5).

4.2 Case A

4.2.1 Case A technology commercialisation

Currently, *A* is a 3D printing distributor and consultancy service provider that focuses on commercialising emerging technologies in niche segments of established industries. According to *A*'s CEO, this choice was determined by the commercialisation potential of these kinds of technologies, as "*it is where the biggest opportunities lie. [..] I want to do something that in 5 or 10 years will be very successful*".

According to *A's* CEO, the commercialisation of 3D printing technologies within the food industry is at a very early stage "*it is all about exploring ideas rather than investing in technology*."

Within this context, *A* opted for an exploratory technology commercialisation strategy to get into the market, not focusing on any specific segment. Hence, they stated that "*we were exploring, we were discussing with them* [potential customers] *what sort of things they were doing, what sort of things they might like do with it* [the 3D food printer]. *And then saying whether the machine could do it or not, and in many cases the answer was a positive maybe.*" From this point onwards, *A* opened discussions to potentially start several business opportunities.

It seems that *A* is adopting an open approach also to scope the potential technology commercialisation strategies. Recently (late 2016), *A* requested a consultancy from MBA students in order to understand how they can implement and expand their BM. *A* is "*still trying to make a success of the same thing, but looking at different ways of making it happen*". Concurrently, *A* is also exploring other 3D printing possibilities related to different industries.

4.2.2 Case A business model innovation history

Background

A was born as a result of the failure of the firm the founders previously worked at. This company unfortunately had to close due to a misadventure with a fraudulent international partner. The firm operated according to a business-to-business (hereafter: B2B) distributor-based model for CNC and rapid prototyping equipment, as shown in table 8.

	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	***Customer segment***	***Value created for customers***	***Communication Channels***	***Sales Channels***	***Customer relationship***	***Key resources/ activities***	***Supplier/ partner structure***	***Revenue stream***	***Cost structure***
BM 0	Distributor of CNC machining and rapid prototyping equipment	Industry firms Education institutions	Easier accessibility to the technologies Guaranteed dedicated assistance on products	Attend events Public talks Word of mouth	Direct sales force	Personal assistance	Material provider *(controlled)* Process technology provider *(controlled)*	Hierarchical	Margin on pieces of equipment sold	Equipment Human resources Time Facilities (e.g. office rent)

Table 8 Previous firm business model archetype

Business Model Development

The variation of *A'*s business model archetypes is shown in table 9.

BM 1: Distribution model

BM 1a: *A* was founded in 2009 following the offer received by the founders to collaborate in commercialising the equipment for a low-cost 3D printer manufacturer. The new firm was configured as a low-cost 3D printer B2B distributor operating mainly in the education industry. The firm mainly replicated the BM adopted in the previous (failed) company, but also wanted to substitute its previous long-term contractual relationship with the manufacturer with one in which new business opportunities were explored more collaboratively (by sharing the risks).

BM 1b: About one year later (2010-2011), the 3D printer producer bypassed the distributor and decided to commercialise the product directly. So, *A* decided to internalise the production of 3D printers. *A* hired a 3D printing designer to produce their own low-cost 3D printer for schools. This represents a change in the value creation building block, from external to internal. This change had a brief life, as according to the CEO: "*Having spent a lot of our money on developing a product which failed, we then had no money and no product. So, the only way to continue the business was to find another external supplier. And at that point we didn't rethink our business, we were just looking for a quick solution to get us back into business without having to close the company*".

BM 1(0): Giving up the production of their own 3D printing machine because "*it took 12 months longer, than he* [the 3D printer designer] *and we had anticipated; and by the time it was launched, the Chinese firms had started coming into the market with machines that cost the same amount, but which were plug and play*", the firm then reverted to the contractual-distributor model in the education industry (BM 0) for its 3D printing equipment.

BM1c: "*We limped along,*" said the CEO. So at the end of 2014, *A* decided on "*trying to improve* [their] *existing business model* [3D Printing technology-based distributor], [..] *always again looking forward to new products* [..], *thinking about new markets*". At this point, they started to proactively consider distributing 3D printers in other industries. In 2014, *A*'s CEO came across a company that was producing a 3D printer that could be used to print food. This serendipitous finding spurred the following thought: "*Maybe there is an opportunity in food, because it is still* [a] *very early stage for 3D printing in food. And there are few competitors around the world*". Initially *A* tried to replicate the same BM (BM1a) for the low-cost 3D printer producer (e.g. close collaboration in commercialising the 3D food printer), but initially the 3D food printer producer prefers to maintain a more transactional relationship.

BM2: Consultancy model

BM2a: At the same time, *A* decided to revert to BM1a (2012-2013), and they also decided to add a service BM on top of a distribution model. This new line of business focused on delivering training and consulting to the education industry. The offering consisted of workshops to teach people how to use 3D printers and related equipment. "*So we have done lots of school projects, spending the whole day with the school, and we would teach the group of people how to use 3D design, 3D scanning and start seeing the results of their designs appearing printed*." This change indicates an Inside-out OI strategy, where the firm started capturing value from the expertise that they were giving away for free in the distribution model. "*Instead of giving away a lot of intellectual property, which was knowledge about the market, knowledge about where the technology was going, knowledge about opportunities in the future, we started selling that*".

BM2b: When in 2014 *A* started considering new markets in which to sell 3D printers, the founders decided to expand the target market for the training and consulting activities to these industries too. In addition to the day workshop on how to use 3D printers, the firm started to offer lectures on the technology, the markets and the related potential business opportunities.

BM 2-1: The linked consultancy - distribution model

BM 2b to BM 1c: In the second half of 2015, *A* bought a prototype food printer with the intention to investigate new business opportunities in the food industry for both their consultancy (BM 2b), and as a means to demonstrate the technology to customers interested in buying the 3D food printer (BM 1c). Since, at that time, the printer was not yet ready for distribution, the firm decided to use their consultancy BM 2b to sell to potential customers, (to those who were interested in using 3D printers in the food market), and also saw the chance to collaborate in testing the market opportunity for such technology. The value capture element of this BM would then be chosen after studying the potential customer business idea, and it would depend on the interests of *A*: "*If we thought the applications, the opportunities, would be big enough, we would do the test ourselves. If we didn't, they would have to pay us to carry out the test and see whether it could be done*". Despite the high interest that *A* gained from the market, at that moment (October, 2016) the work in this area is on hold until the 3D printer is finalised for distribution.

Figure 7 was designed to visualise *A*'s BM evolution. On the Y-axis, market shifts can be observed, while the X-axis displays the time line. Figure 7 also shows the twofold business model innovation strategies adopted by *A*. On the one hand, it shows the BM evolution for the exploitation of 3DP within the education industry. On the other hand, it shows the BM evolution following the exploration strategy to enter new markets.

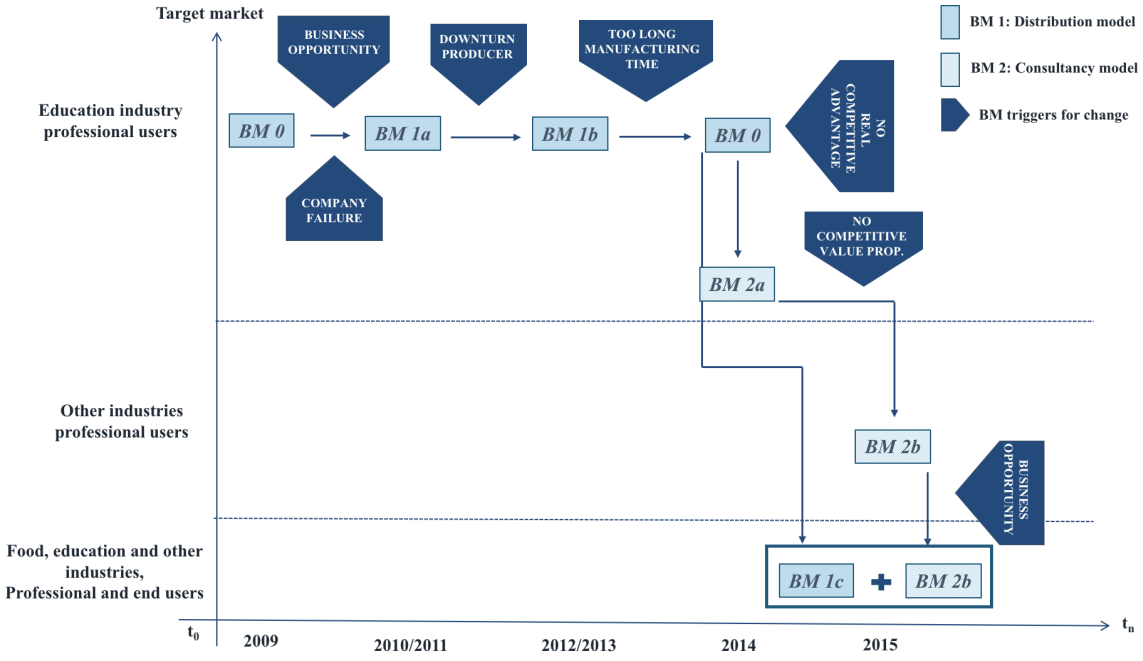


Figure 7 A sequence of business models and change triggers

DISTRIBUTION MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	***Customer segment***	***Value created for customers***	***Communication Channels***	***Sales Channels***	***Customer relationship***	***Key resources/activities***	***Supplier/partner structure***	***Revenue stream***	***Cost structure***
BM 1a	Distributor of low cost 3D printer	Education industry for professional users	Newness Easier accessibility to the technologies Guaranteed dedicated assistance on products	Attend events Public talks Website Email	Direct sales force	Personal assistance	Process technology provider *(not controlled)* Knowledge provider *(controlled)*	Networked	Margin on pieces of equipment sold (Buyers pay in advance)	Time
BM 1b	**Assembler** & Distributor of low cost 3D printer	Education industry for professional users	**Design** Guaranteed dedicated assistance on products	Attend events Public talks Website Email	Direct sales force	Personal assistance	**Digital ICT provider *(controlled)*** **Material provider *(controlled)*** Knowledge provider *(controlled)*	Hierarchical	**Product sale**	**Raw spare parts** Time
BM 1 (0)	Distributor of **3D printing-based equipment**	Education industry for professional users	Easier accessibility to the technologies Guaranteed dedicated assistance on products	Attend events Public talks Website Email	Direct sales force	Personal assistance	**Process technology provider *(controlled)*** Knowledge provider *(controlled)*	Hierarchical	**Margin on pieces of equipment sold (Buyers pay in advance)**	**Demonstration equipment** Time
BM 1c	Distributor of **low cost 3D printer**	**Food, education and other industries for professional and end users**	**Newness** Easier accessibility to the technologies Guaranteed dedicated assistance on products	Attend events Public talks Website Email	Direct sales force	Personal assistance	Process technology provider *(controlled)* Knowledge provider *(controlled)*	Hierarchical	Margin on pieces of equipment sold (Buyers pay in advance)	Demonstration equipment Time

Table 9 The business model history at A (continue)
Changed BM building blocks from previous version are highlighted in bold

CONSULTANCY MODEL															
	VALUE PROPOSITION				VALUE DELIVERY			VALUE CREATION				VALUE CAPTURE			
	Offering		***Customer segment***	***Value created for customers***	***Communication Channels***	***Sales Channels***	***Customer relationship***	***Key resources/activities***		***Supplier/partner structure***		***Revenue stream***		***Cost structure***	
BM 2a	Training & Consulting on 3DP technologies-based knowledge		Education industry for professional users	Customisation	Attend events Public talks Website Email	Direct sales force	Dedicated Personal assistance	Knowledge provider *(controlled)*		Hierarchical		Pay per time		Time	
BM 2b	Training & Consulting on 3DP technologies-based knowledge	Training & Consulting on 3DP technologies-based knowledge *(Partner dependency)*	**Education and food industry professional users**	Customisation	Attend events Public talks Website Email	Direct sales force	Dedicated Personal assistance *(co-creation)*	Knowledge provider *(controlled)*	**Knowledge provider** *(not controlled)*	Hierarchical	**Networked**	Pay per time	**Revenue shared** *(revenue shared)*	Time	

Table 9 continuation

THE LINKED CONSULTANCY - DISTRIBUTION MODEL														
	VALUE PROPOSITION				VALUE DELIVERY			VALUE CREATION				VALUE CAPTURE		
	Offering		***Customer segment***	***Value created for customers***	***Communication Channels***	***Sales Channels***	***Customer relationship***	***Key resources/activities***		***Supplier/partner structure***		***Revenue stream***		***Cost structure***
BM 2b	Training & Consulting on 3DP technologies-based knowledge	Training & Consulting on 3DP technologies-based knowledge *(Partner dependency)*	Education and food industry professional users	Customisation	Attend events Public talks Website Email	Direct sales force	Dedicated Personal assistance *(co-creation)*	Knowledge provider *(controlled)*	Knowledge provider *(not controlled)*	Hierarchical	Networked	Pay per time	Revenue shared *(revenue shared)*	Time
BM 1c	Distributor of low cost 3D printer		Food, education and other industries for professional and end users	Newness Easier accessibility to the technologies Guaranteed dedicated assistance on products	Attend events Public talks Website Email	Direct sales force	Personal assistance	Process technology provider *(controlled)* Knowledge provider *(controlled)*		Hierarchical		Margin on pieces of equipment sold (Buyers pay in advance)		Demonstration equipment Time

Table 9 continuation

4.3 Case B

4.3.1 Case B technology commercialisation

B is a research organisation focused on building innovations for knowledge dissemination. Among *B*'s different areas of business, in the last five years (i.e. since about 2011) *B* has also started to look into the combination of additive manufacturing and food. "*By combining those two fields, we've really learnt about the potential of the technology for that field but also about the complexity of the two*," said the manager interviewed.

Overall, *B's* technology commercialisation strategy for the 3D food printing technology is structured on a roadmap basis. First, the firm developed a main objective (i.e. "*develop printers that can produce fully personalised food products*"), then, *B* pursued this aim through separate but linked steps of development, that were coincidental with the three projects that *B* was already undertaking (i.e. *Project 1*, *Project 2* and *Project 3*). Initially, *B* started by focusing on the development of new food shapes (i.e. *Project 1* with a food company). Then, the organisation moved its attention to 3D printing of personalised food within the umbrella of *Project 2*. Most recently, the firm is digging deeper into the 3D printing aspects related to the engineering of certain food structures or textures within *Project 3*.

4.3.2 Case B business model innovation history

Background

B develops knowledge, technologies and innovations for practical applications. Among *B's* areas of interest, 3D food printing has become a relevant one. The overall aim of B is to understand "*how additive manufacturing could* [..] *really become a big game changer for the food industry in an increasingly demanding consumer market*," said the interviewee. Overall, the firm operates according to pre-defined BM structures (e.g. consultancy; research) with an ecosystem-based model. More specifically, *B* develops the fundamental knowledge together with the other project partners, which can include or exclude the partner's direct competitors, depending on the type of funding.

Business Model Development

The variation of *B*'s business model archetypes is shown in concerning its 3D food printing activities is shown in table 10.

BM 1: Research model

BM1a: B started to develop its interest in 3D food printing in 2011. Thanks to *B's* ecosystem, the firm got in contact with a food company, which at that time (about 2013) was interested in exploring the possibilities of 3D printing food. The food company challenged *B* (i.e. on a project based on mupltiple phases) to undertake research with the main goal to understand whether the research organisation would be able to "*3D print a piece of* [a type of food]". *B* initially funded most of the research project. The companies formed a team of experts taken both from the field of additive manufacturing and food, and started to develop the research and run the tests for this challenge. After some research, the concept was proven. However, the production speed was not yet fast enough to make the product marketable.

BM1b: In 2014, the food company extended the collaboration with *B,* asking them to research the feasibility of speeding up the 3D printing process of a type of food. Consequently, *B* improved the printing speed of that type of food. With the new achieved speed, the technology could be brought to the market. The printer that was developed resulted in a patent filed by *B* in 2014. To develop this printer *B* "*actively talked about the approach and worked with equipment producing companies because [..] they would be a potential partner to [..] build such* [food] *printers*," said the interviewee. In the case of *Project 1*, *B* involved several different specialised actors of the supply chain to develop the product without the partner's competitors. The project is funded (i.e. about 50% - 50%) together with the food company. As a return on the investment, the food company received a "*user licence on the outcome,"* said the interviewee. Now the food company is looking at possible commercialisation strategies for the 3D food printer.

BM 1c: Part of the fundamental research activities run by *B* is funded by funding institutions. So usually *B* looks at its "*own roadmap and, based on that,* [it] *evaluates the fit with the various* [..] *calls*," said the interviewee. At the end of 2012, *B,* along with more than 10 other partners, developed a research project proposal. These partners came together thanks to the network of relations built among the ecosystem of actors operating in the 3D food printing area. The main aim of the project was to develop a 3D food printing system able to realise personalised food. The project was funded by a funding institution and had a length of about three years (2012 – 2015). Along with the other project partners, *B* received a fixed amount of funding to develop some parts of a production system (i.e. the food ingredients system) that allows food to be personalised for people who suffer from specific health issues. This has been realised in a cheaper and more personalised way compared to the current solution on the market, by industrialising the personalised food production process. The project is now at the stage that the concept has been proved (i.e. it is now possible to create personalised food industrially). However, "*further development will have to show if we can indeed scale this up more.* [..] *It's still a bit unclear what the shortest way to market this is, but it's also very dependent on how this technology will further develop*," said the interviewee.

BM 1d: When *Project 2* was coming to an end, *B* came across another call for a research proposal enhanced by a funding institution. Again, thanks to the network of relations built among the ecosystem of actors operating in the 3D food printing area, *B,* along with more than 3 other institutions, received funding for the project for two years (2014 up to 2016). This time the project aimed to investigate 3D printing technology as enabler of more sustainable food production processes. *B* was given a fixed percentage of the overall project funds to focus "*more* [..] *into food textures and food structures.*"

Figure 8 visualises *B*'s BM evolutions and the related triggers of change. The Y-axis shows the market segments targeted, while the X-axis depicts the time line.
Figure 8 also shows the twofold BM archetype adopted by *B* (research) in the 3D food printing industry.

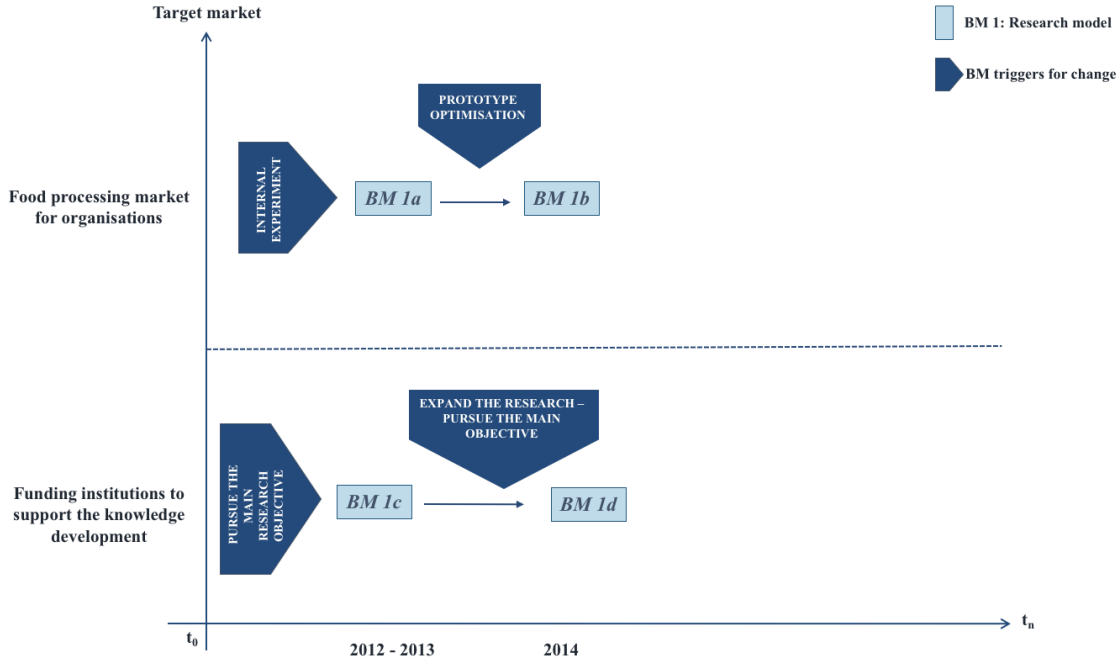


Figure 8 B 's sequence of business models and change triggers

RESEARCH MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	***Customer segment***	***Value created for customers***	***Communication Channels***	***Sales Channels***	***Customer relationship***	***Key resources/activities***	***Supplier/partner structure***	***Revenue stream***	***Cost structure***
BM 1a	Knowledge development of 3D printing feasibility of a type of food *(Partner dependency)*	Organisations in food processing market	Accomplish the requested research	Network Word of Mouth Media	Direct sales of the research to the funding partner-client	Dedicated Personal assistance Co-creation *(Co-creation)*	Design provider *(not controlled)* Material provider *(controlled)* Process technology provider *(controlled)* Knowledge provider *(controlled)*	Hierarchical with suppliers Networked with partner	Pay per research (co-investment)	Equipment Human resources Time Facilities (e.g. laboratory) R&D development
BM 1b	Knowledge development on **speeding up the 3D printing process** of a type of food *(Partner dependency)*	Organisations in food processing market	Accomplish the requested research	Network	Direct sales of the research to the funding partner-client	Dedicated Personal assistance Co-creation *(Co-creation)*	Design provider *(not controlled)* Material provider *(controlled)* Process technology provider *(controlled)* Knowledge provider *(controlled)*	Hierarchical with suppliers Networked with partner	Pay per research (co-investment) **License the IP to the client-partner**	Equipment Human resources Time Facilities (e.g. laboratory) R&D development **IP development**
BM 1c	Knowledge development, **to realise the 3D food printing of personalised recipes** *(Partner dependency)*	**Funding institutions**	**Newness**	**Media** **Word of mouth** Network	Direct sales of the research proposal to the funding institution	**Personal assistance** (periodical reports to the funding institution)	Design provider *(not controlled)* Material provider *(not controlled)* Process technology provider *(not controlled)* Digital ICT provider *(not controlled)* Knowledge provider *(not controlled)*	Networked with partner	**Fixed percentage of the overall funding of the project** *(Revenue shared)*	Equipment Human resources Time Facilities (e.g. laboratory) R&D development
BM 1d	Knowledge development on **engineering certain food structures or textures within the 3D food printing process** *(Partner dependency)*	Funding institutions	Newness	Media Word of mouth Network	Direct sales of the research proposal to the funding institution	Personal assistance (periodical reports to the funding institution)	Design provider *(not controlled)* Material provider *(not controlled)* Process technology provider *(not controlled)* Digital ICT provider *(not controlled)* Knowledge provider *(not controlled)*	Networked with partner	Fixed percentage of the overall funding of the project *(Revenue shared)*	Equipment Human resources Time Facilities (e.g. laboratory) R&D development

Table 10 The business model history at B
Changed BM building blocks from previous version are highlighted in bold

4.4 Case C

4.4.1 Case C technology commercialisation

The main aim of the startup *C,* is to commercialise customised 3D printed confectioneries of different shapes and flavours through online sales. To pursue this aim, the start-up founder developed a technology commercialisation roadmap. After proving the concept of the idea within the research model, he/she is looking for funding to develop the whole the business model that the organisation's ideator has in mind.

4.4.2 Case C business model innovation history

Background

The *C* project was developed during the studies of the organisation's ideator, who became interested in understanding "*why people chew* [confectioneries]*; why people have this kind of need or desire*."
The research advanced and narrowed down to shapes and how the different shapes of confectioneries can generate different sensations for people. "*So once you want to create this kind of form* [different confectionery shapes] *you need technology, you need a new tool, you need new production ways. So I just think about a 3D printer*."

Business Models Development

The variation of *C'*s business model archetypes is shown in table 11.

BM 1: Research model

BM1a: The *C* project was born as a joint research collaboration at the end of 2014. The organisation's ideator teamed up with another student specialised in 3D printing of new materials. The main aim was to understand what sensations specific types of confectionery in different shapes generate in a person's mouth. To pursue this objective, *C's* team built its own 3D printer able to print confectioneries. They developed the whole technology (i.e. the 3D printer) without revealing the recipes of the 3D food printer, as they are aware that they could patent it in the future (when they have the funds to start the patenting process). The main aim of *C's* team in creating a 3D confectionery printer was to "*prove to people, 'Okay, it's possible. You can 3D print food, even* [a specific confectionery]." The project was mainly self-funded (bootstrapped) and in 2015, the project got the attention of the media, and the organisation was invited to take part in exhibitions to show the 3D confectionery printer, and a demonstration video was made.

Particularly from the exhibitions, the organisation's ideator observed that: "*people have a really strong, strong desire to want to try it* [3D printed confectioneries]."

BM 2: 3D printed food manufacturing model

BM2a: With the end of the organisation's ideator's studies in 2015, the research project also came to an end. However, the organisation's ideator was surprised about the public's interest in 3D printed confectioneries. As a consequence, he/she decided to continue the project and shift it from being merely research into a real business. To do so, *C's* organisation's ideator wanted to build a second-generation 3D confectionery printer to produce and sell customised confectioneries, through online channels. The first thing the organisation's ideator did in 2016 was to look for a technical 3D printing specialist to partner up with. Alongside the research for a suitable technical partner, the organisation's ideator is also building a business plan around the start-up idea, in which *C's* organisation's ideator wants to extend to possible external sources of funding (e.g. government funds and or foundations), as the organisation's ideator is currently investing personal funds to develop the business.

BM2b: *C's* projected business model consists of building an online confectionery factory. In it, customers will be able to create their own customised 3D printed confectioneries through an e-commerce system, since *"the printer can create all the flavours and all the forms customers need.*" The ordered confectioneries will then be delivered directly to the customer. According to *C's* organisation's ideator, the business built in this way would be "*universal,* [..]*, and there is no boundary for* [it]." The organisation's ideator is planning to promote the *C* brand through both online and offline channels.

Figure 9 visualises *C*'s BM evolutions and the related triggers of change. The target segments can be observed on the Y-axis, while the X-axis shows the time line. Figure 9 shows the BMI path followed by *C*.

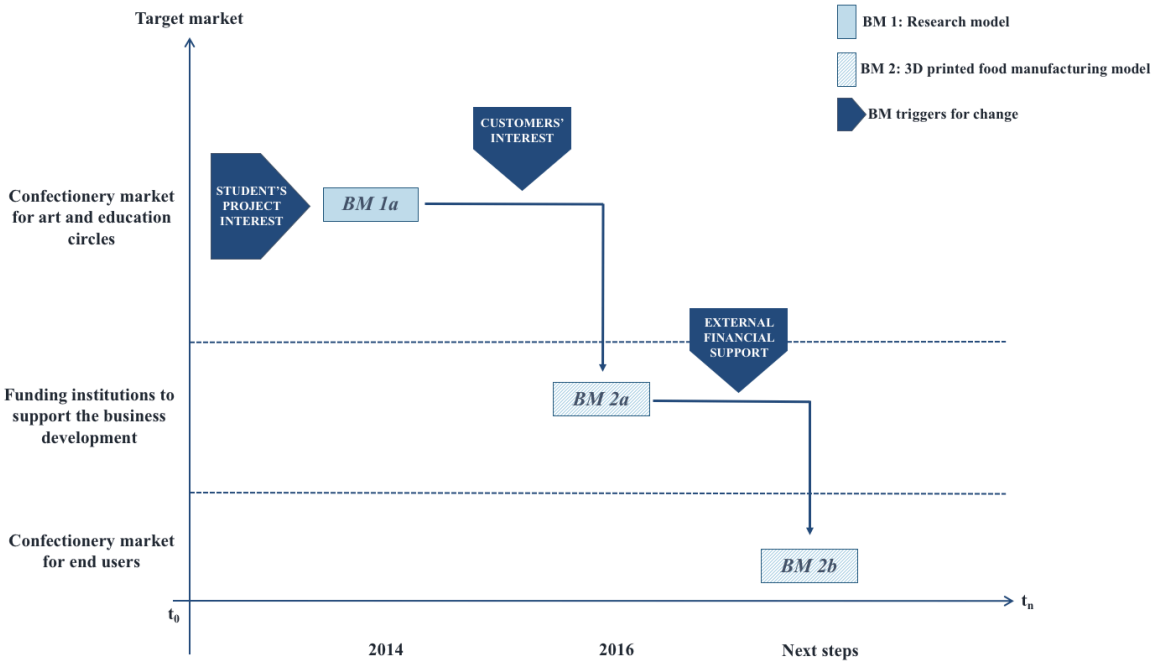


Figure 9 C's sequence of business models and change triggers

RESEARCH MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	***Customer segment***	***Value created for customers***	***Communication Channels***	***Sales Channels***	***Customer relationship***	***Key resources/activities***	***Supplier/partner structure***	***Revenue stream***	***Cost structure***
BM 1a	Knowledge of 3D printing to exploit confectionery printing possibilities	General public reached through exhibitions, workshops and demonstrations	Diffusion of a relatively new concept Show the 3D confectionery printing accessibility	Media Exhibitions Workshops Demonstrations Conferences	No	Personal assistance at the demonstrations	Design provider *(controlled)* Material provider *(controlled)* Process technology provider *(controlled)* Knowledge provider *(controlled)*	Hierarchical	Bootstrapping	Equipment Time

3D PRINTED FOOD MANUFACTURING MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	***Customer segment***	***Value created for customers***	***Communication Channels***	***Sales Channels***	***Customer relationship***	***Key resources/ activities***	***Supplier/ partner structure***	***Revenue stream***	***Cost structure***
BM 2a	**Develop a 3D confectionery factory to 3D print customised confectioneries**	**Funding institutions**	Diffusion of a relatively new concept	**Network**	**Direct sales force**	**Dedicated personal assistance**	Design provider *(controlled)* Material provider *(controlled)* Knowledge provider (3DFP technician) *(looking for not controlled)*	Hierarchical	Bootstrapping	Time **Raw material**
BM 2b	3D confectionery factory to 3D print customised confectioneries	**End users**	**Easier accessibility to the technologies** **Customisable product** Diffusion of a relative new concept	**Media** **Exhibitions** **Workshops** **Demonstrations** **Social Media**	Direct web sales (e-commerce) **Co-creation** *(co-creation)*	**Customers will create their own customised confectioneries themselves**	Design provider ***(not controlled)*** Material provider *(controlled)* Knowledge provider *(controlled)*	Hierarchical with suppliers **Networked with customers**	**Profits from each confectionery item sold (paid in advance)**	Suppliers Office & lab facilities Raw material Marketing **IP costs** Shipping Human resources Time

Table 11 The business model history at C
Changed BM building blocks from previous version are highlighted in bold

4.5 Case D

4.5.1 Case D technology commercialisation

D is a start-up venture that produces a 3D food printer and an Internet of Things (IoT) kitchen appliance. Along with the 3D food printer the firm provides also capsules for food.
D has a twofold business model strategy to commercialise its technology. Hence, at the moment the firm is focusing on professional kitchen users as their main customer segment (i.e. B2B-based business model). However, at the same time, it is developing the future B2C-based business model by implementing the technology as well as developing the online community. In this sense, according to the manager interviewed: "*if you're really building a big business, which we want to, you have to constantly develop and evolve. You can't do one thing and it can't be a linear process*. [..] *You have to look at several things at once*."

4.5.2 Case D business model innovation history

Background

D was born in 2012 out of an idea of one of the early co-founders with a background in the bakery industry. At the beginning, the firm "*was invented to solve a food issue/problem in the food industry. And 3D food printing was actually the best technology to solve that*," said the manager interviewed. From this starting solution the firm evolved and pivoted its business model to streamline some of the daily cooking activities.

Business model development

The variation of *D*'s business model archetypes is shown in table 12.

BM 1: 3D food printer manufacturing model

BM1a: At the end of 2012, the start-up was born as a side project, driven by a gap that the firm noticed in the baking market. The firm noticed that there was a need to find cheaper solutions for shipping specialised bakery products (e.g. vegan or low-carb). "*It's not because of the ingredients or the talent to make it that they're very expensive. It's the cost of actually shipping them,"* said the manager interviewed. Initially the firm wanted to simplify the shipping process by creating mini factories spread across several countries, allowing end customers to print their own bakery products. According to the manager interviewed, the idea was to "*have pre-filled food capsules that you would put into the machine and it would print out your* [bakery products]." To pursue this aim, *D* started its development by

bootstrapping the initial funds. A few months after the creation of the firm, the manager interviewed joined and advanced a turning point in the BM by questioning the reasons why they where using pre-filled food capsules instead of empty ones. Subsequently, the company tested the new idea in order to understand its viability and profitability. The tests went well, and *D* changed its first business model (*BM1a*).

BM1b: The new and current business model (*BM1b*) was launched in mid-2013 with the aim to produce a 3D food printer that comes with empty capsules. The project became the full-time activity of the co-founders. As an initial commercialisation strategy, *D* targeted professional kitchen users, mostly big users, to be able to customise the printer user interface as much as possible. Hence, *D* is also an Internet of Things company, and this requires the collection of lots of data and information behind it. To develop the 3DFP*, D* built a strategic alliance with a large and well-known manufacturer. In 2015, the partnership became even more solid, when the manufacturer decided to invest directly in the company. Along with this, the firm built collaboration projects with universities to run tests contributing in the technology's implementation. The exploitation of this BM is possible due to the firm's strong protection policy: constantly patenting and owning all the most sensitive parts of the 3DFP. The founders both invest their own money in the company as well as seeking funding institution grants. For the firsts rounds of customer sales (which happened in 2016), the firm sold the product directly and offered direct assistance to customers. At this stage, one of the main objectives of *D* is to collect feedback and work with the first set of customers to further implement the product offer.

BM1c: *D*'s vision is "*that in 10 to 15 years we believe that every kitchen will have a 3D food printer in it,*" said the manager interviewed. The idea of underpinning *D's* future business model was born by observing the general habits of food consumers. More specifically, *D*'s proposition is to produce a 3D food printer through which customers can directly "*control all the ingredients going into* [their] *food, not a food manufacturer. So, it's customising* [their] *own food,*" said the manager interviewed. To exploit this proposition, the start-up will engage with selected distributors to re-sell their 3DF printer. Along with this, *D* will also implement the technology, as it has emerged from market research that "*to break into the consumer model* [..], *we need one additional feature that's not in the current box that we're shipping,*" said the manager interviewed. *D's* 3DFP internet device will allow customers to "*choose* [their] *recipes, browsing from a tablet or a PC,*" said the manager interviewed. So, *D* is working behind the scenes to build an online community for its customers. Potential additional implementations of the value created by this business model could include the possibility to collaborate with retail stores that want to sell pre-filled capsules with fresh food.

Figure 10 illustrates *D*'s BM evolutions and the related triggers of change. The Y-axis depicts the target markets, while the time line is shown on the X-axis.

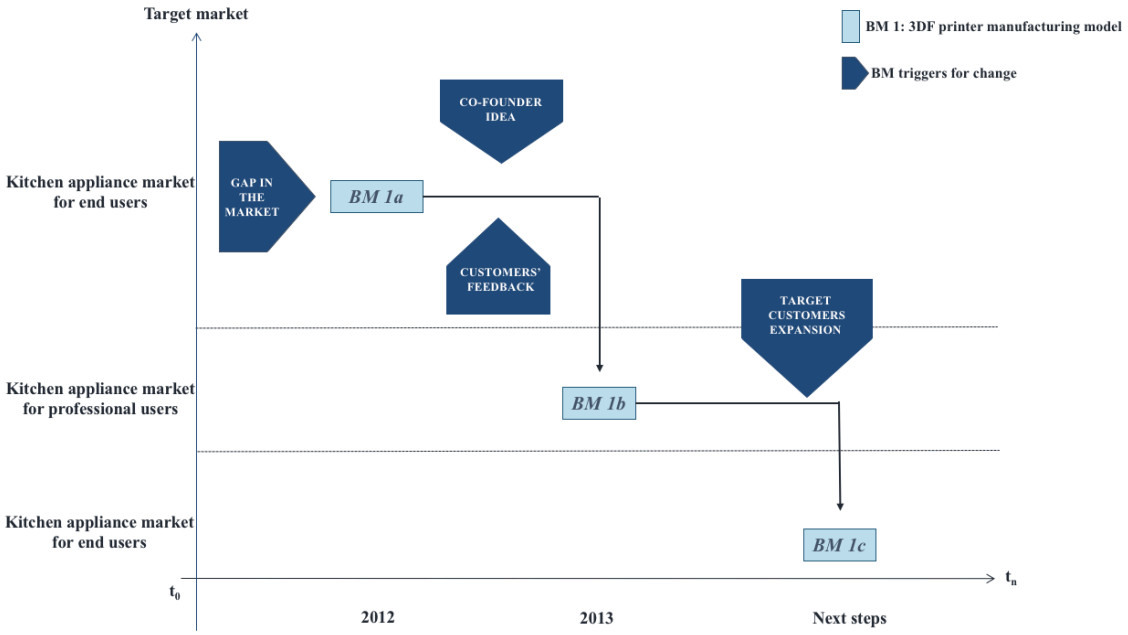


Figure 10 D 's sequence of business models and change triggers

3D FOOD PRINTER MANUFACTURING MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	*Customer segment*	*Value created for customers*	*Communication Channels*	*Sales Channels*	*Customer relationship*	*Key resources/ activities*	*Supplier/partner structure*	*Revenue stream*	*Cost structure*
BM 1a	3DF printer for confectioneries	End customers	Price Cost reduction Accessibility Convenience/usability	Media & Press Online Website Social Media	Stores (mini factories)	Customers independently make their confectioneries at the mini factory	Design provider *(controlled)* Material provider *(controlled)* Process technology provider (*controlled*) Digital ICT provider (*controlled*) Knowledge provider (*controlled*)	Hierarchical	Bootstrapping	Suppliers Office infrastructure Raw material
BM 1b	3DFP system to develop new food shapes	**Professional kitchen users**	Newness Easier accessibility to the technologies Design Cost reduction Convenience/usability	Media & Press **Attend events** Online Website Social Media	**Direct sales**	Personal assistance	Design provider (*controlled*) Process technology provider (*controlled*) Digital ICT provider (*controlled*) Knowledge provider (*controlled*)	Hierarchical	Bootstrapping **Funding institution grants** **Manufacturer investment** **Direct sales of the 3D food printer (paid in advance)**	Office & lab facilities Raw material Shipping **IP costs** **Human resources** **Sales &distribution management**
BM 1c	3DFP system to develop new food shapes	**End customers**	Newness Easier accessibility to the technologies Customisation Design Convenience/usability	Media & Press Attend events Online Website Social Media	Direct sales + **Indirect wholesalers**	**Customers independently buy the printer at selected retail stores or directly through D**	Design provider (*controlled*) Process technology provider (*controlled*) Digital ICT provider (*controlled*) Knowledge provider (*controlled*)	Hierarchical	Sales of the 3D food printer (paid in advance)	Office & lab facilities Raw material IP costs Human resources **Marketing** Sales & distribution management

Table 12 The business model history at D
Changed BM building blocks from previous version are highlighted in bold

4.6 Case E

4.6.1 Case E technology commercialisation

E is a consultant-based firm. More specifically, it is a design studio as well as an innovation laboratory. Within this context, the company has developed, as its "*part-time activity*", a new technique to 3D print food. Out of this technique, they have built a 3D food printer usable as a home kitchen appliance. To commercialise the 3D food printer, the firm has followed a two-step strategy. Hence, the 3D food printing project started with a research phase on the product development. Once they had tested the product prototype and it had gained positive responses from the market, the start-up moved to study the potential users and the possible business models applicable to commercialise the technology. After various tests and research, *E* found a suitable business model and started its exploitation.

4.6.2 Case E business model innovation history

Background

E was founded in 2011 and operates according to a B2B consultancy-based model for designing complex applications. The multidisciplinary nature of *E*'s team, along with its experience in transforming digital interfaces into physical objects, has allowed the company to start developing its own products. According to *E's* CEO, among the various projects run by the firm, the 3D food printer "*is the one that's going to be taken the furthest*." Hence, *E* is "*creating a spin-off*" of the 3D food printer.

Business Model Development

E's business model archetype evolution developed for the 3DFP project is shown in table 13.

BM 1: Research model

BM 1a: The *E* project related to 3D printing technologies started a little before 2014. As a creative firm, the team likes to experiment with new technologies and innovations. Subsequently, the team undertook extensive research on the 3D food printing ecosystem, discovering that "*there is a limitation in terms of materials that people were using* [to 3D print food]*. So, [..] we looked at materials to start with, because we wanted to experiment with it a bit more*," said the interviewee. From this starting point, *E* started the experiments with 3D food printing and developed a new 3D printing technique. "*We developed first and then we looked at how to design technology around it that would fit a particular environment*." As a team, *E* has all expertise in-house, so the firm "*pretty much built the whole thing* [3D food printer]," said the interviewee. Initially, the product was a 3D food printer targeted at professional chefs as well as the general public "*foodies*". To develop this first prototype, the start-up

bootstrapped the project, and was also supported by winning research grants both from funding institutions. In 2014 the company proved the concept by realising the first prototype of their 3D food printer, and filed a patent application (pending) to protect their invention. *E* spent the last year (2015 - 2016) exploring possible various business models in order to identify which one would be most suitable for the project. After extensive research and feedback, the firm "*decided that the* [3D food printer for] *home kitchen kind of needs, it is more urgent,"* said the interviewee.

BM 2: 3D food printer manufacturing model

BM 2a: Once they had identified the most suitable business model, *E* started to design its ecosystem around the users, their habits and needs within the kitchen. From this starting point, *E* has improved its 3D food printer mainly in the chemical aspects as well as its design. Alongside the 3D food printer, *E* developed an environmentally sustainable food capsule system. The capsules will be sold both pre-filled as well as empty. Along with the physical product, the firm is building a strong community in which the users' experience is supported by an Internet of Things (IoT) system. Hence, through the *E* application, the 3D food printer is connected to the user's phone, so he/she can directly realise his/her own designs, recipes and share them with others within the community. The users will also be able to download recipes suggested by professional chefs. To build this ecosystem, *E* developed a system of strategic alliances with manufacturing and design firms and professional chefs. The company is also collaborating with several universities on the research and development side to implement the future development of the 3D food printing system. The 3DFP system will be sold directly online on the product website and the first pre-orders will start in the autumn of 2016. So far, *E* has sustained the business development by bootstrapping, and they will start a crowdfunding campaign. Later, *E* is planning to apply for more substantial angel investment.

BM 3: Food service model

Along with the research model (BM1a) and the 3DF printer manufacturing model (BM2a), *E* started a food service-based model as subsidiary business model in 2015. It supported the research activity (BM1a) first, and subsequently supports the startup's core BM (BM2a) from the marketing perspective.

BM 3a: *E* offered demonstrations, pop-up dinners and entertainment-oriented events based on 3DFP. These activities were used mainly for research purposes (BM1b) into potential users, however they also supported the project. The firm used to organise the events internally and monetised through tickets sold for the events.

BM 3b: E still offers demonstrations, pop-up dinners and entertainment-oriented events based on 3DFP. These activities are now mainly for marketing purposes. The firm is either called to take part in third

party events or directly organise events. *E* monetises through tickets sold per event and/or by being paid to participate in third party events.

Figure 11 visualises *E*'s BM evolutions and the related triggers of change. The industry segment is depicted on the Y-axis, while the X axis represents the time line.

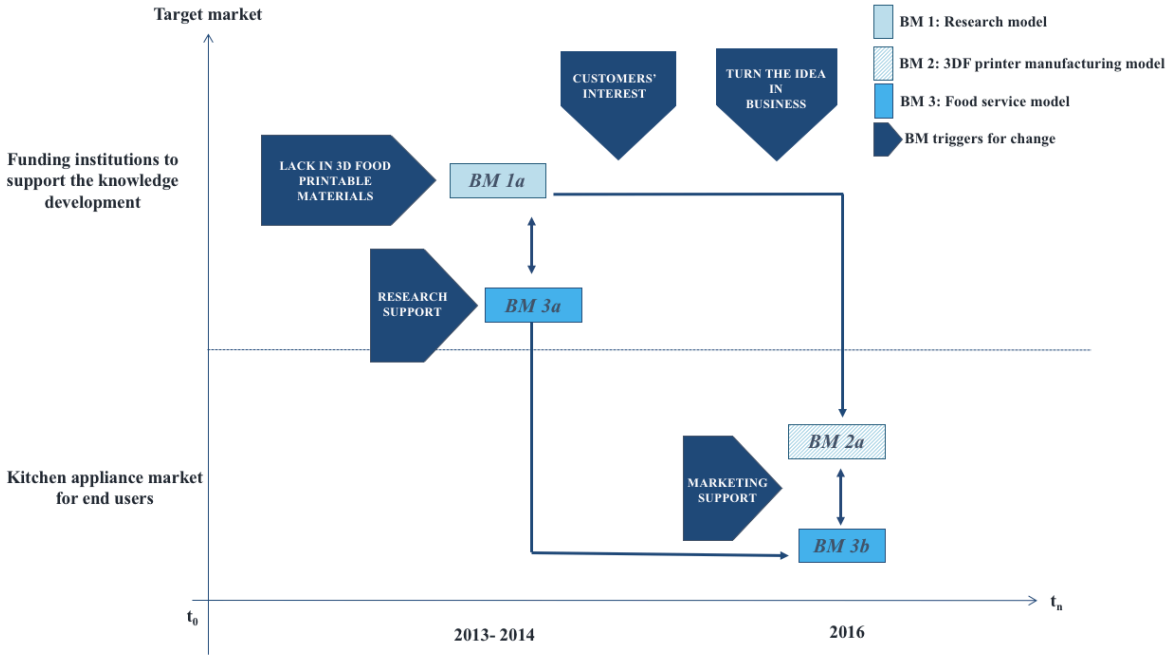


Figure 11 E's sequence of business models and change triggers

RESEARCH MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	*Customer segment*	*Value created for customers*	*Communication Channels*	*Sales Channels*	*Customer relationship*	*Key resources/activities*	*Supplier/partner structure*	*Revenue stream*	*Cost structure*
BM 1a	Knowledge development to develop a new 3D food printing technique	Funding institutions	Newness Overcome a gap in the 3DFP market	Attend events Social Networks (e.g. Twitter) Firm's blog Media Fairs and conferences	Direct sales of the research proposal to the funding institution	Personal assistance (periodical reports to the funding institution)	Design provider (*controlled*) Material provider (*controlled*) Process technology provider (*controlled*) Digital ICT provider (*controlled*) Knowledge provider (*controlled*)	Hierarchical	Bootstrapping Research funds	Equipment Time Raw materials Pop-up events R&D development

3D FOOD PRINTER MANUFACTURING MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	*Customer segment*	*Value created for customers*	*Communication Channels*	*Sales Channels*	*Customer relationship*	*Key resources/activities*	*Supplier/partner structure*	*Revenue stream*	*Cost structure*
BM 2a	**3D food printer system (home kitchen appliance)**	**End users**	**Design** Overcome a gap in the 3DFP market **Customisation** Newness **Convenience/ Usability**	Attend events Social Networks (e.g. Twitter) Firm's blog Media Pop-up events **Ecosystem's network**	**Direct web sales**	Personal assistance **to the initial customers**	Design provider (*controlled*) Material provider (*controlled*) Process technology provider (*controlled*) Digital ICT provider (*controlled*) Knowledge provider (*controlled*)	Hierarchical	**3D food printer sales (pay in advance)** Bootstrapping	Equipment Time Raw materials **Marketing** **Human resources** R&D development

FOOD SERVICE MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	*Customer segment*	*Value created for customers*	*Communication Channels*	*Sales Channels*	*Customer relationship*	*Key resources/activities*	*Supplier/partner structure*	*Revenue stream*	*Cost structure*
BM 3a	3DFP-based pop-up dinners, events and live demonstration at events	End customers	Customisation Newness	Attend events Public talks Website Social Media News/Press Web Platform	Direct sales force	Dedicated Personal assistance	Knowledge provider (*controlled*)	Hierarchical	Pay per event	Human resources Time Food ingredients Event organisation
BM 3b	3DFP-based pop-up dinners, events and live demonstration at events	End- customers and **B2B event organisers**	Customisation Newness	Attend events Public talks Website Social Media News/Press Web Platform	Direct sales force	Dedicated Personal assistance	Knowledge provider (*controlled*)	Hierarchical	**Pay per time** / pay per event	Time Food ingredient Event organisation

Table 13 The business model history at E
Changed BM building blocks from previous version are highlighted in bold

4.7 Case F

4.7.1 Case F technology commercialisation

F was born as a joint venture between an international confectionery manufacturer and the current firm's managing director.

F created a confectionery brand focused on producing a 3DFP system to develop customised confectioneries for end customers in the retail environment. The firm developed a straightforward business model roadmap to exploit its technology. It first focused on testing the business idea and tailoring it to the customers' needs. Then, *F* targeted its market acquisition on the confectionery segment through a geographical expansion strategy. Along with this exploitation strategy, the firm came across another potential business opportunity that arose from market demand. Hence, *F* decided to explore this prospect. This latest business is now becoming a spin-off of the core business model for the retail environment.

Recently, *F* organised meetings to talk with several universities about possible projects that are research-based in order to further expand "*the technology to other types of food. And then also improving the technology to do further capabilities and in relation to colour changes, and even changing medium in the middle of the print,*" said the interviewee.

4.7.2 Case F business model innovation history

Background

F was born after the managing director sold a company he/she was previously running. Once the previous firm was sold the opportunity to build a new business jointly with a large confectionery manufacturer arose and *F* was created.

Business Model Development

The variation of *F's* business model archetypes is shown in table 14.

BM 1: 3D printed food manufacturing model

BM 1a: *F* was started in early 2015 with the idea to "*create a 3D printer that would be able to be used in a retail environment, where consumers could come and have an experience either in the store or online,*" said the interviewee. That idea did not change over time. What changed is the printer's operationalisation process and its design, as well as its offer to the customers. *F* started as a one-person

firm. He/she developed the company's overall strategy. Hence, "*the first thing you have to do, you develop a distribution model, you have to look at your own cost, and what it would take for you in order to consider the business successful*," said the interviewee. Once the main strategy had been developed, *F* started its development process. To do so, the managing director started by looking for long-term partners to outsource the production of the hardware and the software parts of the business. When *F* found suitable partners (after thorough market research), the managing director contracted them on a monthly fee basis, and started working with them to build the firm's core business concept. To develop the core business concept, *F* also relied on the support of several customers' feedback. The finalised concept, which came out of this phase, is that the technology is used as an instrument that allows them to create customisable 3D printed confectioneries. The initial ideas were tested for 12 weeks, directly selling 3D printed customised confectioneries in one of the large manufacturing partner's public locations, where *F*'s first 3D printer was installed. During the testing period, the firm collected feedback from customers, as well as monitoring and recording their reaction to changes. "*Every day, we would do a certain set of things, we would ask people what they thought, and then we would change the next day based on that feedback*," said the interviewee. This practice allowed *F* to define the final retail model and finalise the product offered by the firm. This fast development was possible thanks to the support of the larger partner. Hence, this partnership gives the "*support and a network of people that are part of the* [manufacturer's] *family*", said the interviewee. It allows *F* to be agile, but with the reassurance of having the backing of a solid network.

BM1b: The main outcome that emerged from the beta testing of the concept was that "*it's really the personalization that's the most important to the consumer,*" said the interviewee. In light of this, *F,* with the help of its software partner, implemented the software platform, that allows people to create and design their own personalisable 3D printed confectioneries. The finalised product was successfully launched in early 2016. Within these circumstances, the team also started to grow and the frim started its geographical diffusion. In mid 2016, *F* launched the business in one country by establishing a year-long exclusive retailing partnership with a confectionery chain. At the confectionery chain, the confectioneries can be bought either in the physical stores around the country, or on the confectionery's online shop. The revenue stream developed by *F* is threefold. It consists of leasing the printers to the retailers, who pay a monthly fee in order to keep the 3D printer in their store. Furthermore, *F* sells the retailers the ingredients and the software license, "*so every time that they* [the end customers] *want to make a candy, they have* [indirectly] *to buy an ingredient base from me,*" said the interviewee.

BM1c: Around the summer of 2016, *F's* team came across another business opportunity that consists of licensing their printers for business as well as private events. "*When we originally designed the printer, we didn't actually do it for that reason, but* [for] *corporations and conferences and weddings and birthday parties; it would be* [that] *a number of people that enquire for that type of thing, is huge*,"

said the interviewee. This latter BM branch will run in parallel with the core business (BM1b). This business model does not only represent a new way to spin off *F*'s technology, but it can be also used as marketing support for the core business (BM1b).

BM1d: The next step of *F's* business is to also launch its own online and physical store for their country's market. To do so, they have started by launching a beta-test temporary store in late 2016. The shop will at first be launched for a short period as a beta-test for the business to consumer approach, and then *F* will decide whether it is worthwhile to continue with this line of sales or not. If it is not worth it, *F* will "*find a secondary partner to do that for us as well,*" said the interviewee. Along with the beta-test store, *F* wants to keep implementing the "*geographical expansion too. [..] By the end of this year, we should have printers on four continents, and in every major consumer market,*" said the interviewee. The geographical expansion, from a distribution perspective, will be executed following the same mechanisms and similar agreements of the partnership developed with the confectionery chain showed in BM 1b.

Figure 12 visualises *F*'s business model evolutions and the related triggers of change. The Y-axis shows the target markets, while the X-axis depicts the time line.

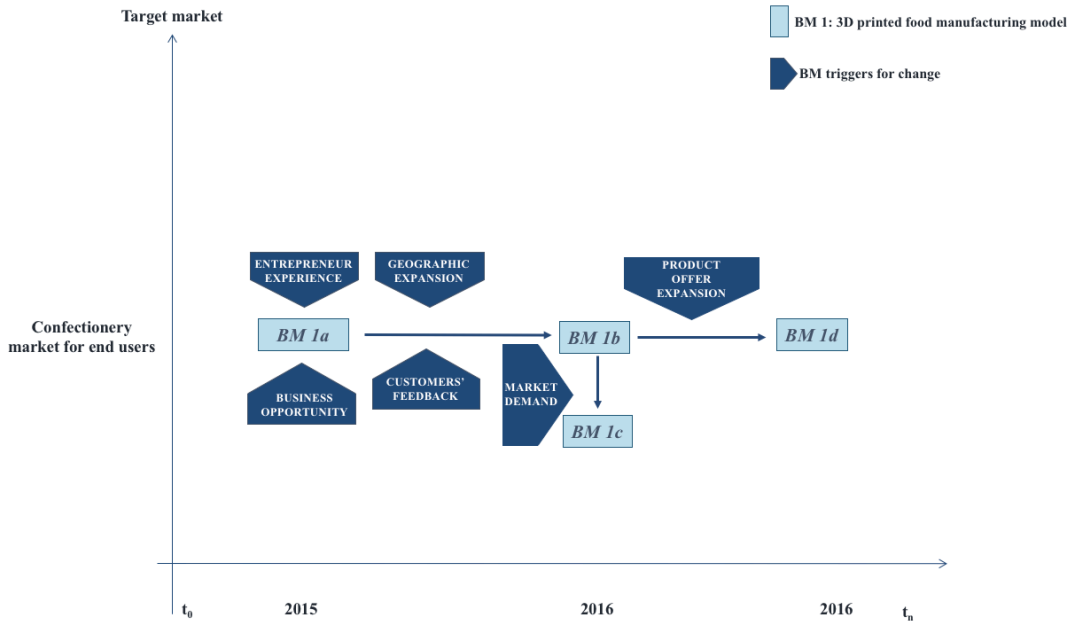


Figure 12 F's sequence of business models and change triggers

3D PRINTED FOOD MANUFACTURING MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	*Customer segment*	*Value created for customers*	*Communication Channels*	*Sales Channels*	*Customer relationship*	*Key resources/activities*	*Supplier/partner structure*	*Revenue stream*	*Cost structure*
BM 1a	3D printed customised confectioneries	End customers	Newness Easier accessibility to the technologies Customisation Convenience/ usability	Media & Press Larger partner's network Online Website Social media	Partner's store (Manufacturing partner)	Customers independently make their confectioneries Customers' feedback	Design provider (*controlled*) Material provider (*controlled*) Process technology provider (*controlled*) Digital ICT provider (*controlled*) Knowledge provider (*controlled*)	Hierarchical with supplier	Sales per item	Suppliers contracts Office & lab facilities Raw material
BM 1b	3D food printer to print **personalised** confectioneries	End customers	Newness Easier accessibility to the technologies Customisation Convenience/ usability	Media & Press Larger partner's network **Retail partners** Online Website Social media	**Retail partners' stores** + **Indirect web sales**	Customers independently make their confectioneries *(Co-creation)*	**Design provider (not *controlled*)** Material provider (*controlled*) Process technology provider (*controlled*) Digital ICT provider (*controlled*) Knowledge provider (*controlled*)	Hierarchical with supplier Networked with customers	**Sales of each ingredient** **Lease of printer** **Software Licence**	Suppliers contracts Office & lab facilities Raw material Marketing POS **IP costs** Shipping Human resources
BM 1c	3D food printer to print personalised confectioneries	**Event organisers (B2B / B2C)**	Newness Easier accessibility to the technologies Customisation Convenience/ usability	Media & Press Larger partner's network Retail partners Online Website Social media	Direct web sales	Customers independently make their confectioneries *(Co-creation)*	Design provider (not *controlled*) Material provider (*controlled*) Process technology provider (*controlled*) Digital ICT provider (*controlled*) Knowledge provider (*controlled*)	Hierarchical with supplier Networked with customers	Sales of each ingredients Lease of printer Software Licence	Suppliers contracts Office & lab facilities Raw material Marketing IP costs Shipping Human resources
BM 1d	3D printed personalised confectioneries	**End customers**	Newness Easier accessibility to the technologies Customisation Convenience/usability	Media & Press Larger partner's network Online Website Social media	Direct web sales **Direct sales** (temporary shop)	Customers independently make their confectioneries **Customers' feedback Collection** *(Co-creation)*	Design provider (not *controlled*) Material provider (*controlled*) Process technology provider (*controlled*) Digital ICT provider (*controlled*) Knowledge provider (*controlled*)	Hierarchical with supplier Networked with customers	**Sales per item**	Suppliers contracts Office & lab facilities Raw material Marketing POS IP costs Shipping Human resources

Table 14 The business model history at F
Changed BM building blocks from previous version are highlighted in bold

4.8 Case G

4.8.1 Case G technology commercialisation

G was born as a research project in which the ideator developed an inkjet printer able to print layer upon layer of alternative nutritional sources to develop a patent out of the technology. The ultimate aim of the project is to bring alternative nutritional sources into individuals' homes.

The inkjet printing technology here is used with the aim of contributing to a "*personalisation and domestication of technologies. [..] I'm not interested in using the technology because it's trendy. [..] We are more interested in implementing what our inkjet printing can do to replace the existing* [processes]," said the interviewee.

4.8.2 Case G business model innovation history

Background

The project started in 2011 with the aim to find answers on "*how can an intersection of design with* [alternative nutritional sources] *generate new applications in the urban indoor environment?"* Within this context "*digital printing, for me, was a big part of our society and environment, and our sort of personal experiences within our everyday living*," said the interviewee. So, in this research, the inkjet printing technology was used as a tool to create food out of alternative nutritional sources.

Business Model Development

The variation of *G'*s business model archetypes is shown in table 15.

BM 1: Research model

BM1a: *G*'s project started when its ideator won research funds to develop the project. The research had the aim to understand "*how* [alternative nutritional] *cells can be grown and digitally printed for the production of 'fresh' food supplements*," said the interviewee.

The main idea was to introduce the printing of alternative nutritional sources as a new element in urban environments and spread personalised health food to individuals' homes. To do so, *G*'s ideator needed to develop a new technology with the help of technical specialists. *G*'s ideator found suitable expertise in a science laboratory, in particular with two scientists specialised in alternative nutritional sources.

The alternative nutritional sources printer was built in partnership with the science laboratory's institution and the research funding institution of *G*'s ideator. Once the concept was tested and developed, it needed to be spread to society. Hence *G*'s ideator decided to expose the project's outcome

at an art exhibition. According to the researcher: "*art installation [..] it's very important. [..] They kind of show not just the technology, but how this could be embedded in everyday life*".

BM1b: The concept researched by *G* was proved, and this phase reached its conclusion in late 2015, along with the ending of the funds. Currently, *G*'s ideator and the research scientist colleagues are looking for other research funds in order to further develop the project to reach the proof of the technology (i.e. IP application), "*and then [*develop*] even more the more commercial prototypes*," said the interviewee.

Figure 13 illustrates *G*'s BM evolutions and the related triggers of change. The target segment is depicted on the Y-axis, while the X-axis shows the time line. Initially, *G*'s ideator and colleagues designed a research BM to prove the concept. They are now re-designing a new BM based on the results obtained in the BM1a in order to move forward with the research and prove the technology.

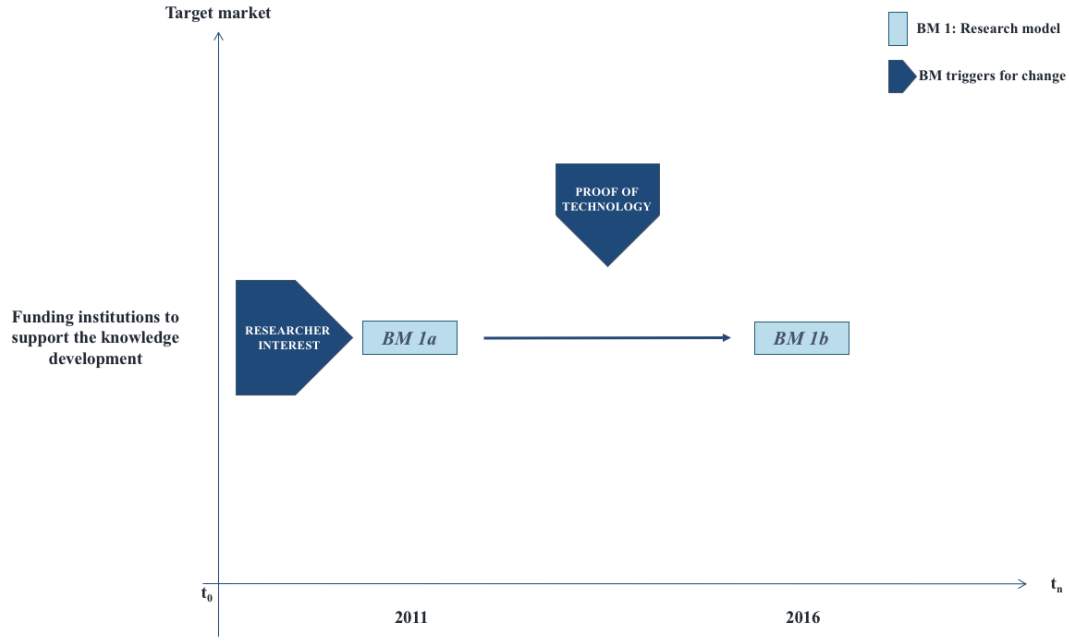


Figure 13 G's sequence of business models and change triggers

RESEARCH MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	***Customer segment***	***Value created for customers***	***Communication Channels***	***Sales Channels***	***Customer relationship***	***Key resources/activities***	***Supplier/partner structure***	***Revenue stream***	***Cost structure***
BM 1a	Knowledge development on 3DFP to stimulate the public interest on the consumption of alternative nutritional sources *(partner dependency)*	Funding institutions	Newness Accessibility Customisation	Media Exhibitions	Direct sales of the research proposal to the funding institution	Personal assistance (periodical reports to the funding institution)	Design provider *(not controlled)* Material provider *(not controlled)* Process technology provider *(not controlled)* Knowledge provider *(not controlled)*	Networked	Research. funds	Time Institution's fees
BM 1b	Knowledge development on 3DFP to stimulate the public interest on the consumption of alternative nutritional sources *(partner dependency)*	Funding institutions	Newness Accessibility Customisation	Media Exhibitions	Direct sales of the research proposal to the funding institution	Personal assistance (applications to the funding institution)	Design provider *(not controlled)* Material provider *(not controlled)* Process technology provider *(not controlled)* Knowledge provider *(not controlled)*	Networked	Research funds ***(revenue shared)***	Time Human resource**s** **Laboratory Facilities** **Structures** **Raw materials**

Table 15 The business model history at G
Changed BM building blocks from previous version are highlighted in bold

4.9 Case H

4.9.1 Case H technology commercialisation

H is a startup born in 2013. The firm focuses on creating customised software platforms for companies that want to incorporate intuitive solutions to create 3D models in their products (e.g. from an image, a text etc.). To commercialise its technology, the firm is adopting an explorative strategy to develop its business, based on market observation. Hence, according to he firm's CEO "*we're always in a research phase, we develop something, we test it, we see how the clients behave, we see how the operators behave*".

H is planning to do a new business model pivot, and toward the end of 2016, the firm wants to test the new possible business activity. The idea of this new line of business originated in the observations made within the service model (BM2a). By combining the firm's expertise both in hardware (collected with the BM 1a) as well as in software (collected in BM 2b), *H* will try to build a new business line as "*creator of experience for retailer environment* [in a given industry, different from food]" said the interviewee. The firm will produce 3D printers to be placed in retail stores where customers can produces their own customised items.

4.9.2 Case H Business model innovation history

Background

The origins of H can be traced back to its CEO's passion for 3D printing, "*I fell in love with 3D printing, and I decided I was going to do that for the rest of my life. [..] I pretty much decided that would be my path no matter what,*" said the interviewee.

Business Model Development

The variation of *H'*s business model archetypes is shown in table 16.

BM 1: 3D printer manufacturing model

BM 1a: H 's CEO started the company as a part-time business in late 2013. The initial idea "*was to create a 3D printer, and it was pretty much building a 3D printer on kits* [for home use] *and sell it in* [some countries]," said the interviewee. To do so, *H*'s CEO's branched from an acquaintance the open source design the firm was using to build its auto replicable 3D printer. It "*ended up being the most auto replicating machine in the world* [..] *and it was the cheapest 3D printer in* [the targeted countries] *as well,*" said the interviewee. The business got lots of media attention in the targeted countries. However, according to the interviewee "*sadly the truth is that we didn't get to sell a lot of printers*"

because the final price of the printer increased exponentially, due to customs and transportation fees that are in place around the targeted countries. To increase sales, *H* also started to offer workshops in which the team explained and demonstrated how to assemble the 3D printer. However, "*it did not work either. It was [involving] lots of costs for us to give those workshops for the small margin that we had per printer*," said the interviewee.

Hence, the business was not sustainable, "*because there were tensions, the money was not coming in, we were spending a lot,*" said the interviewee. So, the team struggled and then split.

BM 2: Software provider model

BM 2a: After the team's split *H* 's CEO started his journey in software. This choice was determined by *H*'s CEO's constrictions; "*I had no money at all, because I'd spent pretty much all my money on this first project,"* said the interviewee. As *H*'s CEO's background is in software engineering, he/she decided to start a new business from this perspective. Hence, *H's* CEO developed a software taking the idea from a gap observed in the 3D market: the need for software that would facilitate the process of transforming an image into a 3D printable model. After about six months (early 2015) of development *H's* CEO released a platform that allows people to transform "*an image into a 3D model.*" With this early version of the product *H* received funds from a funding institution. The funds also included mentorship and office facilities. Thanks to this support, the firm's CEO could keep the costs of development as low as possible.

Until mid 2015, *H* was a 1-person business, and from early autumn the firm's CEO hired a collaborator to help develop the business. *H* was conceptualised as a business to consumer (hereafter: B2C) activity based on a freemium revenue model. "*We were very confident that we were going to be successful on a B2C perspective, as we had so much traffic. But the reality is that we were not making that much money,* [..] *we still had to put some money in from our pockets to make the project work,*" said the interviewee. At the same time *H's* CEO noticed that companies were starting to intensively use the platform's premium services. In this, the firm saw the potential for a business opportunity.

BM 2b: The third phase of *H* began (late 2015) when the team decided to start directly contacting each customer that was doing more than four transactions per day. Many of the firms contacted by *H*'s CEO "*were like, 'well, we're in love with your solution* [..]*, and we want you to develop something for our business, specifically for our needs,*" said the interviewee. The change in the BM, from B2C in B2B, did not happen in a structured way; "*it was something very simple, once we realized that businesses were willing to pay, our solution would make them produce more money, make more money, we decided to switch to B2B*," said the interviewee. Nowadays, the firm creates value by developing and implementing customised software solutions for companies, and by building long-term contractual-based partnerships with them. They monetise with a monthly fee-based model and the more the partners

are able to increase their revenues, the higher the fee becomes. Among the most relevant partnerships there are those within 3D food printing environment. Often *H* adopts a twofold customer engagement strategy. On the one hand, firms find *H* through *H*'s platform. On the other hand, every time *H*'s CEO travels to a new country he/she presents its product to the 3D printing scene in that place. This business model has allowed *H* to become a sustainable business, which grew also in term of human resources.

Figure 14 visualises *H*'s BM evolution and the related triggers of change. The Y-axis shows the market covered, while the X-axis represents the time line.

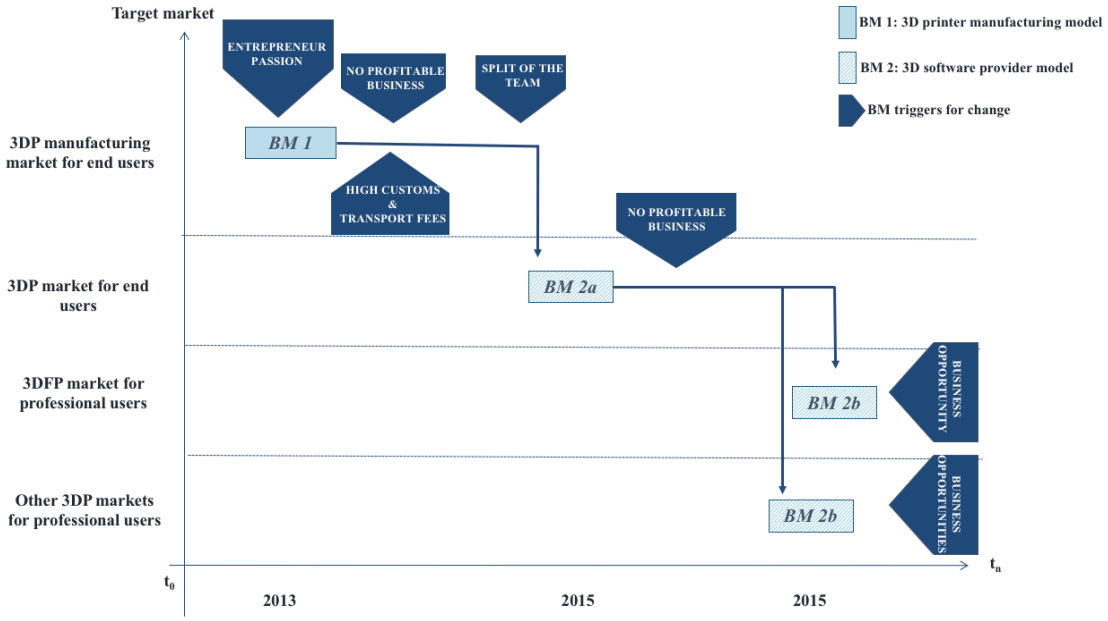


Figure 14 H 's sequence of business models and change triggers

3D PRINTER MANUFACTURING MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	*Customer segment*	*Value created for customers*	*Communication Channels*	*Sales Channels*	*Customer relationship*	*Key resources/activities*	*Suppliers/partner structure*	*Revenue stream*	*Cost structure*
BM 1a	Low cost auto replicating 3D printer on kits (home 3DP)	End users	Performance Price Convenience/usability	Media Press News Online	Direct web sales + direct sales (workshops)	Personal assistance to customers	Design provider (open source) (*not controlled*) Material provider (*controlled*) Process technology provider (*controlled*) Digital ICT provider (*controlled*) Knowledge provider (*controlled*)	Hierarchical with suppliers Networked with designer	Bootstrapping Pay per item Pay per event + item (workshops + 3DP)	Time Raw materials Workshops organisation costs

SOFTWARE PROVIDER MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	*Customer segment*	*Value created for customers*	*Communication Channels*	*Sales Channels*	*Customer relationship*	*Key resource/ activities*	*Supplier/ partner structure*	*Revenue stream*	*Cost structure*
BM 2a	**Software platform to transform an image into a 3D model**	End users	Answer to a need (Problem solving)	Attend specialised events LinkedIn Website Facebook groups 3DP forums News	Direct web sales	Self-service (the customers realise their product by themselves)	**Digital ICT provider (*controlled*)** **Knowledge provider (*controlled*)**	Hierarchical	Institution funds Freemium model	Time Human resources
BM 2b	**Customised easy modelling software tools for 3DP (3DFP)**	**Professional users**	Answer to a need (Problem solving) **Customised solutions**	Attend specialised events **Email to loyal customers**	**Direct sales force**	**Dedicated Personal assistance** **Co-creation of solutions with customers** *(co-creation)*	Digital ICT provider (software's' features) **(not *controlled*)** Knowledge provider (*controlled*)	**Networked with customers**	**Fee for software and maintenance use**	Time Human resources **Marketing** **Demonstration activities** **Travel and sustenance costs**

Table 16 The business model history at H
Changed BM building blocks from previous version are highlighted in bold

4.10 Case I

4.10.1 Case I technology commercialisation

I is a product-service family business that produces personalised 3D printed confectioneries and provides 3DFP demonstrations mainly for business environments. The long-term vision of *I* is to realise a digital confectionery platform, in which confectionery professionals can order online 3D food printed topping decorations. The firm adopts a content-driven technology commercialisation approach to 3D food printing. To exploit this strategy, *I* built its own 3D food printer that it uses to provide its products and services which were identified through thorough market research. More specifically, "*we are developing an online platform. We basically developed equipment to develop the market, but our whole thing is not to sell the machines, it's actually to sell the service, facilitating 3D food printing*," said the interviewee. To do so, *I* built its activity independently from partners, and it bases its relationships with its ecosystem of suppliers on a transaction basis.

4.10.2 Case I business model innovation history

Background

I was created in early 2014, and started as a side project. It resulted from matching the professional experience of one of *I's* founders with a passion for cooking. The business idea, which was to realise a digital confectionery (i.e. making regular confectioneries with 3D food printed decorations), came up in the managing director's mind by observing a friend's confectionery designing activity. "*I saw what she was doing as model making, so I thought, 'Oh, this could be fun', and I got into it.*" said the interviewee.

Business Model Development

The variation of *I's* business model archetypes is shown in table 17.

BM 1: 3D printed food manufacturing model

BM 1a: It was early 2014 when the managing director started the part-time business in the bakery industry. Initially, the business started as confectionery design with 3D food printed decorations. After thorough research, the managing director realised that confectionery design was a very time consuming process, from which confectionery professionals do not make a great deal of money. The entrepreneur saw a gap in the market that could be overcome by 3D printing all the decorations for confectionery professionals. Consequently, the firm started conceptualising a web platform, where *I* would offer a

catalogue of confectionery decorating shapes, from which the confectionery professionals would choose and place their order. Then, *I* would 3D print the food decorating shapes and ship them to the confectionery professionals. *I* would have captured the value per each item ordered by the confectionery professionals. *I* started working according to this business model, however, the firm noticed a significant technology barrier. The confectionery decoration shapes that were realised with the available technology, were very fragile and broke easily during the shipping process. According to the interviewee, this business model "*has the biggest potential, but the printers need to come a lot further than their current stat*e." So, *I* decided to realise this business model as a main long-term goal, and to progress with interim strategies.

BM 1b: *I* started by building its own 3D food printer, with which the firm started printing small confectionery treats because, according to the interviewee, "*printing small stuff* [..] *was easy*." In doing this, the managing director noticed a potential business opportunity in the realisation of customised confectioneries. It was about mid-2015 when the managing director started producing customised confectioneries for a selected merchant. "*That actually worked out really well. So they* [the customised confectioneries realised] *are still making money, and they have a bit of a 'wow' factor going on.* [The merchant is] *still using it, and it still goes great*," said the interviewee. *I* captures value per stock of items sold. It was at this time that the entrepreneur decided to make *I* a full-time activity.

BM 1c: To expand the business, along with the customised confectioneries for the specialised merchant activities, *I* started exploring other potential business opportunities. *I*'s managing director started to talk with people and ask for feedback, and this resulted in the development of a business model that is to sell customised confectioneries as promotional goods. This product has been tailored for "*companies who wanted an advantage, an edge, while on trade shows or at meetings and stuff like that*," said the interviewee. *I* captures value per stock of customised 3D confectioneries sold. Nowadays, this business model is very stable and allows the firm to be financially auto-sustainable.

BM 2: Food service model

BM 2a: Along with the manufacturing-service model (BM1), almost since its beginning *I* has carried on a service model based on 3D food printing demonstrations at a specific event, and that can have either a commercial or educational purpose. *I* captures value by charging per the time invested in the activity. *I* started using this business model as leverage to get in contact with companies. Initially, along with the digital confectionery model (BM1a), the firm was offering 3DF printed confectionery decorations at events, but "*then the* [confectionery decorations] *side reduced* (BM 1a)," said the interviewee.

BM 2b: According to the interviewee, the demonstration business model "*has always been very well-received*." So, when the 3DF printed confectionery decorations business model decreased, and the 3DF printed customised confectioneries for promotional purposes BM emerged, the firm kept providing demonstrations. *I* still captures value charging per the time invested in the activity. Furthermore, *I* also used this business model as a sales channel (i.e. *I* brings free gadgets while some others are for sale) for 3DF printed confectioneries. In addition, *I* uses the proposals for demonstration events as a testing ground for their business experimentations. Hence, "*We say, 'this is what we can do', and if they go for it then we create it. Then we look at the feedback, and analyse the feedback, and see if it worked or didn't, or what can we improve, or what we can leave ou*t," said the interviewee.

BM 2c: During the year 2016, *I* added another extra service to the demonstration model; "*doing a* [confectionery]*, and actually theming* [it] *towards* [an] *event,*" said the managing director. Actually, this latest offer is very similar to the initial demonstration business model (BM 2a). It seems that *I* is using this latest business model to move a step closer to the auspicated business model, and the digital confectionery platform (BM 1a).

Figure 15 illustrates *I*'s BM evolutions and the related triggers of change. The target markets can be observed on the Y-axis, while the X-axis represents the time line. Figure 15 shows a linked business model innovation strategy adopted by *I* (e.g. from BM 1a + BM 2a to BM 1b + BM 2b).

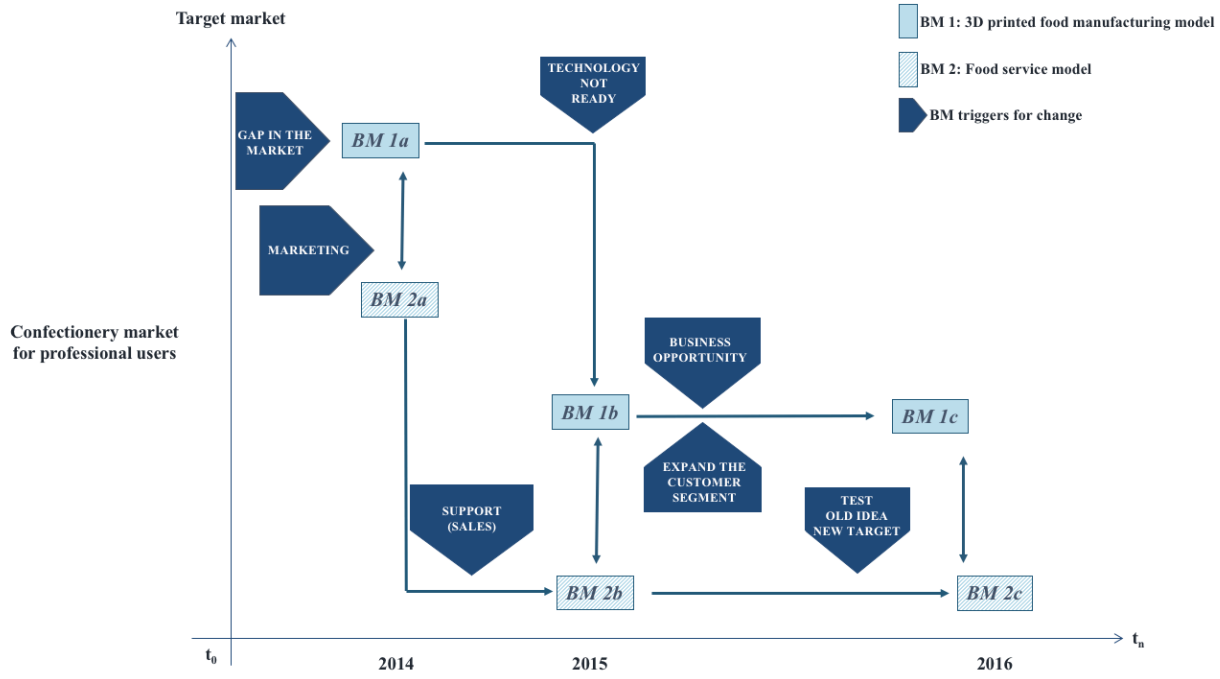


Figure 15 I 's sequence of business models and change triggers

3D PRINTED FOOD MANUFACTURING MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	***Customer segment***	***Value created for customers***	***Communication Channels***	***Sales Channels***	***Customer relationship***	***Key resources/activities***	***Supplier/partner structure***	***Revenue stream***	***Cost structure***
BM 1a	**3Dprinted confectioneries platform**	Professional Users	Newness Convenience/usability Design	3DFP demonstrations Website Word of mouth Social media	e-commerce	Self-service	Design provider (*controlled*) Material provider (*controlled*) Process technology provider (*controlled*) Digital ICT provider (*controlled*) Knowledge provider (*controlled*)	Hierarchical	Product sales Bootstrapping	Suppliers Office infrastructure Raw material Food ingredients Travel & sustenance Time Equipment
BM 1b	**Customised 3D printed confectioneries**	Professional users	Newness **Customisation** Design	3DFP demonstrations Website Word of mouth Social media	e-commerce + **direct sales + workshops/ demonstrations events**	Dedicated personal assistance *Co-creation*	Design provider (*not controlled*) Material provider (*controlled*) Process technology provider (*controlled*) Digital ICT provider (*controlled*) Knowledge provider (*controlled*)	Hierarchical with suppliers **Networked with customers**	Product sales	Suppliers Office infrastructure Raw material Food ingredients Travel & sustenance Time Equipment **Logistics expenses**
BM 1c	**Customised 3D printed confectioneries for promotional purposes**	Professional users	Newness Customisation Design	3DFP demonstrations Website Word of mouth Social media	direct sales + workshops/demonstrations events	Dedicated personal assistance *Co-creation*	Design provider (*not controlled*) Material provider (*controlled*) Process technology provider (*controlled*) Digital ICT provider (*controlled*) Knowledge provider (*controlled*)	Hierarchical with suppliers Networked with customers	Product sales	Suppliers Office infrastructure Raw material Food ingredients Travel & sustenance Time Logistics expenses Equipment

Table 17 The business model history at I (continue)
Changed BM building blocks from previous version are highlighted in bold

FOOD SERVICE MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	***Customer segment***	***Value created for customers***	***Communication Channels***	***Sales Channels***	***Customer relationship***	***Key resources/activities***	***Supplier/partner structure***	***Revenue stream***	***Cost structure***
BM 2a	Live 3DFP **confectioneries** for demonstration at events	Professional users	Customisation Newness	3DFP demonstrations Website Attend events Social Media Word of mouth	Direct sales force	Dedicated Personal assistance	Design provider (*controlled*) Knowledge provider (*controlled*)	Hierarchical with suppliers	Pay per time	Travel & sustenance Time Food ingredients
BM 2b	Live 3DFP demonstration + **customised giveaway for an event**	Professional users	Customisation Newness	Previous demonstrations Attend events Website Social Media Word of mouth	Direct sales force	Dedicated Personal assistance	Design provider (*controlled*) Knowledge provider (*controlled*)	Hierarchical with suppliers	Pay per time **Pay per gadget**	Travel & sustenance Time Food ingredients **Free sample**
BM 2c	Live 3DFP demonstration + customised giveaway for an event + **confectioneries with 3D Printed decoration realised during an event**	Professional users	Customisation Newness	Previous demonstrations Attend events Website Social Media Word of mouth	Direct sales force	Dedicated Personal assistance	Design provider (*controlled*) Knowledge provider (*controlled*)	Hierarchical with suppliers	Pay per time Pay per gadget	Travel & sustenance Time Food ingredients Free sample

Table 17 continuation

4.11 Case J

4.11.1 Case J technology commercialisation

J is a small enterprise. The firm produces and commercialises food texturising systems, comprising pulverised basic food ingredients and additives which can be used with 3D Printing equipment.
J applies the food texturising systems in several markets (e.g. texture market for professional users and end users as well as for people with health difficulties). *J* offers three distinct product lines (i.e. Product 1, Product 3 and Product 2), according to the three main target markets addressed. To implement its products lines, *J* is keen to improve the research and development (hereafter: R&D) side of the business, but as a small firm it does not have all the laboratory facilities inside the company. So, to enhance its R&D, *J,* "*collaborates with universities or research institutes;*" said the manager interviewed at *J.*
Since the start, *J's* development strategy has been structured in a twofold way. It simultaneously develops "*the products on the one side, and the research (through funded projects) on the other side*," said the manager interviewed. In other words, it seems that the firm pursues two linked strategies. On the one hand, *J* implements its research activities by participating in funded research projects, which are targeted according to the firm's R&D needs. On the other hand, the innovations that emerge from the research activities are integrated and commercialised within the firm's product lines, and this allows the latter to grow.

4.11.2 Case J business model innovation history

Background

J was founded in 2001 by a group of scientists and engineers. It is a food innovation based firm operating in the gastronomy sector, specifically active in the food texturising market. To build *J*'s expertise, there are employees that cover roles like: food technologists, engineers, food manufacturers and food marketing experts.

Business Model Development

J implemented their business model several times during its history. However, the basic structure has remained the same, with additions inserted over time. A list of the changes is summarised below in table 18.

BM 1: Food material provider model

BM 1a: Even though *J* was established in 2001, the first product line named Product 1, was launched on the market in 2006. The Product 1 product line is subtitled by *J* as a "*professional food texturiser*

for the molecular gastronomy [market].” The target customers are mainly professional kitchen users. The firm developed Product 1 line and commercialises it through different sales channels. Hence, *J* commercialises Product 1 line not only by selling the texturing products, but also by selling accessory products and/or services in molecular gastronomy. Overall, the product line along with its accessories is sold through the firm’s online shop as well as through its sales partners around the world.

BM 1b: About three years later (2009), *J* developed another product line called Product 2. This product line was launched in a specific geographical market in 2013.
The idea for Product 2 line was born by observing the growing market demand for personalised food. According to the manager interviewed, *J* developed Product 2 as their “*product line which focuses on personalisation.*” It is tailored for end users devoted to specific nutrition dietary habits. Product 2 is a product line that allows each user to create his/her personalised drinks and gels. According to the person’s specific level of physical activity, intolerances and taste. The value of this product line is also enhanced through the support of four main partners. Product 2 products are sold only through the company’s e-commerce channel.

BM1c: The latest product line developed by *J* was launched shortly after the creation of Product 2 (2011). At that time, *J* was considering expanding its product lines. The firm was exploring alternative ways to apply texturisers in different target markets. The idea of a new product line came up when *J* observed that especially frail people with eating difficulties, living in specialised facilities, were all given the same food mash. “*If you imagine having that kind of food every day, it’s not really appealing* [..] *and* [..] *problems like malnutrition are very common among those people,*” said the manager interviewed. Within this context, the firm, jointly with professional chefs, came up with a conceptual idea to provide “*appealing and tasty food to people who* [have food eating difficulties],” continued the manager interviewed. To commercialise this conceptual idea, *J* launched a new additional product line, Product 3. It combines the texturising elements that characterise the Product 1 line with the individual degree of eating difficulty. As well as the Product 1 line, the Product 3 line is also supported by accessory business models such as consultancy services. Like the Product 1 line, this second line of products is sold through *J*’s e-commerce channel as well as by third party sales partners.

BM2: Consultancy model

J offers workshops linked to two of *J* ’s product lines: Product 1 and Product 3.

BM2a: The workshop model linked to the Product 1 line aims to create value by teaching “*the techniques of molecular cooking in a practical environment*” mainly to professional kitchen users. The workshop can be booked on *J* ’s website.

BM2b: The workshop related to the Product 3 underpinning concept, is held by a chef (one of the Product 3's underpinning concept ideators). The chef teaches, mostly to food issues related health specialists, "*how it is possible to make puree and strained food for persons with* [food eating] *difficulties in such a way that it also looks appealing.*" As well as the workshops linked to the Product 1 line, the Product 3 workshops can also be booked via *J 's* e-commerce channel.

BM 3: Research model

BM3a: It was about 2012 when *J* noticed a growing demand for the Product 3 products by small, specialised facilities for frail people, that were directly preparing the meals for their guests. However, *J* observed that the Product 3 underpinning concept is not easy to use in specialised facilities that are served by centralised kitchens.

In 3D printing technology *J* found, the most suitable technology that would enable the development of a customised industrial production process. To further explore and exploit this idea, *J,* jointly with other partners, developed a research project (i.e. PROJECT 1). The overall aim of the project was the development of a 3DFP system for the production of mass customised meals for individuals suffering from eating difficulties. PROJECT 1, won institutional funds. Each partner gained a fixed amount of the overall budget to develop specific parts of the project. The project started in 2012 and ended in 2015. By using 3D printing technologies, the project team proved that is possible to industrialise and personalise food for frail people with eating difficulties. There is a need to optimise the outcomes of the project in terms of costs and printing speed before the 3DFP system can go to the market. To do so, *J*, as a small firm, needs further research funds. So, when PROJECT 1 came to an end, the firm started considering other research funding possibilities.

BM3b: Thanks to the network of relations built among the ecosystems of actors operating in the 3D food printing area, once PROJECT 1 was coming to an end *J* came across to another call for research proposals, again enhanced by an institutional funding body. So, *J*, jointly with other partners, wrote the project proposal and won the institutional funding for the so-called PROJECT 2. The overall aim of this project was to investigate 3DP technologies as a sustainable food production process. In PROJECT 2, *J*, jointly with another project, had the role of selecting specific food materials (e.g. ingredients, texturising systems) to build personalised food structures. The project lasted for two years (2014 – 2016). Similarly to the previous project, each partner had specific tasks and was funded for a fixed percentage of the whole project fund.

Figure 16 shows *J*'s business model evolution and the related triggers of change. The Y-axis depicts the market segments targeted by the firm, while the X-axis represents the time line. Figure 16 also

shows the three main business model typologies adopted by *J* (i.e. food material provider – consultancy – research).

J's business model evolution is primarily focused on the exploitations of the firm's product lines. Hence, both the consultancy, as well as the research model, serve as support of the core business (i.e. the product manufacturer).

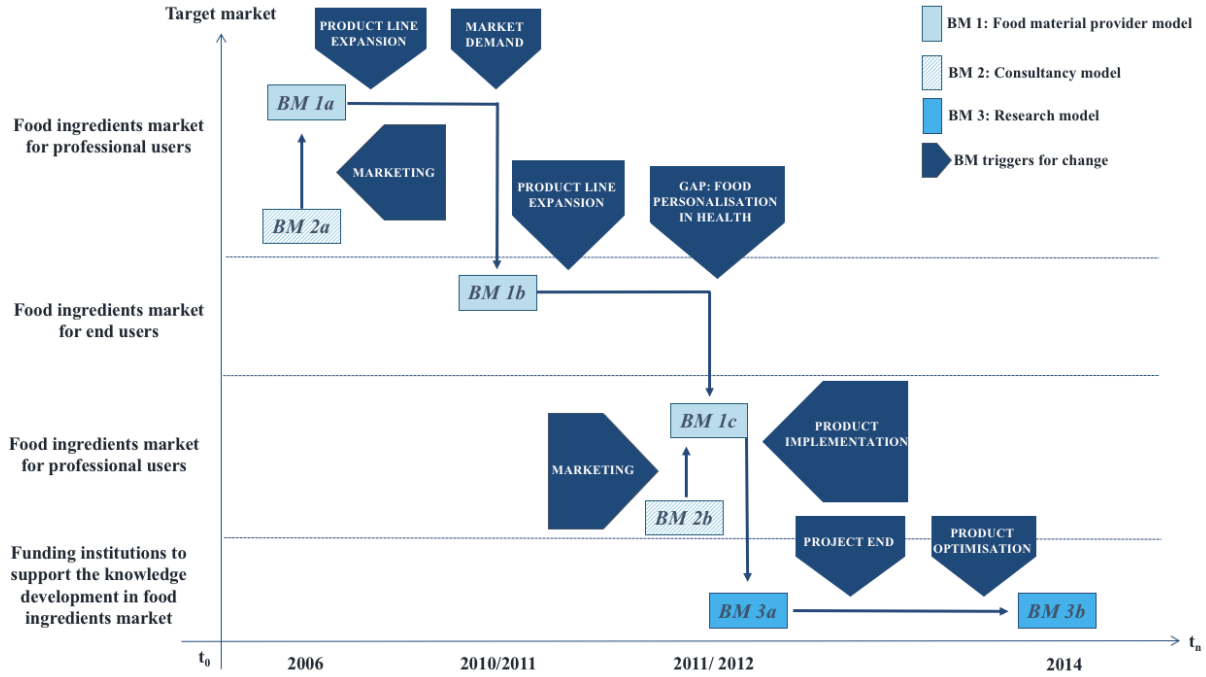


Figure 16 J's sequence of business models and change triggers

FOOD MATERIAL PROVIDER MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	***Customer segment***	***Value created for customers***	***Communication Channels***	***Sales Channels***	***Customer relationship***	***Key resources/activities***	***Supplier/partner structure***	***Revenue stream***	***Cost structure***
BM 1a	Product 1: Food ingredients (texturising)	Professional kitchen users	Newness Easier accessibility to the product Convenience/Usability of the products	Word of mouth Website Workshop Research Network	Direct web sales and indirect partner sales	Self service	Material provider (*controlled*) Knowledge provider *(controlled)*	Hierarchical	Product sale	Equipment Human resources Time Facilities (e.g. office & laboratory) Raw materials (ingredients)
BM 1b	Product 2: Food ingredients (texturising)	**specific nutrition dietary habits**	Newness Easier accessibility to the product Convenience/Usability of the products **Personalisation**	Word of mouth Website Workshop Research Network	**Direct web sales**	Self service	Material provider (*controlled*) Knowledge provider *(controlled)*	Hierarchical	Product sale	Equipment Human resources Time Facilities (e.g. office & laboratory) Raw materials (ingredients)
BM 1c	Product 3: food ingredients (texturising)	**Professional in health**	Newness Easier accessibility to the product Convenience/Usability of the products Personalisation	Word of mouth Website Workshop Research Network	Direct web sales and **indirect partner sales**	Self service	Material provider (*controlled*) Knowledge provider ***(not controlled)***	Hierarchical **Networked**	Product sales	Equipment Human resources Time Facilities (e.g. office & laboratory) Raw materials (ingredients)

Table 18 The business model history at J (continue)
Changed BM building blocks from previous version are highlighted in bold

CONSULTANCY MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	***Customer segment***	***Value created for customers***	***Communication Channels***	***Sales Channels***	***Customer relationship***	***Key resources/activities***	***Supplier/partner structure***	***Revenue stream***	***Cost structure***
BM 2a	Training & Consulting on food preparation techniques	Professional kitchen users or private end users	Simplify the products applications for customers. Convenience/Usability of the knowledge	Word of mouth Website Network	Direct web sales	Dedicated Personal assistance	Knowledge provider *(controlled)*	Hierarchical	Pay per time	Time Equipment Materials
BM 2b	Training & Consulting on food preparation techniques	**Health food related professionals**	Simplify the products applications for customers. Convenience/Usability of the knowledge	Word of mouth Website Network	Direct web sales	Dedicated Personal assistance	Knowledge provider *(controlled)*	Hierarchical	Pay per time	Time Equipment Materials

RESEARCH MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	***Customer segment***	***Value created for customers***	***Communication Channels***	***Sales Channels***	***Customer relationship***	***Key resources/activities***	***Supplier/partner structure***	***Revenue stream***	***Cost structure***
BM 3a	Develop knowledge on 3DFP to develop a system to produce mass-customised meals for people with eating difficulties *(partner dependency)*	Funding institution	Newness	Media Word of mouth Network Project website Project reports	Direct sales of the research proposal to the funding institution	Personal assistance (periodical reports to the funding institution)	Design provider *(not controlled)* Material provider *(not controlled)* Process technology provider *(not controlled)* Knowledge provider *(not controlled)*	Networked	Fixed percentage of the overall funding of the project *(revenue shared)*	Equipment Human resources Time Facilities (e.g. laboratory) R&D development Marketing Project activities
BM 3b	Develop knowledge to be commercialise **(3DP system ingredients/printers/designs)** *(partner dependency)*	Funding institution	Newness	Media Word of mouth Network Project reports	Direct sales of the research proposal to the funding institution	Personal assistance (periodical reports to the funding institution)	Design provider *(not controlled)* Material provider *(not controlled)* Process technology provider *(not controlled)* Knowledge provider *(not controlled)*	Networked	Fixed percentage of the overall funding of the project *(revenue shared)*	Human resources Time Facilities (e.g. laboratory) R&D development

Table 18 continuation

4.12 Case K

4.12.1 Case K technology commercialisation

K is a service-based firm that provides consulting, food services, research and training on 3D food printing mainly to professional users. The firm runs a website in which news and open source digital cooking techniques for the 3D food printing ecosystem are reported. According to one of the founders, the main aim of *K* is to "*help* [the 3D food printing ecosystem to] *grow by sharing it.* [We want to help] *others get involved and understand it better.*" *K* opted for an exploratory commercialisation strategy to get into the market. Hence, the firm is using both its website, as well as its consultancy activity, to identify new business avenues to share 3D food printing in society.

4.12.2 Case K business model innovation history

Background

K was founded as a result of the failure of the business activity of the company one of the partners was previously working at. This company unfortunately had to close due to the absence of a structured business model.

Business Model Development

The variation of *K*'s business model archetypes is shown in table 19.

BM 1: Consultancy model

BM 1a: K started with the website around the end of 2013, created by one of the two partners of the firm. Initially, the firm started as a one-person part-time activity guided by his/her passion for 3DFP. *K* had (and still has) the main aim "*to merge food with technology to create new food experiences.*" To pursue this aim, *K*'s founder started interviewing other actors involved in 3D food printing and sharing his/hers experience. Through one of his/hers interviews, the founder met the person who would later become the second partner of the firm. Up to then, this activity was undertaken on a part-time basis by both founders. Value was captured by offering consultancy as well as presentation services and revenues were gained per the time invested in the activity. This was, however, not yet sufficiently financially auto-sustainable. So, they started thinking of possible ways to scale up their monetisation model. In mid 2015, the founders noticed a gap in the understanding of the 3D food printing environment. They observed that while there was growing traction of the 3D food printing topics, there

was still little knowledge about the topic among people in general. So, in line with the aim of *K*, the two partners started to think about 3D food printing and education. They came up with the idea of developing a workshop. To develop the latter idea, the two partners started asking feedback from people within the 3D food printing community, either through direct emails or through a web survey. They asked people what they would have liked to have within the workshop offer.

BM 1b: In 2016, *K*'s partners within the consultancy activity of the firm started developing a workshop format. The workshop offers sessions spanning from a theoretical introduction to 3D food printing to applied 3D food printing techniques. A 3D food printing tool designer came to help *K*'s founders with the workshops. *K* monetises the workshop activity by gaining revenues for each workshop ticket sold. According to one of the firm's partners the workshops "*are a really important step forward* [..] *to find new ways and resources."* More specifically, according to another firm partner, starting to do workshops will help them "*to implant ourselves as experts in the field so that others can come to us, and get their questions answered*."

Figure 17 visualises *K*'s BM evolutions and the related triggers of change. The Y-axis shows the target market, while the X-axis depicts the time line. Figure 17 shows a linear business model innovation strategy adopted by *K*. Hence, the firm exploits a consultancy business model within the 3D food printing environment.

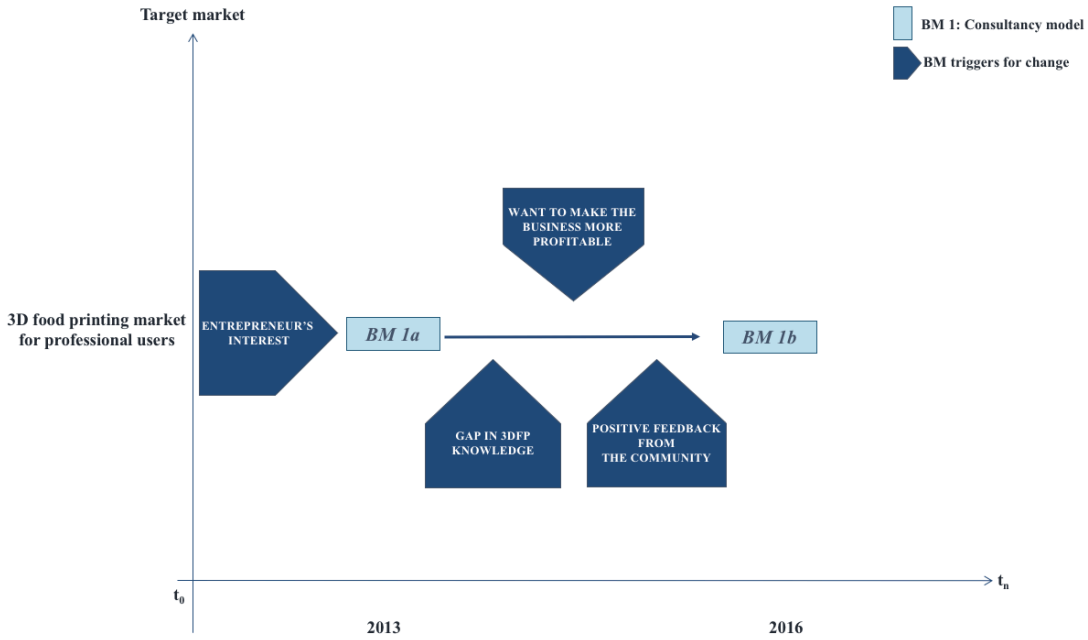


Figure 17 K 's sequence of business models and change triggers

CONSULTANCY MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	***Customer segment***	***Value created for customers***	***Communication Channels***	***Sales Channels***	***Customer relationship***	***Key resources/ activities***	***Supplier/partner structure***	***Revenue stream***	***Cost structure***
BM 1a	Knowledge sharing / Consulting on 3DFP technology-based knowledge	3DFP users	Customisation Accessibility	Attend events Public talks Website 3DFP interviews Email Survey	Direct sales force	Dedicated Personal assistance	Knowledge provider (*controlled*)	Hierarchical	Pay per time	Time Equipment
BM 1b	Knowledge sharing / **Training &** Consulting on 3DFP technology-based knowledge	3DFP users	Customisation Accessibility	Attend events Public talks Website 3DFP interviews	Direct sales force	Dedicated Personal assistance	Knowledge provider (*controlled*)	Hierarchical	Pay per time	Time Equipment

Table 19 The business model history at K
Changed BM building blocks from previous version are highlighted in bold

4.13 Case L

4.13.1 Case L technology commercialisation

L offers a temporary restaurant for end customers. The long-term vision of *L* is to spread the 3DFP concept by establishing 3DFP-based theme restaurants around the world. The restaurants would also serve as a marketing platform, making it possible to sell 3DP-related products to end customers. Since opening a restaurant is a very expensive and risky investment, *L* decided to start by organising dinners around the world, to validate the concept, refine and improve the format, and to promote the brand. After demonstrating the global proof of concept, they hope to have attracted sufficient interest from investors, as well as franchise partners in various cities, in order to open multiple permanent-venue restaurants.

L opted for a collaborative technology commercialisation strategy to get into the market. Hence, the firm built a new business model by gathering the knowledge of experts in different fields (e.g. technology, gastronomy, nutrition, furniture design, interactive multimedia) into one organisation to commercialise the 3DFP technology, and therefore, exploit its business activity. The firm does not focus directly on the 3DFP niche, but on the gourmet food market. This is still a niche, but it is broader than the 3DFP community.

4.13.2 Case L Business model innovation history

Background

L was founded as a result of the vision of one of the partners. The business idea, which is to realise a 3DFP restaurant, came as the result of more than two years of thorough research into 3D food printing (early 2014), and was carried on by the firm's ideator. The business began to take formal shape in early 2016.

Business Model Development

The variation of *L*'s business model archetypes is shown in table 20.

BM 1: Restaurant model

BM 1a: The first practical development of *L* started when the ideator met the 3D printing food specialist (i.e. future partner) "*we realised that* [we] *shared a vision for doing a 3D printing* [..] *restaurant, but what we also had in common was a bit of a frustration with what we saw was the problem with* [some] *3D printing companies*. [Hence, only] *few of these companies really marketed themselves properly*,"

said the firm's ideator. So, *L* has the aim to overcome this gap by spreading the 3DFP concept in the fine food market, and by organising high-end 3DFP-based temporary restaurants in one specific geographic location. In early 2016, both *L*'s founders started working on the formalisation of the firm. They run all aspects of the business such as the creation and design of the dishes on the menu. Initially, they thought about working closely with only one 3DFP manufacturer in an arrangement which would benefit both firms; where the 3DF printer manufacturer provides the 3D food printers for the temporary restaurant in exchange for both marketing exposure and testing feedback. The firm initially bootstrapped its start-up development. Before further structuring the business, the co-founders decided to test the business idea with a first exploratory dinner. Through the exploratory event, the firm gathered feedback in order to target their customers' needs more closely. The exploratory event went very well. This was the signal for the firm to move forward.

BM 1b: *L* improved its business model by deciding to organise a world tour of the temporary 3DF printed dinners rather than stay in a single location. The idea to set up the temporary restaurant around the world would make the identification the of the most suitable geographical target market easier. They are planning to organise exclusive weekly temporary restaurants in several different cities between late 2016 and early 2017. Another slight adjustment in the BM made by *L* was the decision to collaborate with multiple 3DF printer providers, according to the unique advantages of various printer models. Furthermore, *L* slightly changed its market positioning. While the first event was targeted at medium-high end customers, the firm decided to change the target to very high-end customers. *L* started to collaborate more closely with top chefs who specialised in 3D food printing, a 3DP furniture producer, a 3DP utensils producer, and with a 3DP cups and plates creator. All these actors join forces to spread the firm's concept (usually for free) in exchange for gathering marketing exposure.
At this stage, *L* is still bootstrapping its development and gain revenues through the sales of the dinner tickets.

Figure 18 illustrates *L*'s BM evolutions and the related triggers of change. The Y-axis shows the target market, while the X-axis represents the time line. Figure 18 shows a linear business model innovation strategy adopted by *L*, whereby the firm exploits a restaurant-based business model within the fine food market.

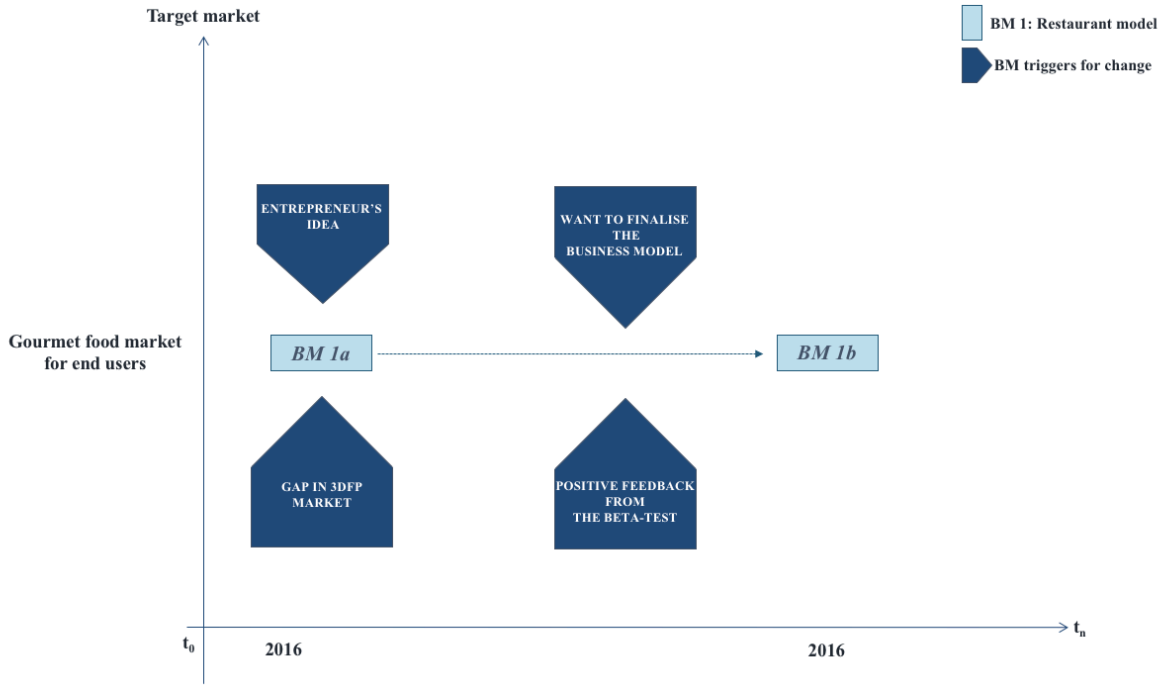


Figure 18 L 's sequence of business models and change triggers

RESTAURANT MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	***Customer segment***	***Value created for customers***	***Communication Channels***	***Sales Channels***	***Customer relationship***	***Key resource/activities***	**Supplier/partner structure**	***Revenue stream***	***Cost structure***
BM 1a	3DFP dinners in a fixed location *(partner dependency)*	End customers	Newness	Public talks 3DFP specialised web news Partner & collaborator network	Indirect web sales	Personal assistance	Design provider (*controlled*) Material provider (*controlled*) Process technology provider (not *controlled*) Digital ICT provider (not *controlled*) Knowledge provider (*not controlled*)	Hierarchical food supplier Networked with partner	Bootstrapping Pay per meal	Time travel & sustenance food shopping legal advisory
BM 1b	3DFP dinners **around the world & 3DP platform in several industries (food, furnishing and soft furnishing, 3DP appliances)** *(partner dependency)*	End customers (fine food market)	Newness **Brand/status**	**Attend events and fairs** **Public talks** **Website** **Social media** **Pop-up events** **General news** Partners & collaborators network 3DFP web specialised news	**Direct** web sales	Personal assistance	Design provider (*not controlled*) Material provider (*controlled*) Process technology provider (not *controlled*) Digital ICT provider (not *controlled*) Knowledge provider *(not controlled)*	Hierarchical food supplier Networked with partner	Bootstrapping Pay per meal	Time **event location rent** food shopping **marketing**

Table 20 The business model history at L
Changed BM building blocks from previous version are highlighted in bold

4.14 Case M

4.14.1 Case M technology commercialisation

M is a start-up, which is focused on producing and commercialising a 3D food printing system. It is a 3D food printing system for professional kitchen users (e.g. gastronomy, catering, confectionery and baking). The system offered by *M* comprises a 3D food printer, a food refill system (i.e. food capsules) and a user interface. The next step *M* is working on is to implement its system to make food items more personalisable. Besides the business to business target (i.e. professional kitchen users), the firm will also start focusing on the end users (business to consumer target).

4.14.2 Case M business model innovation history

Background

M was founded in 2014, as a spin-off of a University. Hence, the founders of the firm are food technologists and food experts (both from academia as well as from industry) with "*a lot of experience in texturising food. And when the first assembly kits, for 3D food printers came, of course we wanted to* [explore the possibilities offered by] *these exciting topics together." M's* founders actually started to run tests to 3D print food from the end of 2012.

Business Model Development

The variation of *M's* business model archetypes is shown in table 21.

BM 1: 3D food printer manufacturing model

BM 1a: *M* was founded in mid-2014, with the aim of overcoming a gap noticed among 3D food printing appliances. Hence, the firm's founders noticed that it was missing "*a universal system,* [..] *that is universal for different printers, and universal for different foods*." As a result, M decided to build a universal 3D printing head. Along with the 3D printer, the firm also prototyped a system of pre-confectioned food refill capsules (customers could buy these along with the printer as well as separately) and a user interface system. Contextually, *M* also prototyped a platform with the aim of connecting professional kitchen users and the firm. *M* tested its 3DFP prototype system and once it was ready, the firm decided to test it on the market by launching a crowdfunding campaign in order to start production. *M* overreached that goal. "*And that was for us a signal to start, we saw the community is ready, if we go on and further optimise our system."*

BM 1b: The successful conclusion of the crowdfunding campaign gave to *M* the impetus to move forward with the development of their 3D food printing system. The "*next important step for us was to scale up.*" So, *M* searched and found the right hardware manufacturer to partner with to implement their 3DFP system. Together with the manufacturer, they implemented the 3D printer system (i.e. more integrated 3DFP printer, more sustainable food refill capsules, more intuitive user interface). Along with the internal development, *M* is also very interested in getting feedback from its customers in order to implement and tailor their offer to the customers' needs. Once the 3DFP system's implementations were ready (about mid-2016) the firm started to ship the pre-ordered printers from the crowdfunding campaign. By late 2016, *M* had completed its first round of production and all the 3DFP printers that had been ordered were shipped.

BM1c: Nowadays, the 3DFP printer, as well as the 3DFP refill system can be ordered directly on *M*'s website (the printer is ordered in advance, it is then produced and shipped). The firm has set up the logistic system for delivering in a number countries, but it is also possible to have the printer delivered in other countries upon request. The firm monetised through the sales of each 3DF printer, as well as the sales of the food refills (i.e. food capsules). The firm is moving toward the food personalisation, as *M* noticed that there is a growing demand for "*personalized food items due to the allergies and due to special nutritional demands of people. And 3D food printing can give an answer to this*." *M* started implementing its 3DFP platform, to do so the firm is integrating the platform with recipes, demonstration videos, manuals and possible 3DFP business applications.

BM 2: Food service model

Along with the linked manufacturing-service model (BM1c), M started a subsidiary business model in 2015 that supports, from a marketing perspective, the core business (BM1). This business model (BM2) has two main offers (BM2a and BM2b), as well as one linked offer (BM2 a + b).

BM 2a: *M* offers to perform live 3D food printing demonstrations at conferences, trade fairs and product presentations. The firm offers to customers a service package composed of: 1) the 3D food printing system 2) and the firm's team. All the objects printed can be used by the customer as giveaways. The firm captures value per the time invested in the activity.

BM2b: This business model is manufacturing-service oriented. Hence, here *M* offers its clients an opportunity to produce a stock of customised giveaways (i.e. food artworks tailored for the specific event). In this case, the firm prints the giveaways for the specific event in advance. The firm captures value from the 3D food printed products sold.

BM2a + BM2b: The services offered (i.e. BM2a and BM2b) independently can also be combined in a unique offer. Here, in advance of a specific event, the giveaways are 3D food printed and, on the day of the event, the firm will be at the event with its 3DFP printer to show live how it is possible to 3D print food. The firm captures value both from the time invested in the activity and the 3D food printed giveaways realised.

Figure 19 illustrates *M*'s BM evolutions and the related triggers of change. The market target can be observed on the Y-axis it is possible to observe, while the X-axis represents the time line. Figure 19 also shows the twofold BM innovation strategy adopted by *M*. On the one hand, it shows the BM evolution for the exploitation of the 3D food printing system. On the other hand, it shows the BM evolution adding a subsidiary business model archetype (BM2) to support and enhance the implementation of the core business (BM1c).

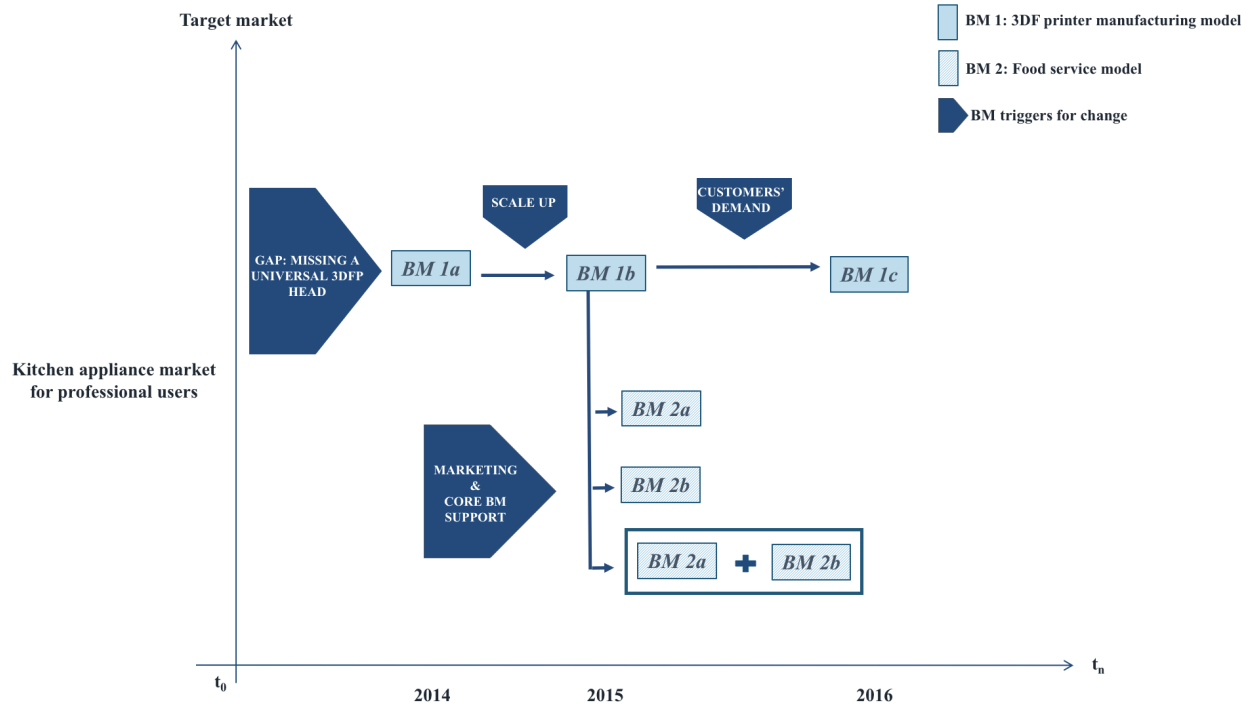


Figure 19 M 's sequence of business models and change triggers

3D FOOD PRINTER MANUFACTURING MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	***Customer segment***	***Value created for customers***	***Communication Channels***	***Sales Channels***	***Customer relationship***	***Key resources/activities***	***Supplier/partner structure***	***Revenue stream***	***Cost structure***
BM 1a	3DFP system to develop new food shapes	Professional kitchen users	Newness Easier accessibility to the technology Convenience/usability	Attend events Public talks Website Social Media News/Press	-	-	Design provider (*controlled*) Material provider (*controlled*) Process technology provider (*controlled*) Digital ICT provider (*controlled*) Knowledge provider (*controlled*)	Hierarchical	University support (spinoff) Bootstrapping	Supplier (manufacturer) Office infrastructure Raw material Food ingredients Human resources
BM 1b	3DFP system to develop new food shapes	Professional kitchen users	Newness Easier accessibility to the technology Convenience/usability	Attend events Public talks Website Social Media News/Press **Web Platform**	Partner store (crowdfunding platform) *(co-creation)*	Self-service	Design provider (*controlled*) Material provider (*controlled*) Process technology provider (*controlled*) Digital ICT provider (*controlled*) Knowledge provider (*controlled*)	Hierarchical	**Crowdfunding**	Suppliers Office infrastructure Raw material Food ingredients **Marketing** **Logistics** Human resources
BM 1c	3DFP system to develop new food shapes	Professional kitchen users	Newness Easier accessibility to the technology Convenience/usability	Attend events Public talks Website Social Media News/Press Web Platform	**Own e-commerce**	Self-service / **Personal assistance**	Design provider (*controlled*) Material provider (*controlled*) Process technology provider (*controlled*) Digital ICT provider (*controlled*) Knowledge provider (*controlled*)	Hierarchical	**Assets (3DFP, food refills) sales**	Suppliers Office infrastructure Raw material Food ingredients Marketing Logistics Human resources

Table 21 The business model history at M (continue)
Changed BM building blocks from previous version are highlighted in bold

FOOD SERVICE MODEL										
	VALUE PROPOSITION			VALUE DELIVERY			VALUE CREATION		VALUE CAPTURE	
	Offering	***Customer segment***	***Value created for customers***	***Communication Channels***	***Sales Channels***	***Customer relationship***	***Key resources/activities***	***Supplier/partner structure***	***Revenue stream***	***Cost structure***
BM 2a	Live 3D food printing demonstration at events	Professional users	Customisation Newness	Attend events Public talks Website Social Media News/Press Web Platform	Direct sales force	Dedicated Personal assistance	Knowledge *(controlled)*	Hierarchical	Pay per time	Human resources Time Food refill capsules
BM 2b	**Production of 3D food printed customized giveaway for specific events**	Professional users	Customisation Newness	Attend events Public talks Website Social Media News/Press Web Platform	Direct sales force	Personal assistance	**Design provider *(controlled)*** **Material provider *(controlled)*** **Process technology provider *(controlled)*** Knowledge *(controlled)*	Hierarchical	Pay per time	Time **Food ingredient**
BM 2a+b	Live 3DFP demonstration + customized giveaway for an event	Professional users	Customisation Newness	Attend events Public talks Website Social Media News/Press Web Platform	Direct sales force	**Dedicated Personal assistance**	Design provider *(controlled)* Material provider *(controlled)* Process technology provider *(controlled)* *Knowledge provider (controlled)*	Hierarchical	Pay per time	**Human resources** Time Food ingredients **Food refill capsules**

Table 21 continuation

4.15 Summary of case studies

This chapter provided information on the business model development history of the cases under study with a technology commercialisation approach. First, a general overview on the way the cases were presented and structured was given. The case studies were then discussed in depth.

The following chapter details the findings of the study through a cross-case study analysis. In a subsequent chapter, a discussion merging the findings with the literature will be presented. As such, this work aims to implement the theoretical framework and contribute to the knowledge-base both from an academic and practitioner perspective.

Chapter 5 Findings

5.1 Chapter introduction

In the previous chapter, each case was analysed individually in terms of its technology commercialisation and BMI. In this chapter the data that have emerged from the vertical analysis of the cases have been summarised in order to highlight the common patterns, and therefore, answer the gaps detected in the literature (chapter two).

The chapter is outlined according to the two expanded aims of the research: 1) to gain an understanding of what types of BMs emerge when firms commercialise an emerging technology in an established industry, and 2) to gain an understanding of what the BMI dynamics are under the abovementioned circumstances. The chapter follows the structure outlined in the data analysis part of the methodology chapter (see section 3.4.5).

The presentation of the cross analysis is split into four sections according to the objectives highlighted in chapter three (see section 3.2.1).

5.2 Expanded aim I: What types of BMs emerge when firms commercialise a new technology in an established industry?

Table 22 gives a general overview of the variables used to understand what types of BMs emerge when firms commercialise an emerging technology in an established industry. The analysis is carried out following the two main objectives of this part of the research (i.e. identify the links between strategic choices and specific business model solutions within the collaboration frame; identify the business model archetypes and their revolutionary potential within the collaboration frame).

To facilitate the reader, the BM tags that where defined in chapter 4, and which are corresponding to the short-term or to the long-term BMs are indicated in the various tables developed. In the case of missing long term BM tags, the code ‘technology commercialisation strategy’ (sometimes abbreviated as TCS) has been used in the tables.

Sample	Technology commercialisaiton stage	Activity	BM name short term	BM name long term	BM tag short term	BM tag long term	Market strategy short term	Market strategy long term	Uncertainity short term	Uncertainity long term	Decision logic short term	Decision logic long term	Value proposition short term	Value proposition long term	VP short term	VP long term	VD short term	VD long term	VCr short term	VCr long term	VCa short term	VCa long term	BM short term	BM long term	Why use this BM? Short term	Why use this BM? Short term
A	Deployment	Service	Consultancy model	Distribution model	2b	1c	Diversification	Diversification	Range of futures	Clear enough future	Effectual	Causal	3DP knowledge	3DP appliance and parts	Open - closed	Closed	Open - closed	Closed	Open - closed	Closed	Open - closed	Closed	5+6 - 2	3	Explore and identify viable markets/VP	Distribute 3DP equipment and parts
B	Development	Service	Research model	Research model	1d	Technology commercialisation strategy	Niche	Niche	Alternative futures	Alternative futures	Causal	Causal	3DP knowledge	3DP knowledge	Open	Open	Closed	Open	Open	Open	Open	Open	5+6	5+6	Develop knowledge to be commercialsed in disembodied form	Sell the knowledge in disembodied form
C	Development	Product+ Service	3D printed food manufacturing model	3D printed food manufacturing model	2a	2b	Niche	Niche	Clear enough future	Clear enough future	Causal	Causal	3DP Food	3DP food	Closed	Closed	Closed	Open	Closed	Open	Closed	Closed	3	6	Develop the 3DP system	Selling the food customised according to the end customers designs
D	Deployment	Product	3D food printer manufacturing model	3D food printer manufacturing model	1b	1c	Niche	Niche	Clear enough future	Clear enough future	Causal	Causal	3DP appliance	3DP appliance	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	3	3	Sell 3DP appliance to professional kitchen users who develop and provide recipes via platform	Sell 3DP appliance to professional and home kitchen users who develop and provide recipes via platform
E	Deployment	Product	3D food printer manufacturing model	3D food printer manufacturing model	2a	Technology commercialisation strategy	Niche	Niche	Clear enough future	Clear enough future	Causal	Causal	3DP appliance	3DP appliance	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	3	3	Sell 3DP appliance to home kitchen users who develop and provide recipes via platform	Sell 3DP appliance to home kitchen users who develop and provide recipes via platform
F	Deployment	Product+ Service	3D printed food manufacturing model	3D printed food manufacturing model	1b	1d	Niche	Niche	Clear enough future	Clear enough future	Causal	Causal	3DP system ingredients/printers/designs	3DP system ingredients/printers/designs	Closed	Closed	Open	Open	Open	Open	Closed	Closed	6	6	Selling food customised according to the end customers designs through franchised shops	Sell 3DP confectionaries through franchised shops and e-commerce and own store
G	Development	Service	Research model	N/A	1b	Technology commercialisation strategy	Niche	Niche	Alternative futures	True ambiguity	Causal	Causal	3DP knowledge	3DP appliance	Open	N/A	Closed	N/A	Open	N/A	Open	N/A	5+6	N/A	Develop knowledge to be commercialsed	N/A
H	Deployment	Product	3D food printer manufacturing model	3D food printer manufacturing model	2b	Technology commercialisation strategy	Diversification	Niche	Range of futures	Range of futures	Effectual	Effectual	3DP software	3DP system software/printers/designs	Closed	N/A	Open	N/A	Open	N/A	Closed	N/A	5	N/A	Explore and identify viable markets/VP	Sell 3DP goods through franchised shops
I	Deployment	Product+ Service	3D printed food manufacturing model	3D printed food manufacturing model	1c	Technology commercialisation strategy	Niche	Niche	Range of futures	Clear enough future	Effectual	Causal	3DP food	3DP food	Closed	Closed	Open	Closed	Open	Closed	Closed	Closed	6	3	Selling food customised according to the end customers designs	Selling food pre-defined food according to pre-defined desings
J	Development	Service	Research model	N/A	3b	Technology commercialisation strategy	Niche	N/A	Range of futures	True ambiguity	Effectual	N/A	3DP knowledge	3DP system ingredients/printers/designs	Open	N/A	Closed	N/A	Open	N/A	Open	N/A	5+6	N/A	Develop knowledge to be commercialise (3DP system ingredients/printers/designs)	N/A
K	Deployment	Service	Consultancy model	N/A	1b	Technology commercialisation strategy	Niche	N/A	Range of futures	True ambiguity	Effectual	N/A	3DP knowledge	N/A	Closed	N/A	Closed	N/A	Closed	N/A	Closed	N/A	2	N/A	Explore and identify viable markets/VP	N/A
L	Deployment	Assembler	Restaurant model	Restaurant model	1b	Technology commercialisation strategy	Niche	Niche	Clear enough future	Clear enough future	Causal	Causal	3DP service/food/distribution	3DP service/food/distribution	Open	Open	Closed	Closed	Open	Open	Closed	N/A	5+6	5+6	Selling 3D printing pop-up dinner experience to end customers and providing a platform for 3DP suppliers	Selling 3D printing dinner experience to end customers and providing a platform for 3DP suppliers in franchised restaurants
M	Deployment	Product	3D food printer manufacturing model	3D food printer manufacturing model	1c	Technology commercialisation strategy	Niche	Niche	Clear enough future	Clear enough future	Causal	Causal	3DP appliance	3DP appliance	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	3	3	Sell 3DP appliance to professional kitchen users who develop and provide recipes via platform	Sell 3DP appliance to professional and home kitchen users who develop and provide recipes via platform

Table 22 Use of open business models in achieving the commercialisation strategies of emerging technology-based organisations in an established industry

5.2.1 Objective Ia: Identify the links between strategic choices and specific business model solutions within the collaboration frame

Table 23 synthetises the main findings that emerged from table 22, related to the strategies adopted by the organisations to commercialise their products and/or services. In order to link strategic choices to specific BM solutions and understand the role of collaborations, the cases were observed according to 1) the possible customer segmentation strategies highlighted by Osterwalder and Pigneur (2010); 2) the attitudes toward uncertainty (Courtney, et al., 1997) adopted by the organisations (highlighted in the third column); and 3) the decision logic adopted by the sample of organisations (Sarasvathy, 2001). The analysis was carried out by detailing the strategies adopted by the organisations both from the short and long-term perspectives.

Sample	**Value proposition** **Short term and long term (BM tag in brackets)**	**Commercialisation strategies** **Short term and long term (target market in brackets)**	**BM attitude toward uncertainty (clear enough future – alternate futures - range of futures - ambiguity)**	**BM logic for commercialisation (causation vs effectuation)**
A	*3DP Knowledge (2b)* *3DP Appliances and parts (1c)*	*Short-term strategy*: <u>Diversification</u> Consulting on 3DFP (tech and market opportunities). Through these, identify further strategic goals. **(Education and food industry professional users).** *Long-term strategy*: <u>Diversification</u> Distribution of 3DP equipment in education, food and other industries**. (Food, education and other industries, professional and end users).** The BM for the possible other industries, is not yet defined.	Range of futures Clear enough future	Effectuation Causation
B	*3DP Knowledge (1d)* *3DP Knowledge* *3DP IP on equipment (TCS)*	*Short-term strategy*: <u>Niche</u> Research on 3DFP for food personalisation. **(Funding institutions to support the knowledge development).**	Alternative futures Alternative futures	Causation Causation

		Long-term strategy: Niche Consulting and licencing for the diffusion of a universal 3D printer for food personalisation. **(Food processing market for organisations)**.		
C	*3DP Food (2a)* *3DP Food (2b)*	*Short-term strategy*: Niche. 3DFP customised confectionery. **(Funding institutions to support the business development).** *Long-term strategy*: Niche. 3D customisable confectioneries through e-commerce. **(Confectionery market for end users).**	Clear enough future Clear enough future	Causation Causation
D	*3DP Appliances (1b)* *3DP Appliances (1c)*	*Short-term strategy*: Niche. Commercialisation of the 3DFP appliance. **(Kitchen appliance market for professional users).** *Long-term strategy:* Niche Commercialisation of the 3DFP appliance. **(Kitchen appliance market for end users)**.	Clear enough future Clear enough future	Causation Causation
E	*3DP Appliances (2a)* *3DP Appliances(TCS)*	*Short-term strategy:* Niche Commercialisation of the 3DFP appliance in a selected geographic area. **(Kitchen appliance market for end users).** *Long-term strategy*: Niche Commercialisation of the 3DFP appliance globally. **(Kitchen appliance market for end users).**	Clear enough futures Clear enough futures	Causation Causation
F	*3DP System Ingredients/Printers/ Designs (1b)*	*Short-term strategy*: Niche. 3DFP system to develop customised confectioneries for end	Clear enough futures	Causation Causation

	3DP System Ingredients/Printers/ Designs (1d)	customers through confectionery shops in specific locations. **(Confectionery market for end users**). *Long-term strategy*: Niche. 3DFP system to develop customised confectioneries for end customers through confectionery shops in specific locations and via e-commerce and or direct store. **(Confectionery market for end users).**	Clear enough futures	
G	*3DP Knowledge (1b)* *3DP Appliances (TCS)*	*Short-term strategy*: Niche Research on 3DFP to stimulate the public interest on the consumption of alternative nutritional sources. **(Funding institutions to support the knowledge development).** *Long-term strategy*: Niche Commercialisation of the 3D food printer more widely. **(Kitchen appliance market for end users).** BM not yet defined.	Alternative futures True ambiguity	Causation Causation
H	*3DP Software (2b)* *3DP system software/printer/designs (TCS)*	*Short-term strategy*: Diversification Commercialisation of the software through customisation. **(3DFP market for professional users).** *Long-term strategy*: Niche 3D printing system to develop customised goods for end customers through dedicated shops**.** **(N/A)** BM not yet defined.	Range of futures Range of futures	Effectuation Effectuation
I	*3DP Food (1c)* *3DP Food (TCS)*	*Short-term strategy*: Niche. 3D customised confectionery for end-customers.	Range of futures Range of futures	Effectuation Causation

		(Confectionery market for professional users). *Long-term strategy*: Niche 3D printed confectionery customised and sold via online platform e.g. customised decorations for confectionery shops. **(Confectionery market for professional users)**.		
J	*3DP knowledge (3b)* *3DP System Ingredients/Printers/ Designs (N/A)*	*Short-term strategy*: Niche. Research on 3DFP to develop a system to produce mass-customised meals for people with eating difficulties. **(Funding institutions to support the knowledge development).** *Long-term strategy*: Niche 3DFP system to produce mass-customised meals for people with eating difficulties. **(N/A)** BM not yet defined.	Range of futures True ambiguity	Effectuation N/A
K	*3DP Knowledge (1b)* *N/A*	*Short-term strategy*: Niche Consulting on 3DFP. **(3DFP market for professional users).** *Long-term strategy*: Not yet defined.	Range of futures True ambiguity	Effectuation N/A
L	*Combined 3DP Service/Food/Distribution (1b)* *Combined 3DP Service/Food/Distribution (TCS)*	*Short-term strategy*: Niche. 3DFP pop-up restaurant around the world & 3DP platforms in several industries. **(Gourmet food market for end users).** *Long-term strategy*: Niche. 3DFP restaurants around the world & 3DP platforms in several industries. **(Gourmet food market for end users).**	Clear enough futures Clear enough futures	Causation Causation
M	*3DP Appliance (1c)*	*Short-term strategy*: Niche	Clear enough futures	Causation

	3DP Appliance (TCS)	Commercialisation of a 3D food printer via e-commerce (only in a few countries). **(Kitchen appliance market for professional users).** *Long-term strategy*: Niche Commercialisation of the 3D food printer via e-commerce globally. **(Kitchen appliance market for professional and end users).**	Clear enough futures	Causation

Table 23 Commercialisation strategies

From the data presented in table 23, four main observations have emerged:

1. A and H are the only cases to adopt a diversification strategy, while the rest of the sample adopt a niche strategy (C, B, G, E, D, I, J, K, M, F, L).
2. A, H and K adopt interim sub-strategies to explore new possible business opportunities (see table 22), while others (e.g. C, D, G) adopt sub-strategies to achieve the pre-defined one.
3. The organisations that adopt a causal logic usually have a clear strategy (L, F, D, M, E, C) or a set of possible alternatives (B) that they want to implement under uncertainty conditions. The organisations that adopt an effectual logic for their business development tend to have a range of possible business model strategies (K, H, A).
4. A and I are the only cases that will shift from an effectual logic to a causal one if they identify (A) and achieve (I) the final strategy.

1. Mostly niche market strategy with two diversification examples.

Across the sample (table 22) it is possible to see that, in the short and long term, most firms tend to adopt niche strategies to commercialise their product and or service (e.g. C, B, G, E, D, I, J, K, M, F, L). AM was considered by the organisations as a way to satisfy specific needs in market niches (e.g. food kitchen appliance industry, nutritional and health care).

A and H adopted diversification strategies as: A is still at an inquisitive stage by commercialising through consultancy its knowledge of 3D printing. Through consultancy it aims to identify a long term strategy. For this reason, A has developed a BM with a flexible element (value capture) through which it can switch from a transactional outbound OI model (2), whereby it sells knowledge to others, to an OBM (5+6) where the relationship with the partner changes in order to define and size up the market

opportunity in a collaborative way. However, A's final aim is to identify a possibility that would give them the opportunity to take the role of distributor for 3D Printing equipment.
H has developed an 'internal platform' (according to the definition by Gawer & Cusumano, 2014) to adapt its software to the client's needs. By using this BM, H presents an outbound OBM (5). In the long term H aims to develop its own 3DP system in customised goods (not necessarily food), by using this model H will move from a diversification strategy to a niche one. The firm has not structured yet a BM for this possible future activity. As they are a startup venture that lacks resources, they are planning to launch a beta test of the 3DP system to collect feedback, and then decide whether it would be feasible to move forward with the business activity or not.

2. Development of sub-strategies to pursue (but also to identify) strategies.

In line with Marx and Hsu (2015), several organisations have developed sub-strategies to achieve the final one. Since the start, D has planned a two-step strategy to enter the market. Hence, the firm is first commercialising its 3D food printer to professional kitchen users, and then, when the technology is well-known and accepted among lead-user customers, the firm will move to sell it to end customers. C is developing an interim sub-strategy to find external investors who are willing to cooperate in the development and commercialisation of the 3DFP customised confectionery business. Similarly, G is looking for funding institutions to develop its technology, to then be able to license it to others. In the majority of cases (B, C ,D, E, F, G, L, M), even if they pursued their strategies in more than one step, the strategies have been pre-defined with a causation logic approach. This is in line with what was noticed by Marx and Hsu (2015) who observed that new tech-commercialising ventures in established markets in general do not develop substantially different interim sub-strategies, but tend to start the BM with the one they want to implement. However, in contrast Marx and Hsu (2015), who see interim sub-strategies as temporary phases subservient to reaching the already predetermined ultimate aim, A and H use a temporary strategy to explore and define the final one. Similarly, K is using an outbound OI model (2), whereby it sells knowledge to others (i.e. consultancy activity) in order to find new possible business opportunities and identify its long term strategy.

3. Strategy logics are associated to specific strategic approaches to face uncertainties (e.g. who adopt causal logics have clear strategy).

Overall, as expected, the decision logic adopted, either causal or effectual, is linked to the attitude of the organisations toward uncertainty. The organisations that adopt a causation-based decision logic usually have a clear strategy (L, F, D, M, E, C), or a set of possible alternatives (B) that they want to implement under uncertainty conditions. The organisations that adopt an effectual decision logic for

business development tend to have a range of possible business model strategies (K, H, A). The only exception is I, which has an ideal strategy, and also an idea of the business model suitable to exploit this strategy. The issue in this case is related to the technology, which is not yet advanced enough.

4. Open BM to reach closed BM.

An interesting observation relates to the variation of the degree of openness in the BMs utilised in the short or in the long term. For instance, I is adopting a sub-strategy of commercialisation by adopting an effectual logic to discover other business opportunities while the technology advances. As soon as the technology is ready, the firm already has the business model in mind that they want to adopt. I will close its boundaries, and from an inbound OBM (6), will move to a stand-alone BM that gathers the technology needed from the external environment (inbound OI model 3). Similarly, A adopts an OBM (5+6) to exploit new business opportunities, and once a suitable one is found the firm already has in mind the strategy that they want to pursue (e.g. becoming a 3D printing appliance distributor), so it closes its boundaries (inbound OI model, 3), and takes from the external environments only the products/knowledge needed to exploit the business. Therefore, A shifts from an effectual to a causal strategic decision logic. Across the rest of the sample, organisations usually do not shift in their decision logic process.

5.2.2 Objective Ib: Identify the business model archetypes and their revolutionary potential within the collaboration frame

In the commercialisation process, once the strategies have been defined, they are implemented through BMs. Table 24 shows: 1) the BMs of each organisation as illustrated in the methodology section 3.4.5; 2) the role of collaboration and openness used (OI/OBM - following the classification by Vanhaverbeke and Chesbrough 2014, pp. 54); and 3) the main archetypes. The BM archetypes have been obtained as illustrated in the methodology section 3.4.5. Three main BM archetypes emerged: product providers (e.g. 3DF printer (D, E, M), 3D printed food (C, F, I), digital ICT products (H)), knowledge service providers (e.g. consultancy (A, K), research (B, G, J)), competences assemblers (e.g. industry platforms (L)).

Table 25 details whether the BM dimensions are closed or open, according to the types of collaboration approaches (OI/OBM) adopted by the sample. It lists 1) the organisations' value propositions and the related BM, 2) the openness of each BM dimension according to the presence of a value network (see chapter three, section 3.4.5), and 3) the typology of the BM according to the classification done by Vanhaverbeke and Chesbrough (2014, pp. 54).

Finally, table 26 groups the sample based on the BM archetypes and the related collaboration approaches adopted (OI/ OBM).

Sample	Commercialisation strategies & BM tag Short Term (target market in brackets)	Short-term BM	BM type short term (Vanhaverbeke and Chesbrough, 2014, pp. 54)	BM archetypes	Commercialisation strategies & BM tag Long Term (target market in brackets)	Long-term BMs	BM type long term (Vanhaverbeke and Chesbrough, 2014, pp. 54)
A	Diversification Consulting on 3DFP (tech and market opportunities). Through these, identify further strategic goals **(education and food industry professional users).** 2b	*VP:* Consulting on technical/market applications of 3DP in education and food.	2 or 5+6	Knowledge service provider (consultancy)	Diversification Distribution of 3DP equipment in education, food and other industries.**(food, education and other industries, professional and end users).** The BM for the possible other industries, is not yet defined. 1c	*VP:* Distribution of 3DP equipment in education and food.	3
		VD: Direct to customers or co-creation depending on the business opportunity.				*VD:* Direct to customers.	
		VCr: Controlled sales of internal knowledge *(outbound OI 2)* or not controlled relationship (*inbound+ outbound OBM 5+6*) with customers to develop a new business. This depends on the potential of the business opportunity.				*VCr:* Internal knowledge and external 3DP equipment controlled relationship both with 3DP equipment suppliers and with customers.	
		VCa: A uses a different value capture model depending on the potential of the business opportunities: transactional or co-development of business opportunity.				*VCa:* Margin per asset sold.	
B	Niche Research on 3DFP for food personalisation **(funding institutions to**	*VP:*Step forward in the knowledge (IP) on the development of 3DFP.	5+6	Knowledge service provider (research)	Niche Consulting and licencing for the diffusion of a universal 3D printer for food personalisation	*VP:* Consulting and licencing of universal 3D printer for food personalisation.	5+6

	support the knowledge development). 1d				**(food processing market for organisations)**. TCS		
		VD: Direct to the funding provider.				*VD:* Direct to customers (licensor).	
		VCr: Not controlled: project partners to co-develop the product.				*VCr:* Not controlled: projects and clients' partners.	
		VCa: Value is captured through shared project funds.				*VCa:* Value is captured through IP licencing sales.	
C	Niche. 3DFP customised confectionery **(funding institutions to support the business development).** 2a	*VP:* 3DFP customised confectioneries.	3	Product provider (3D printed food)	Niche. 3D customisable confectioneries through e-commerce **(confectionery market for end users).** 2b	*VP:* 3DFP customised confectioneries.	6
		VD: Direct to funding institutions.				*VD:* Direct to clients (e-commerce) – co-creative relationship with customers.	
		VCr: Controlled: recipe, ingredients and design, looking for external knowledge (3DFP technician).				*VCr:* Controlled: internal knowledge recipe, ingredients, Not controlled: external designing (co-developed with customers).	
		VCa: Value is captured through external funds for the business development.				*VCa:* Value will be captured through the sales of each confectionery item.	
D	Niche. Commercialisation of the 3DFP appliance **(kitchen appliance market for professional users).**	*VP:* 3DFP system to develop new food shapes for professional kitchen users.	3	Product provider (3DF printer)	Niche Commercialisation of the 3DFP appliance **(kitchen appliance market for end users)**.	*VP:* 3D food printing system to personalise food for home kitchen users.	3
		VD: Direct to customers.				*VD:* Direct to customers.	

	1b	*VCr:* Controlled: Internal: 3DFP equipment, software and External: R&D knowledge implementations with universities collaborations.			1c	*VCr:* Controlled: Internal: 3DFP equipment, software and External: R&D knowledge. implementations with universities collaborations.	
		VCa: Value is captured by payment up front for each 3D food printer sold.				*VCa:* Value is captured by payment up front for each 3D food printer sold.	
E	<u>Niche</u> Commercialisation of the 3DFP appliance in a selected geographic area **(kitchen appliance market for end users).** 2a	*VP:* 3DFP system to develop new food shapes for home kitchen users.	3	Product provider (3DF printer)	<u>Niche</u> Commercialisation of the 3DFP appliance globally **(kitchen appliance market for end users).** TCS	*VP:* 3DFP system to develop new food shapes for home kitchen users.	3
		VD: Direct to customers.				*VD:* Direct to customers.	
		VCr: Controlled: Internal: 3DFP equipment, design and External: pre-filled food capsules and chef's recipes (are considerable as consultants).				*VCr:* Controlled: Internal: 3DFP equipment, design, External: pre-filled food capsules and chef's recipes (are considerable as consultants).	
		VCa: Value is captured by payment upfront for each 3D food printer sold and/or pre-filled food capsules.				*VCa:* Value is captured by payment up front for each 3D food printer sold and/or pre-filled food capsules.	
F	<u>Niche</u>. 3DFP system to develop customised confectioneries for end	*VP:* 3DFP system to develop customised confectioneries for end customers.	6	Product provider (3D printed food)	<u>Niche</u>. 3DFP system to develop customised confectioneries for end	*VP:* 3DFP system to develop customised confectioneries for end customers.	6

	customers through confectionery shops in specific locations **(confectionery market for end users**). 1b	*VD:* Indirect, through franchising. co-creative relationship with customers.			customers through confectionery shops in specific locations and via e-commerce and or direct store. **(confectionery market for end users).** 1d	*VD:* Indirect, through franchising. Direct through e-commerce and physical store. Co-creative relationship with customers.	
		VCr: Controlled: Internal: 3DFP ingredients, recipes, technology designs and External*:* software, 3D printer manufacturer. Not controlled: end-customers make the design (3D customised food).				*VCr:* Controlled: Internal: 3DFP ingredients, recipes, technology designs, External*:* Software, 3D printer manufacturer. Not controlled: end-customers make the design (3D customised food).	
		VCa: Renting 3D food printer – licensing software - value captured through each confectionery sold.				*VCa:* Renting 3D food printer – licensing software - value captured through each confectionery sold.	
G	<u>Niche</u> Research on 3DFP printing to stimulate the public interest on the consumption of alternative nutritional sources **(funding institutions to support the knowledge development).** *1b*	*VP:* Stimulate the public interest on the consumption of alternative nutritional sources through 3D printing technologies.	5+6	Knowledge service provider (research)	<u>Niche</u> Commercialisation of the 3D food printer more widely. **(kitchen appliance market for end users).** BM not yet defined. TCS	*Not yet defined*	N/A
		VD: Direct to funding institutions.					
		VCr: Not controlled: with other project partner.					
		VCa: Value is captured through shared project funds.					

H	Diversification Commercialisation of the software through customisation **(3DFP market for professional users).** 2b	*VP:* Embedded software for 3DP (3DFP). *VD:* Direct to customers (B2B). *VCr:* not controlled: customers (B2B). *VCa:* Fee for software and maintenance use.	5	Product provider (digital ICT products)	Niche 3D printing system to develop customised goods for end customers through dedicated shops**. (N/A).** BM not yet defined. TCS	*Not yet defined*	
I	Niche. 3D customised confectionery for end-customers. **(confectionery market for professional users).** 1c	*VP:* 3DFP customised confectioneries for professionals. *VD:* Direct to customers and through workshops and demonstrations. co-creative relationship with customers. *VCr:* Controlled: Internal: design, and ingredients Not controlled: customers. *Vca:* Sales of each confectionery product.	6	Product provider (3D printed food)	Niche 3D printed confectionery customised and sold via online platform e.g. customised decorations for confectionery professionals. **(confectionery market for professional users)**. TCS	*VP:* 3DFP customised confectioneries platform for professionals. *VD:* Direct to customers (e-commerce). *VCr:* Controlled: Internal:design, ingredients, External:3DFP technology. *VCa:* Sales of each confectionery product.	3
J	Research on 3DFP to develop a system to produce mass-customised meals for people with eating difficulties. **(funding institutions to support**	*VP:* Develop knowledge to be commercialised (3DP system ingredients/printers/designs). *VD:* Direct to the funding provider. *VCr:* Not controlled: project partners to co-develop the product.	5+6	Knowledge service provider (research)	Niche 3DFP system to produce mass-customised meals for people with eating difficulties. **(N/A)** BM not yet defined. TCS	*Not yet defined*	N/A

	the knowledge development). 3b	*Vca:* Value is captured through shared project funds.					
K	Niche Consulting on 3DFP. **(3DFP market for professional users).** 1b	*VP:* Consultancy on 3DFP. *VD:* Direct to customers. *VCr:* Controlled sales of internal knowledge. *VCa:* Value is captured per consultancy/workshop activity (transactional).	2	Knowledge service provider (consultancy)	*Not yet defined*	*Not yet defined*	
L	Niche. 3DFP pop-up restaurant around the world & 3DP platforms in several industries **(gourmet food market for end users).** 1b	*VP:* 3DFP dinners around the world & 3DP platforms in several industries (food, furnishing and soft furnishing, 3DP appliances). *VD:* Direct to customers (e-commerce). *VCr:* Not controlled: 3D printer manufacturer, chef, 3DP furnitures (advantages for the network in terms of branding). *VCa:*Value is captured per experience sold.	5+6	Competences assembler (industry platform)	Niche. 3DFP restaurants around the world & 3DP platforms in several industries **(gourmet food market for end users).** TCS	*VP:* 3DFP dinners around the world & 3DP platforms in several industries (food, furnishing and soft furnishing, 3DP appliances). *VD:* Indirect, franchised. *VCr:* Not controlled: 3D printer manufacturer, chef, 3DP furnitures (advantages for the network is in term of branding and sales through the platform). *VCa:*Value is captured per experience sold (platform VCa to be determined).	5+6

M	Niche Commercialisation of a 3D food printer via e-commerce (only in a few countries) **(kitchen appliance market for professional users).** 1c	*VP:* 3DFP system to develop new food shapes for professional kitchen users.	3	Product provider (3DF printer)	Niche Commercialisation of the 3D food printer via e-commerce globally **(kitchen appliance market for professional and end users).** TCS	*VP:* 3DFP system to develop new food shapes for professional and home kitchen users.	3
		VD: Direct to customers (e-commerce).				*VD:* Direct to customers (e-commerce).	
		VCr: Controlled: Internal: 3DFP head design, recipes, ingredients and Extenal: 3DF Printer manufacturer.				*VCr:* Controlled: Internal: 3DFP head design, recipes, ingredients, Extenal: 3DF Printer manufacturer.	
		VCa: Value is captured by payment upfront for each 3D food printer sold and/or pre-filled food capsules.				*VCa:* value is captured by payment upfront for each 3D food printer sold and/or pre-filled food capsules.	

Table 24 3DFP business models and the type of BM according to Vanhaverbeke and Chesbrough (2014)

Sample	Value proposition short term (BM tag in brackets)	Value proposition long term (BM tag in brackets)	Openness of the BM dimensions (short and long term) according to the presence of a value network								BM type short term according to Vanhaverbeke and Chesbrough,(2014) classification	BM type long term according to Vanhaverbeke and Chesbrough,(2014) classification
			VP short term	VP long term	VD short term	VD long term	VCr short term	VCr long term	VCa short term	VCa long term		
A	3DP knowledge (2b)	3DP appliance and parts (1c)	Open - closed	Closed	Open - closed	Closed	Open - closed	Closed	Open - closed	Closed	5+6 - 2	3
B	3DP knowledge (1d)	3DP knowledge (TCS)	Open	Open	Closed	Open	Open	Open	Open	Open	5+6	5+6
C	3DP food (2a)	3DP food (2b)	Closed	Closed	Closed	Open	Closed	Open	Closed	Closed	3	6
D	3DP appliance (1b)	3DP appliance (1c)	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	3	3
E	3DP appliance (2a)	3DP appliance (TCS)	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	3	3
F	3DP system ingredients/printers/designs (1b)	3DP system ingredients/printers/designs (1d)	Closed	Closed	Open	Open	Open	Open	Closed	Closed	6	6
G	3DP Knowledge (1b)	3DP appliance (TCS)	Open	N/A	Closed	N/A	Open	N/A	Open	N/A	5+6	N/A
H	3DP software (2b)	3DP system software/printers/designs (TCS)	Closed	N/A	Open	N/A	Open	N/A	Closed	N/A	5	N/A
I	3DP food (1c)	3DP food (TCS)	Closed	Closed	Open	Closed	Open	Closed	Closed	Closed	6	3
J	3DP knowledge (3b)	3DP system ingredients/printers/designs (TCS)	Open	N/A	Closed	N/A	Open	N/A	Open	N/A	5+6	N/A
K	3DP knowledge (1b)	N/A (TCS)	Closed	N/A	Closed	N/A	Closed	N/A	Closed	N/A	2	N/A
L	3DP service/food/dstribution (1b)	3DP service/food/distribution (TCS)	Open	Open	Closed	Closed	Open	Open	Closed	N/A	5+6	5+6
M	3DP appliance (1c)	3DP appliance (TCS)	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed	3	3

Table 25 Open and closed dimensions of the BM

BM archetypes		Sample	BM type	Open and closed variables
Competences assemblers	Competences assembler (industry platform)	L	OBM (5+6)	All the BM dimensions are *open* except for VD (the openness is mostly not with end-customer, but with partners) and VCa (at this stage the captured value is mostly used to cover the events' expenses)
Knowledge service provider	Knowledge service provider (research)	B, G, J		All the BM dimensions are *open* except for VD (the openness is mostly not with end-customer, but with partners)
	Knowledge service provider (consultancy)	A (if applies co-development BM)		All the BM dimensions are *open*
	Knowledge service provider (consultancy)	A (if applies transactional BM), K	Stand-alone BM + outbound OI (2)	All the BM dimensions are *closed*
Product provider	Product provider (digital ICT products)	H	OBM (5)	*Open*: the VD – VCr *Closed*: the VP - VCa
	Product provider (3D food printer)	D, E, M	Stand-alone BM + inbound OI (3)	All the BM dimensions are *closed*
	Product provider (3D printed food)	C, F, I	OBM (6)	*Open*: VD (co-creative relationship between organisation and customers) – VCr (customers become designer provider in the value chain) *Closed*: VP and VCa

Table 26 BM archetypes and related collaboration activities (OI/OBM)

1. Collaborations (through OI/OBM) play different roles according to the different type of BM archetype exploited by the organisations.

3D printing-based organisations that aim to commercialise within the food industry adopt a combination of outbound and inbound OBM (5+6), to identify new business opportunities (A), to develop a platform (L), or to sell the advancement of technical knowledge (B, G, J). The OBM (5+6), advance the classification outlined by Vanhaverbeke and Chesbrough (2014, pp. 54), by adding a new typology in their classificaiton: the coupled-linked OBM.

A further typology of OBM adopted by 3D food printing organisations is the outbound OMB (5). This OBM form has been adopted by digital ICT product provider (H) to enable its clients to have their personalised software, that are developed with the knowledge of the digital ICT product provider. Hence, the firm embeds its software within the 3DP appliances, and usually the realisation of the software itself is done in collaboration with the client.

Inbound OBMs (6) are adopted by the providers of customised 3D printed food (C, F, I) to include customers in their product development process, as providers of designs and needs. This activity finds its roots in the co-creation process highlighted by Rayna and Striukova (2015), where customers intervene in the product design process.

When it comes to the providers of 3DF printers (D, E, M), the firms adopt inbound OI activities to develop the products, but they exploit their commercialisation with a stand-alone BM (3).

An outbound OI model (2) has been observed among the firms (A, K) that sells their knowledge to others, but do not need external parties to exploit their activity.

The above described roles of collaborations (OI/OBM) can be further detailed by analysing them in comparison to three main models through which food organisations commercialise their innovations.

2. An adapted version of the "Want, Find Get Manage" model (Bigliardi Galati, 2013)

Usually the product providers of 3D printed food (C, F, I), establish a hierarchical relationship with the upstream actors of the supply chain (e.g. ingredients provider, software, 3DP equipment), while developing a networked one with the end-customers (downstream side of the supply chain). Hence, in these cases customers become part of the supply chain (Bogers,et al., 2016) by providing content (e.g. designs of food, recipes) so that the focal firm can produce the personalised outcomes (e.g. 3D personalised conferctionery) for a numbers of reasons (e.g. health, personal preference). In doing so, these organisations adopt an inbound OBM (6), by opening up the BM dimensions of value creation and value delivery. These BMs relate to the features of the technology to enable food customisation and personalisation (Piller, 2007).

This model contrasts with the "Want, Find, Get, Manage" model highlighted by Bigliardi & Galati, (2013), whereby the collaborations for knowledge acquisition can be developed along the whole supply chain, depending on the firm's specific needs.

3. A variation of the "food machinery framework" (Bigliardi and Galati 2013)

In contrast with what was illustrated by Bigliardi & Galati, (2013), at the development stage of the commercialisation process, the research organisations (B, G, J) from peripheral assume a central role in the ecosystem, they orchestrate the network in order to develop the final product.

In the food industry, many of the BMs, that have been adopted in the sample are known as the "food machinery framework" (Bigliardi and Galati 2013). A large part of this model is based on collaborations across partners to develop a new manufacturing process (e.g. D, E, M). However, for the ventures commercialising emerging technologies, on the contrary to what is illustrated by Bigliardi and Galati (2013), the machine/process equipment manufacturers are the orchestrators of the ecosystems and try to extend the value network to develop the missing elements (e.g. ingredients, software and designs). These organisations use OI activities to develop their products, by involving 3D printer manufacturers, software providers and designers. However, the commercialisation activity is usually done directly by the 3D food-printer providers (i.e. the equipment manufacturer) (inbound OI 3), without the networked support of partners.

A variation of the "food machinery framework" model is adopted also for developing new knowledge (Research) for a 3D food printing ingredients system. This BM was observed in equipment manufacturers (B), ingredients manufacturer (J) or University groups (G). For instance, B has the long term objective of developing the knowledge for a 3D food-printer (3DFP) system able to offer fully personalised food for a variety of uses. The firm is systematically seeking public/private funds for a chain of research projects to develop this knowledge which it aims to eventually commercialise through out-licensing (5) and/or to co-create the supply chain through consultancy (6), with the range of partners who contributed to the research projects (e.g. ingredients providers, product provider (3D food printer)).

4. A variation of the "sharing is winning" model (Bigliardi and Galati 2013)

The "sharing is winning" model (Bigliardi & Galati, 2013b) is characterised by collaboration activities between partners within the upstream elements of the value chain, to create value for the customers. One example of the "sharing is winning"model is L who uses a BM already existing in the food industry. Hence, L provides service and experience through restaurants. This BM has been conceived as a two-sided market (Baden-Fuller and Mangematin 2013). On the one hand, the restaurant experience is delivered to customers in collaboration with the partners value network comprising the food, 3D Printer

manufacturers and ingredient providers, chefs, soft and hard furnishing providers (6). On the other hand, the events are, for the value network partners, opportunities to market their products/designs and skills and (in the future) also to sell them through the restaurant (5). L is hence developing a platform BM (Gawer and Cusumano, 2014) which bridges across different industries. It adopts an inbound and outbound OBM (5+6), with all the BM dimensions open, except for the value capture and value delivery.

5.3 Expanded aim II: What are the BMI dynamics in the commercialisation process of an emerging technology in an established industry?

I focused on how the BM of organisations commercialising emerging technologies in established markets have been developing over the time, highlighting 1) the patterns (types) in the business model innovation; and 2) the triggers and the degree of innovativeness.

5.3.1 Objective IIa: Identify the patterns in the process of BMI

To contribute to a deeper understanding of the mechanisms underpinning the BMI process, when firms are considering developing a business opportunity around an emerging technology in an established industry.

The case studies analysed in chapter four are mainly early stage organisations or projects, with no more than five/six years' experience in the 3D food printing area. So, according to the business model innovation literature, all the sample of organisations that are in their early stage should be considered within the BM design phase of the BMI process (Cortimiglia, et al., 2016; Massa & Tucci, 2013).

1. The BM reconfiguration process takes place also in new ventures

In contrast with what mentioned by Massa and Tucci (2013), whereby the BM reconfiguration processes concerns only existing organisations, the organisations in the sample designed a BM and then had to reconfigure all or most of the BM's dimensions. The sample of organisations all started by designing a BM. Then, the BM changed (i.e. was reconfigured) and evolved in different ways. For example, H went from the 3D printing manufacturing model (BM 1a), to change it completely due to the difficulties in sustaining that business (i.e. too high delivery fees, team splitting up). H then became a software provider (BM 2a). C shows 2 BM reconfiguration stages. It started with a research model (BM 1a) to prove the concept, and once it was proven, they went through great changes across the various BM

dimensions yelding the BM 2a (3D printed food manufacturing model). However, when the firm will find new source of funding to develop its business, C is planning to target initial 'lead users', using the originally intended BM (i.e. 3D printed food manufacturing model for end users - BM 2b). There are also cases in which the organisations, after having designed a BM had to go through smaller reconfigurations of their BM (e.g. specific request from the market). For instance, F (i.e. a 3D printed food provider) went from BM 1a, in which they tested the product with end customers, to BM 1b. In this latter case they changed the value delivery channels (i.e. from a model in which the 3D printed food was sold directly in one of the firm's locations, to a model in which the firm would sell the 3D printed food through franchised retail partners). Similar small reconfigurations occurred to D, K, L, B, G. Except in the cases of K and G, which do not have a clear view of the long term commercialisation BMs, the rest of the sample that went through small reconfigurations (D, F, L, B) usually have a clear view of the future (see section 5.2.1), having, since the beginning, a clear strategy.

2. BM design and BM reconfiguration are iterative processes that can coexist and run in parallel.

Dmitriev, et al., (2014) described the BMI process (BMD and BMR) as a cyclical process happening in a sequential and iterative order. In contrast with this view, it has been observed that some cases across the sample (A, J, M, I) have added a new layer (i.e a new BM) to the core BMs. In doing so, while the core BM was going through a reconfiguration process, the new layer of the BM was designed. For example, in the case of A while the BM design of the distribution archetype was going through its latest reconfiguration process (i.e. BM 1b → BM 1c), the firm introduced and designed another linked-BM, the knowledge service provider (consultancy) BM (i.e. 2a). Another example is J. Here, the firm first designed the product provider model (BM1a) and to this product line the firm added a knowledge service (consultancy) model (BM 2a). These BM innovation cycles run in parallel (BM 1a → BM 1a + BM 2a). Once the firm decided to expand its product line, they replicated and adapted the linked product provider model (BM 1b) and the knowledge service model (BM 2b) to this new line of business. Hence, it has been observed that BMD and BMR are iterative processes that can coexist and run in parallel.

3. The BMI for the commercialisation of AM in the food industry takes place according to four types of changes.

To identify the types of changes in the BM (i.e. the BM evolution mechanisms), I observed how the sample of organisations changed their value proposition over the time (Trimi & Berbegal-Mirabent, 2012) (i.e. BM archetypes - e.g. from a knowledge service provider (research) BM to a product provider

(3D food printer) BM). From this observation I have identified four types of changes in the BM, as shown in table 27.

BM Archetype evolution model	Sample	BM archetype evolution model description
i) Single BM archetype evolution	D, F, K, L	No changes in the BM archetype. Organisations developed, since the beginning, one BM archetype and over time kept and implemented that archetype.
	B, G	No changes in the BM archetype. Small changes in a few BM dimensions.
ii) Multiple BM archetype evolution	A, M, J, I	New BM archetype is added to the core activity: combination of two or more BMs that evolve together and can be used in combination (or separately).
iii) Changing BM archetype	C, H	Completely change the BM archetype. After one radical change in the BM archetype, organisations keep evolving and implementing the latest archetype.
iv) Multiple-changing BM archetype evolution	E	Completely change the BM archetype. After one radical change in the BM archetype, organisations keep evolving and implementing the latest archetype. Additionally, a new BM archetype is added to the core activity

Table 27 Types of changes: BM archetypes evolutions models

5.3.2 Objective IIb: Identify the triggers and the degree of innovativeness associated with different types of BM changes

The particular types of BM changes outlined in table 28 are further detailed in this section, in association with their degree of innovativeness in table 28 (based on Rayna & Striukova, 2016b) and the triggers that motivated the changes in table 29.

BM archetypes changes overtime																									
A		B		C		D		E		F		G		H		I		J		K		L		M	
BM archetype	**Inside-outside BMI**	**BM archetype**	**Inside-outside BMI**	**BM archetype**	**Inside-outside BMI**	**BM archetype**	**Inside-outside BMI**	**BM archetype**	**Inside-outside BMI**	**BM archetype**	**Inside-outside BMI**	**BM archetype**	**Inside-outside BMI**	**BM archetype**	**Inside-outside BMI**	**BM archetype**	**Inside-outside BMI**	**BM archetype**	**Inside-outside BMI**	**BM archetype**	**Inside-outside BMI**	**BM archetype**	**Inside-out BMI**	**BM archetype**	**Inside-outside BMI**
Distribution model (BM 1a)	N/A	Knowledge service provider (research) model (BM 1a)	N/A	Knowledge service provider (research) model (BM 1a)	N/A	Product provider (3D food printer) (BM 1a)	N/A	Knowledge service provider (research) model (BM1a)	N/A	Product provider (3D printed food) model (BM 1a)	N/A	Knowledge service provider (research) model (BM 1a)	N/A	Product provider (3D printer) model (BM 1a)	N/A	Product provider (3D printed food) model (BM 1a)	N/A	Material provider and knowledge service provider (consultancy) model (BM1a+BM2a)	N/A	Knowledge service provider (consultancy) model (BM 1a)	N/A	Competence assembler (industry platform) model (BM 1a)	N/A	Product provider (3D food printer) model (BM1a)	N/A
Distribution model (BM 1b)	Many components, minor changes + same customers	Knowledge service provider (research) model (BM 1b)	One component, minor change + same customers	Product provider (3D printed food) model (BM 2a)	Many components, major changes + same market, new customers	Product provider (3D food printer) model (BM 1b)	Few components, major changes + same market, new customers	Knowledge service provider (research) model and knowledge service provider (consultancy) (BM 1a + BM 3a)	Many components, minor changes + same market, new customers	Product provider (3D printed food) model (BM 1b)	Many components, minor changes + same customers	Knowledge service provider (research) model (BM 1b)	One component, minor change + same customers	Product provider (digital ICT) model (BM 2a)	Many components, major changes + new market	Product provider (3D printed food) model and knowledge service provider (consultancy) model (BM 1a + BM 2a)	Many components, minor changes + same customers	Material provider, knowledge service provider (consultancy) model and knowledge service provider (research) model (BM 1c + BM 2b + BM 3a,b)	Many components, minor changes + same market, new customers	Knowledge service provider (consultancy) model (BM 1b)	One component, minor change + same customers	Competence assembler (industry platform) model (BM1b)	Many components, minor changes + same customers	Product provider (3D food printer) model (BM1b)	Many components, minor changes + same customers
Distribution model (BM 1(0))	Many components, minor changes + same customers	Knowledge service provider (research) model (BM 1c)	Many components, minor changes + same market, new customers	Product provider (3D printed food) model (BM2b)	Many components, minor changes + same market, new customers	Product provider (3D food printer) model (BM 1c)	One componenet , minor change + same market, new customers	Product provider (3D food printer) model and knowledge service provider (consultancy) (BM 2a + BM 3b)	Many components, minor changes + same market, new customers	Product provider (3D printed food) model (BM 1d)	One component, minor change + same customers			Product provider (digital ICT) model (BM 2b)	Many components, major changes + new market	Product provider (3D printed food) model and knowledge service provider (consultancy) model (BM1b+BM2b)	Many components, minor changes + same customers							Product provider (3D food printer) model and knowledge service provider (consultancy) model (BM 1c + BM 2a,b)	Many components, minor changes + same customers
Distribution model and knowledge service provider (consultancy) model (BM1c+BM 2b)	Many components, minor changes + new market	Knowledge service provider (research) model (BM 1d)	One component, minor change + same customers													Product provider (3D printed food) model and knowledge service provider (consultancy) model (BM 1c + BM 2c)	One component, minor change + same customers								

Table 28 BM archetypes changes overtime and degree of innovativeness. [1]

1 To reduce the complexity, only the core BMs or the linked forms have been reported in this table.

To reduce the complexity and maintain the consistency with the original framework, in some of cases tagged as 'one component, minor changes', sometimens the changes happened also in a few BM components, still with minor changes.

The main triggers underpinning the changes in the BMs are: 1) triggers that enable the starting of the BM, 2) triggers underpinning the decision of an organisation to keep the same business model over time, 3) triggers that enhanced a change in the BM archetype, and 4) triggers that led to the addition of another BM layer. All these triggers are summarised in table 29.

Sample	Starting triggers	Triggers for keeping the same BM archetype	Triggers for changing the BM archetype	Triggers for additional BM layers
A	Business opportunity - Business failure	Familiar skills	N/A	Support core business - Marketing need
B	Research interest	Pursue strategic goal	N/A	N/A
C	Research interest	N/A	Feedback	N/A
D	Market gap	Pursue strategic goal	N/A	N/A
E	Market gap	N/A	Feedback	Support core business - Marketing need
F	Business opportunity	Pursue strategic goal	N/A	N/A
G	Research interest	Pursue strategic goal	N/A	N/A
H	Personal interest	N/A	Business failure	N/A
I	Market gap	Familiar skills	N/A	Support core business - Marketing need
J	N/A	Pursue strategic goal	N/A	Support core business - Marketing need
K	Personal interest	Familiar skills	N/A	N/A
L	Market gap	Pursue strategic goal	N/A	N/A
M	Market gap	Pursue strategic goal	N/A	Support core business - Marketing need

Table 29 Triggers enhancing BM changes

BM Archetype evolution model	Sample	BM archetype evolution model description	Starting triggers	Triggers for keeping the same BM archetype	Triggers for changing the BM archetype	Triggers for additional BM layers	Inside-outside BMI (BMI variations in brackets)
i) Single BM archetype evolution	D, F, K, L	No changes in the BM archtype. Organisations, since the beginning developed one BM archetype and over the time kept and implemented that archetype.	Market gap, Business opportunity, Personal interest	Pursue strategic goal	N/A	N/A	Few components, major changes + same market, new customers (D [BM 1a →BM 1b]) Many components, minor changes + same customers (L [BM 1a →BM 1b]) One component, minor change + same market, new customers (D [BM 1b → BM 1c]) One component, minor change + same customers (F [BM 1a →BM 1b]; F [BM 1b → BM 1d]; K [BM 1a → BM 1b])
	B, G	No changes in the BM archtype. More research is needed due to the radical nature of the projects. Small changes in few BM dimensions.	Research interest				One component, minor change + same customers (B [BM 1a →BM 1b]; B [BM 1c →BM 1d]; G [BM 1a → BM 1b]) Many components, minor changes + same market, new customers (B [BM 1b →BM 1c])

ii) Multiple BM archetype evolution mode	A, M, J, I	New BM archetype is added to the core activity: combination of two or more BMs that evolve together and can be used in combination (or separately).	Business opportunity - Business failure - Market gap	Pursue strategic goal - Familiar skills	N/A	Support core business - Marketing need	Many components, minor changes + same market, new customers (J [BM 1a + 2a → BM 1b + 2b +3 a,b]) Many components / one component (I), minor changes + same customers (A [BM 1a → BM 1b]; A [BM 1b →BM 1(0)]; M [BM 1a → BM 1b]; M [BM 1b →BM 1c+2a,b]; I [BM 1a → BM 1a + 2a]; I [BM 1a + 2b → BM 1b + 2b]; I [BM 1a + 2b → 1c + 2c]) Many components, minor changes + new market (A [BM 1 (0) → BM 1c + 2b])
iii) Changing BM archetype evolution model	C, H	Completely change the BM archetype. After one radical change in the BM archetype, organisations keep evolving and implementing the latest archetype.	Personal/Research interest	N/A	Feedback - Business failure	N/A	Many components, major changes + new market (H [BM 1a → BM 2a]; H [BM 2a → BM 2b]) Many components, major changes + same market, new customers (C [BM 1a → BM 2a]; C [BM 2a → BM 2b])
iv) Multiple-changing BM archetype evolution model	E	Completely change the BM archetype. After one radical change in the BM archetype, organisations keep evolving and implementing the latest archetype. Additionally, a new BM archetype is added to the core activity	Market gap	N/A	Feedback	Support core business - Marketing need	Many components, major changes + same market, new customers (E [BM 1a → BM 1a + 3a]; H [BM 1a +3a → BM 2a + 3b])

Table 30 BM archetype evolution model and related triggers for change

1. When organisations are at the beginning of the innovation diffusion cycle, four types of BM changes take place

1) Single BM archetype – evolution paths

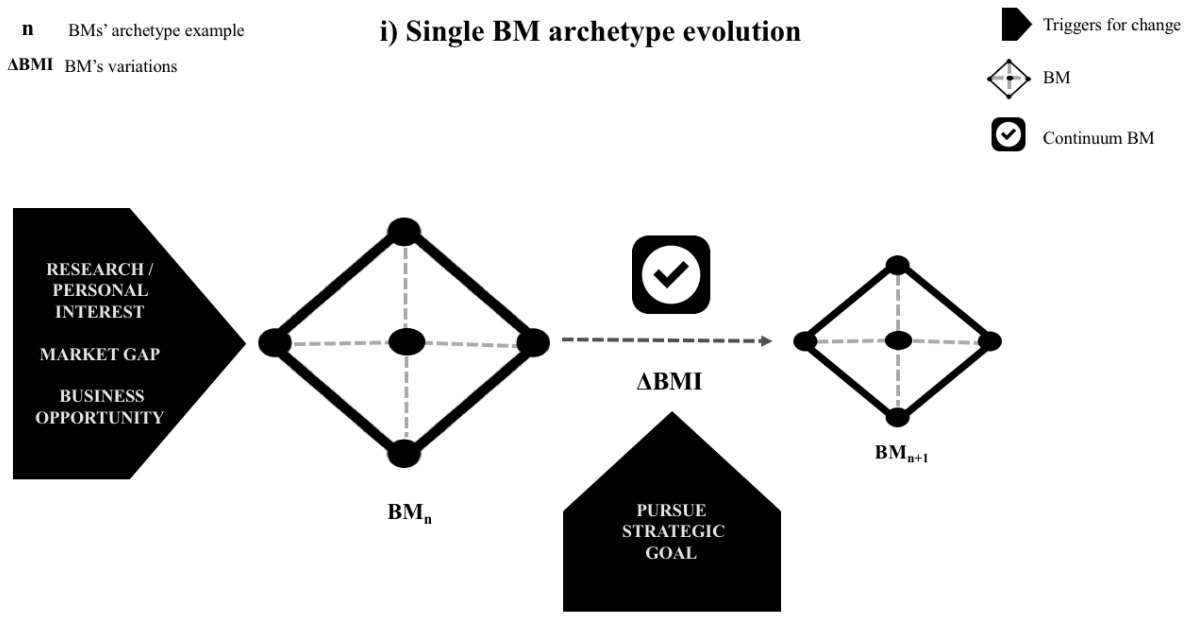


Figure 20 Single BM archetype evolution model
Icon source: BM - adapted from GraphicsBay; Contiuum BM - OCHA

The single BM archetype evolution model (figure 20), is the case in which organisations, since the beginning, developed one BM archetype and over time have kept and implemented that archetype. This BM evolution model applies to all the archetypes, from the knowledge service BMs, both consultancy (K) and research (B, G), up to the product providers BMs, either of food (F) or of 3DP appliance (D). The model is applied also to the component assembler (L) BM. A similar BM evolution was found by Casprini et al. (2014), when they looked at the BM evolution of technology-based small ventures in an established sector (i.e. cultural heritage). However, only a small part of the sample in Casprini et al's presented a linear BM evolution, whilst most the cases analysed adopted a single BM archetype that changed for a brief period to then return to the original BM. In contrast to Casprini et al. (2014), most BMs present in the sample (D, F, K, L, B, G) have started with one BM archetype and kept this over the time, it has been only slightly reconfigured. For instance, G and B, that are research organisations, did not change the BM archetypes mostly because more research is still needed to deliver either a 3D printing appliance able to print alternative nutritional sources (G) or a 3D food printer able to print full personalisable food (B). In these cases, the organisations keep implementing the knowledge service (research) BM, making changes only in a few building blocks.

The organisations displaying the *single BM archetype evolution* pattern (D, F, K, L, B, G) have started their BMs spurred by three main endogenous triggers: 1) research or personal interest of the organisation/entrepreneur (Casprini et al. 2014), 2) a gap noticed in the market (Demil & Lecocq, 2010), or 3) the identification of a business opportunity (Johnson et al., 2008). Across all the cases within this group (D, F, K, L, B, G) the small reconfigurations of the BM have been mainly trigged by the objective of pursuing the firm's main strategic goal as indicated by other literature (Demil & Lecocq, 2010).
According to the scale proposed by Rayna & Striukova (2016b), the organisations that maintain the same BM archetype do not develop a radical BMI process, nor present a BM with a disruptive impact on the external environment over time. In fact, the changes in the BM components were mostly minor and always carried a low impact on the external environment (i.e. even after the change, the organizations targeted the same customers or new customers in same market).

2) Multiple BM archetype – evolution paths

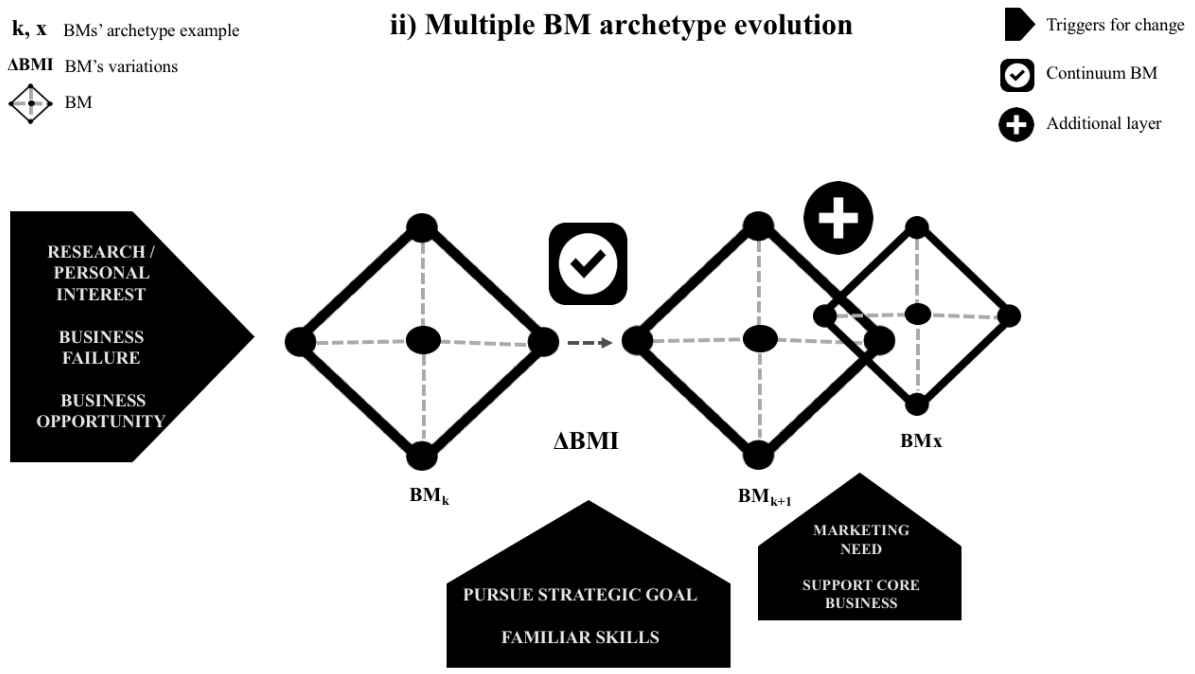


Figure 21 Multiple BM archetype evolution model
Icon source: BM - adapted from GraphicsBay; Contiuum BM – OCHA; Additional layer - Anas Ramadan

M, J, A, and I started with one BM archetype and added a new BM archetype to the core activity. So, the BM archetype becomes a combination of two or more BMs that evolve together and that are usually used in combination. Often, the additional BM archetype implemented by the organisations is a knowledge service BM (i.e. a BM to commercialise the knowledge the firm has/develops). M, I and J, used the service BM as a support and marketing for the core BM archetype (product provider either of

3D printed food or 3D food printer). An example is M, who started as a product provider (3D food printer) for professional users, however, to scale up the firm needed further funds, that came from a crowdfunding campaign. As most of the new ventures, M did not have great resources availability (i.e. lack of money), but at the same time the firm needed to become known to potential customers (i.e. marketing need). So, the firm added a knowledge service provider (consultancy) BM to the core business. The service activity consists in doing activities, such as workshops and demonstrations at events, and/or producing customised gadgets for specific events. In this way M could support the frim's core business with the profit gained from the services and at the same time could promote its core BM by taking part in events. A similar situation occurred to A, I and J.

As in the single BM archetype evolution type (i), the BMs in this group were mainly started by: 1) the observation of a gap in the market (Demil & Lecocq, 2010), 2) or the raising of a business opportunity (Johnson et al., 2008), 3) as well as the business failure of a previous activity (Demil & Lecocq, 2010). Then the organisations changed their BMs, adding a layer triggered either by the need of pursuing the firms'strategic goal (e.g. product line expansion, market expansion) as observable in the cases of J and M; or by developing the business following the experience and skills of the entrepreneurs (A and I).

In all of the four cases, the new BM archetypes enabled a new source of value delivery and value capture for the organisations. Whilst the addition of a BM has been discussed in the literature, Aversa et al. (2015) consider this option as *augmenting operations*, added to develop a new layer of a multi-sided BM. However, from the cases in the present study, the addition of another layer (i.e. another BM) to the core BM develops multiple-linked BMs.

Adding a new layer in the BM, however, implied small overall degree of radical change in the BM (Rayna & Striukova, 2016b) as the additions were resulting either in the reaching out to new customers in the same market, or in a deeper expansion of the same customer segment.

3 and 4) Changing BM archetype and Multiple-changing – evolution paths

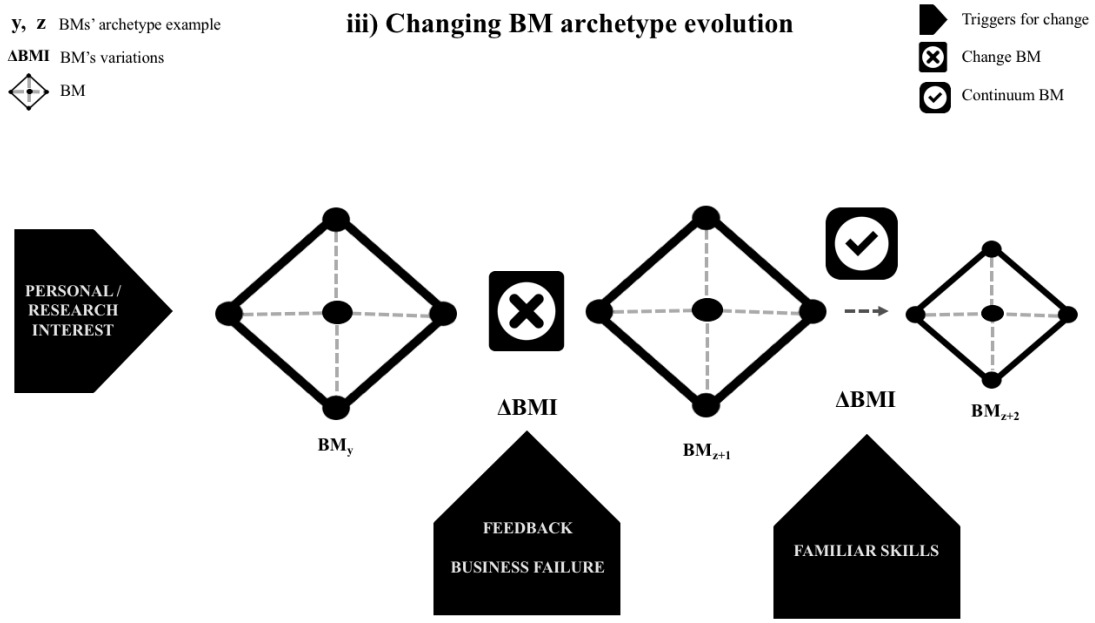


Figure 22 Changing BM archetype evolution model
Icon source: BM - adapted from GraphicsBay; Contiuum BM – OCHA; Change BM - Freepik

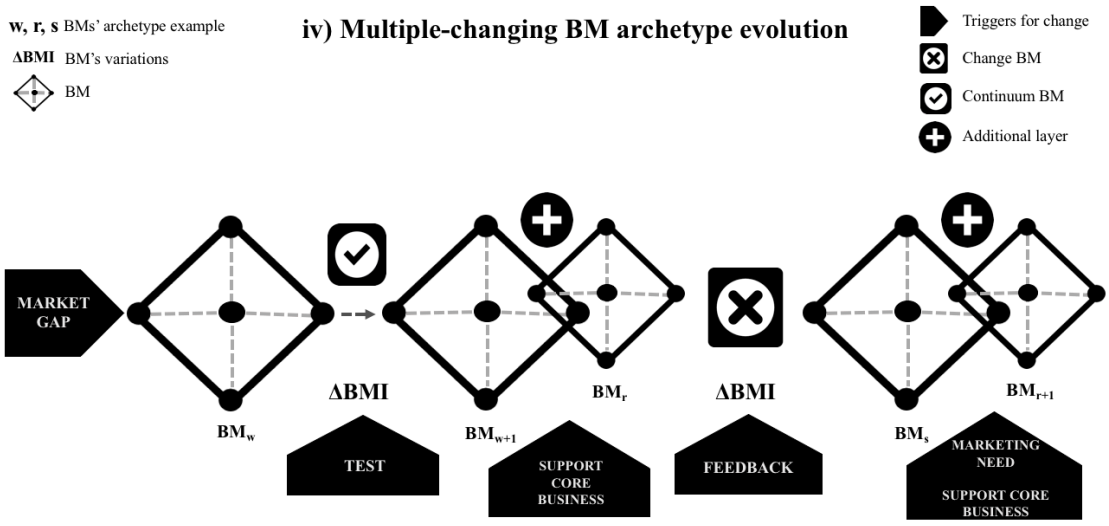


Figure 23 Multiple-changing BM archetype evolution model
Icon source: BM - adapted from GraphicsBay; Contiuum BM – OCHA; Change BM – Freepik; Additional layer - Anas Ramadan

In some cases (e.g. C and H), the ventures started with one BM archetype, and soon after, changed it to another archetype developing the latter with a subsequent series of adjustments (iii – figure 22). This was the case of H. H's CEO's interest in 3D printing lead him/her to start the business activity in this

field. H initially wanted to produce and sell 3D printers (product provider BM), but when the business started to encounter difficulties (i.e. too high delivery fees, team splitting), they had to completely change the BM. The choice was to revert to a BM that better suited the CEO's skills (Martins, et al., 2015). H became a digital ICT product provider, selling customised software solutions for other businesses. In this case the firm, after one radical change in the BM archetype, kept evolving and implementing the latest archetype.

On occasion (vi - Figure 23), the ventures started with a BM, then firstly tried to add a supportive BM (as in model ii) to help the business take off. However, as the firms got their firsts feedback, they needed to change the BM archetype. In doing so the firms keep the additional BM as support of the core business. This was the case of E. This firm identified a gap in the market and, through the knowledge service provider (research) BM, pushed the development of the technology and the testing of the project feasibility. Along with this BM, a service provider BM (i.e. knowledge service provider (consultancy) BM), through which the firm organised 3D food printing events, supported E in the testing of the technology's perception on potential customers. Once the organisations obtained positive customer responses, they decided to invest more effort in developing a business model to produce and commercialise the technology (product provider BM).
Interpreting these BMs changes according to Rogers' (1962) theory, when E did research (knowledge service provider (research) BM) it was targeting the initial adopters (innovators) of the innovation (these are the investors, such as the research funding organisations). When the technology matured, the organisation shifted to its intended BM (product provider BM), but E needed to find 'lead users'. To do so, the firm added also to this latter BM a knowledge service provider (consultancy) BM with the aim to increase the marketing and therefore find 'lead users'. A similar situation occurred to C (i.e. moving from a research BM to a product provider BM), with the only exception that the firm did not add any supportive BMs to the core business neither before or after changing the archetype.

Instead, H changed BM archetype expanding the business to other markets (from 3DP manufacturing market for end users, to 3D food printing market for professional users). This represents the most radical and disruptive example of BMI across the sample, considering the scale proposed by Rayna and Striukova. However, even though the internal changes of the BM components are major, for C and E the impact on the external environment was low because both organisations are at a very early stage of their development. In C and E, the VP changed from knowledge service (research) to product provider, but they targeted the same markets (i.e. C always targeted the confectionery market, while E has always been targeting the kitchen appliance market).

5.4 Summary of findings

This chapter provided the findings that were derived from the case studies detailed in chapter four. The findings in the chapter follow the two expanded aims highlighted in chapter three (i.e. what are the types of BM and what are the BMI dynamics in the commercialisation process of an emerging technology in an established industry). Section 5.2 explores the static dimension of the research, and the two related research objectives (i.e. explore the links between strategic choices and specific business model solutions within the collaboration frame; identify the business model archetypes and their revolutionary potential within the collaboration frame). Section 5.3 highlights the dynamic dimension of the study. The exploitation of this part of the analysis followed the sub-research questions outlined in chapter three (i.e. what are the patterns in the business model innovation; and what are the triggers and the degree of innovativeness).

In the following chapter, a combination of the findings reported in the present chapter with the existing literature, will be provided.

Chapter 6 Discussion

6.1 Chapter introduction

In this chapter, the findings that have emerged from the case study analysis are compared and contrasted with the existing literature. The structure of the chapter follows the same one used to detail the findings (chapter 5). To scope the overall research aim of understanding how business models are framed in the commercialisation processes of a new technology (i.e. 3D printing) in an established industry (i.e. food industry), the discussion has been divided in two main sections according to the expanded aims of the research (i.e. understanding the types of BMs emerging when firms commercialise a new technology in an established industry, and understanding what are the BMI dynamics in these circumstances), and are further detailed according to the different objectives.

6.2 Expanded aim I: What types of BMs emerge when firms commercialise a new technology in an established industry?

6.2.1 Objective Ia: Identify the links between strategic choices and specific business model solutions within the collaboration frame

1. The BM-strategy link for the commercialisation of emerging technologies

To commercialise emerging technologies, organisations define either a narrow or a wide range of strategies that enable them to exploit their technologies within uncertain environments (Courtney, et al., 1997). Teece (2010), claim that new ventures' commercialisation strategies are reflected in the firms' business model construct. Although in the last decades, the literature on strategy, as well as the one on BMs have been constantly increasing, there is still the need for a clearer understanding of the links between the strategy and the BM, especially from an empirical perspective (Baden-Fuller & Haefliger, 2013; Hacklin & Wallnöfer, 2012; Spieth et al., 2016). Whilst so far most of the studies in this field are conceptual in nature (e.g. Casadesus-Masanell & Ricart, 2010; DaSilva & Trkman, 2014; Teece, 2010). Zott and Amit (2008) initially contributed to the BM-strategy link, by claiming that strategy (i.e. is the plan that the firm develops to face the competition in a given target market) and BM (i.e. is the organisational frame in which are indicated the firm's mechanisms to create and capture value) are two different constructs that complement each other and contribute to the firm's ability to gain competitive advantage. More recently Cortimiglia et al. (2016) analysed the linkages between the strategic making process (SMP) and BM (I). From their empirical study it emerged that the BM construct is related to the execution of the strategy.

In the technology commercialisation context, it often happens that organisations suffer of resource scarcity. To overcome this issue, Marx et al. (2014) and Marx and Hsu (2015), pointed out that new ventures can adopt interim dynamic commercialisation strategies to achieve the ideal one. However, my cases have shown that interim strategies can be adopted also to find the final one. Furthermore, my findings indicate that a different strategic decision logic (i.e. causal or effectual - Sarasvathy, 2001) is adopted by organisations depending on whether it is used to support the achievement (i.e. causal) or the identification (i.e. effectual) of the ideal strategy.

My study contributes to the above literature, by providing empirical evidence of the BM typologies that accompany specific strategies. I found that organisations tend to adopt different types of BMs depending on whether they are achieving the ideal strategy or if they are identifying it. In particular, to identify the final strategy I have observed that organisations adopt either a consultancy BM (i.e. knowledge service provider (consultancy) BM) or a BM based on the supply of digital ICT solutions (i.e. product provider (digital ICT products) BM). Both types of BMs have a structure that can be changed and adapted according to the different needs with the investment of minimum time and costs.

2. Understanding the role of openness related to the link between BM and strategy for the commercialisation of emerging technologies

When organisations are either in the process of achieving or identifying the ideal strategy to diffuse their innovations into the market, they face challenges in dealing with uncertainties (Maine & Garnsey, 2006) and with the cognitive biases and structural constraints (e.g. resource availability) (Teece, 2010). Collaborations with other organisations can help in the sharing of risks, and hence, reduce the complexity of technology commercialisation for new ventures (Chesbrough, 2003). Along these lines, this thesis further extends the prior research on the link between BM and strategy, which has not yet fully explored the role of collaborations (i.e. open innovation/ open business model) within this context (Bogers, et al., 2016a). Thus, according to the literature, business strategies use collaborations either as an open innovation (OI) activity, or to develop a form of open business model (OBM) (Vanhaverbeke & Chesbrough, 2014). In addition to the existing literature, my findings indicate that that OI activities with closed BMs (outbound (2) and inbound (3)) and OBMs (outbound (5) and inbound (6)) (Vanhaverbeke & Chesbrough, 2014, pp. 54) could be developed at different times and might impersonate different strategic roles. This depends if they are supporting the design or the execution of the firms' strategies (how OI/OBM activities are developed is detailed in the following section – 6.1.2 at point 2).

6.2.2 Objective Ib: Identify the business model archetypes and their revolutionary potential within the collaboration frame

1. BM typologies for the commercialisation of technologies at the beginning of the technology diffusion process

Technology commercialisation is a complex process that has been studied for decades, and several researches, both of theoretical and empirical nature, have been contributing to enrich this literature. Most of the studies in the field have so far focused either on the overall processes that leads to the commercialisation of an innovation (see e.g. Datta, et al., 2015; Mitchell, 1989; Teece, 1986; Teece, 2007), or on specific aspects of the commercialisation process (see e.g. Garcia & Calantone, 2002; Soh, 2003). However, the literature on the commercialisation of innovation does not show the BM typologies for innovations' commercialisation at the beginning of their diffusion process (Datta et al., 2015; Rogers, 1962). My study contributes to fill this gap.

Datta et al. (2015) have recently contributed to the technology commercialisation process literature by detailing the three steps of ideation, development and deployment that an entrepreneur typically encounters when he/she aims to commercialise innovation/s in six sub-phases (i.e. innovation source, innovation type, market entry: competence and feasibility, protection, development and deployment). My thesis contributes to this literature, by identifying the different typologies of BMs used in the stages of the commercialisation process. I have observed that two knowledge-based BMs are pivotal in the early stages of the commercialisation/innovation diffusion process and are used to identify the key innovation users (Rogers, 1962): in the development stage of their commercialisation process ventures often adopt a research BM (i.e. knowledge service provider (research) BM) to find their 'innovators' users (i.e. funding institutions/investors) (Rogers, 1962). This typology of BM can help organisations to convince innovators (i.e. funding institutions/investors) to contribute to the development of a new technology. Organisations that are deploying their innovations into the market, have added to their core BM a supportive service BM (e.g. consultancy, demonstrations, workshops - i.e. knowledge service provider (consultancy) BM). This typology of BM was used to help the organisations to convince 'early adopters' (i.e. lead-users) (Rogers, 1962) to use their new technology.

2. Understanding the role of openness in BM development for early stage technology commercialisation

This dissertation adds to the literature which talks about the role of openness in BM development. In particular, the present research identifies the role of OI/OBM in the BM development process of digital technologies that aim to diffuse their innovations in an established environment. So far the literature on collaborations (OI/OBM) have provided a series of definitions of the concept of open business model (see for example: Frankenberger, et al., 2014; Vanhaverbeke & Chesbrough, 2014; Weiblen, 2014).

Along these lines, Vanhaverbeke & Chesbrough (2014) outlined a classification of the possible combinations of OI and OBM, whereby, they have identified six typologies of business models, either related to OI activities with closed commercialisation strategies or to OBMs related to collaborative commercialisation strategies. To date there are no empirical studies on how firms combine OI activities with either open or closed BMs (Bogers, et al., 2016a), especially in the context of digital technologies commercialisation (Bogers, et al., 2016b; Ford, et al., 2016). My research contributes to fill this gap by providing empirical evidence on the role of collaborations in BM development (OI/OBM).

By operationalising the classification outlined by Vanhaverbeke & Chesbrough (2014, pp. 54), I have noticed a further possible class of OI/OBM: the coupled-linked OBM (5+6), whereby an organisation simultaneously adopts outbound (5) and inbound (6) collaborative BM to commercialise its innovation. This is particularly the case when companies use a knowledge-based BM (i.e. research or consultancy) to identify the commercialisation strategy and to identify the innovators partners. However, for this latter purpose, organisations can also use OI but adopting a closed BM, by providing others with the firm's own knowledge to enable them to develop their innovations (e.g. via a consultancy BM). When the technology is more mature, and there is the need to attract lead users (i.e. early adopters), the open-linked BM changes. In this case, new ventures can develop and use a coupled-linked BM (the competence assembler BM), whereby, they can collaborate with partners to find a greater number of potential early adopters and commercialise a joint offer to the end customers (e.g. an experience based on 3D printing). New ventures seeking early adopters can also use an outbound OBM (5), whereby, they offer to customise their technology for the clients' needs. Often the technology customisation process is done jointly with the clients. Ventures looking for early adopters can also use an inbound OBM (6), whereby, they involve end customers in the supply chain, by giving them the role of designs providers. This concurs with the literature that highlights the central role of end customers as active players in the firm's commercialisation ecosystem (Bogers, et al., 2016; Rayna & Striukova, 2015). However, my cases show that the customers' involvement happens only in specific circumstances, such as in the BMs that provide personalised items (e.g. customised 3D printed confectionaries). Furthermore, ventures looking for early adopters can also use a closed BM, relying on inbound OI activities. These are the cases of ventures that rely on the support of partners for the development of a new product (inbound OI), but decide to vertically integrate the supply chain and commercialise though a closed BM (e.g. product provider (3DF printer) BM).

3. BMs and revolutionary potential

This thesis adds to the literature which talks about the BM development for the commercialisation of digital technologies. Whilst most of the contributions in this field have a conceptual nature (see for example: Bogers, et al., 2016; Jia, et al., 2016; Rayna & Striukova, 2016b), my cases add empirical evidence to the theory, providing a real sample that can be scrutinised to evaluate the revolutionary

potential of a digital technology, such as 3D printing, on firms' BMs in an established industry (i.e. new BMs against other BMs currently used).

Most of the prior research in the field highlights, among the main advantages enabled by 3D printing, its ability to deliver personalised and customised goods, as this was not possible with other technologies or tools (Bogers, et al., 2016). Along this line, prior research also highlighted the central role played by customers, who can become an active part of the supply chain (e.g. customers become the design providers of their 3D printed food) (Bogers, et al., 2016; Jia, et al., 2016; Rayna & Striukova, 2016b). These elements can enable, in most industries, new and revolutionary BMs. For example, Jia et al. (2016) outlined a potential disruptive BM for the traditional luxury chocolate market enabled by 3D printing technology. The authors detailed a retailer supply-chain centric BM, where the retailer is the focal firm and it produces the chocolate products using a 3D chocolate printer. The customer can either go to the retailer shop and create his/hers personalised 3D printed confectionery or can order the product online. This BM needs to reach the mainstream market in order to have a great impact on the external environment; otherwise, it does not add great differences to what is already enabled by the existing BMs in the food industry. Hence, in the food industry, even with traditional kitchen appliances and tools, anyone can develop their own personalised and customised recipes and food. Further, there are already many (small-scale) personalised food providers that distribute food to the users, and they have been doing this activity without 3D printing technology. So, for 3D printing technologies in food, nowadays, it seems to be difficult to enable disruptive BMs. As confirmation of that, as illustrated in my cases, among the main advantages enabled by the adoption of 3D printing technology (the key value proposition) there are: the reliability in obtaining particular food shapes and the possibility to scale-up the replicability of professional looking food. However, the organisations analysed are operating at a small-scale level, similarly to the already existing personalised food providers (e.g. bakeries, restaurants, food designers). So, the actual impact on the market is still low. Hence, the application of 3D printing in food reflects the case in which the radicalness of the technology does not (yet) have a disruptive impact on society (i.e. the external environment) (Rayna & Striukova, 2009). The disruptiveness might be reached along with some other technological innovation (Rayna & Striukova, 2016b).

Even though a digital technology in an established industry, such as 3D printing in food, enables organisations to develop BMs with a certain degree of novelty, so far the diffusion of this technology is not sufficient enough to allow the development of BMs that present great novelty in comparison to the traditional BMs already existing in the food industry. These BMs will might have a stronger impact when the 3D printing of food will reach the scale of mass-customisation of food.

However, most BMs, present in the sample, introduce some differentiation to the BMs which rely on Open Innovation already outlined in the mass food industry (e.g. compare to Bigliardi & Galati, 2013).

This is an indication of the potential for disruption in future times, when/if the technology becomes adopted industrially. For instance, in addition to what is illustrated by Bigliardi & Galati, (2013), my cases show that 3D printing food providers give the customers an integral role in the supply chain by becoming the designer providers of their personalised 3D food printed products (inbound OBM, 6).

6.3 Expanded aim II: What are the BMI dynamics in the commercialisation process of an emerging technology in an established industry?

6.3.1 Objective IIa: Identify the patterns in the process of BMI

1 BM design and BM reconfiguration in the technology commercialisation process

This dissertation contributes to the stream of the literature that looks at the processes of BMI. So far, scholars have separated the designing process for creating new business models (i.e. business model design - BMD) and the reconfiguration process (i.e. business model reconfiguration - BMR) for changing the BM in already existing firms (Massa & Tucci, 2013). The literature refers to the BMI phases of BMD and BMR as constant processes that happen in a sequential order (Dmitriev, et al., 2014; Zott & Amit, 2010). Also Spieth et al. (2014) outlined the differences between the processes of BMI aimed to design a new BM from those focused on the development of already existing BMs. However, contrasting with the existing literature, I have observed across the sample that BM reconfiguration, which typically is attributed to incumbent firms (Massa & Tucci, 2013), can also be found in new ventures. Furthermore, sometimes both BMI processes (BMD and BMR) can co-exist for BM extension and revision (Cavalcante, et al., 2011).

2 BMI dynamics in the technology commercialisation process

I looked at the BM dynamics in the BMI processes of organisations which try to legitimise and diffuse their innovations in an established environment (Rogers, 1962). So far the literature, which talks about this topic has highlighted that often emerging technologies ventures develop their BM through a 'trial and error' learning process (Lubik & Garnsey, 2015). Sosna et al. (2010) observed the 'trial and error' of an established organisation in the BM development. Their study outlined that BM development, through a 'trial and error' approach, is a strategic development mechanism adopted by organisations. However to date, only a few scholars have attempted to highlight the various stages and the patterns of these processes. A series of patterns concerning the process of BMI have been highlighted (see for example: Aversa, et al., 2015; Casprini, et al., 2014; Cavalcante, et al., 2011; Dmitriev, et al., 2014).

However, as highlighted also by Cavalcante et al. (2011) and Achtenhagen et al. (2013), there is the need to understand the patterns in the BMI processes, especially in the cases of organisations that are trying to diffuse their innovations in an established industry (Probert et al., 2013). My cases contribute to this gap, by detailing how organisations operationalise the 'trial and error' process of BMI. From the analysis of my cases four patterns in the BMI process emerged. Two of the BMI patterns identified (i.e. i) single BM archetype evolution path and iii) changing BM archetype evolution path – see chapter five, section 5.3.2) aligns with the ones identified by Casprini et al. (2014). While another BMI pattern identified (i.e. the ii) multiple BM archetype evolution path - chapter five, section 5.3.2) aligns with the 'augmenting' BM modulation conceptualized by Aversa et al. (2015). However, my cases highlighted another pattern in the BMI process (i.e. the multiple-changing BM archetype evolution path). In this pattern, ventures switching from seeking funding (from innovators), through a combination of a research BM and a knowledge service BM (e.g. workshop and demonstrations), to finding early adopters (lead-users), through a combination of a business-related BM (e.g. product provider) and a knowledge service BM (e.g. workshop and demonstrations). I have noticed that this BMI pattern has been used to reduce the issues that can arise in a venture during the transition process from the first innovation diffusion phase (i.e. find the innovators users) to the following one (i.e. finding the early adopters users).

6.3.2 Objective IIb: Identify the triggers and the degree of innovativeness associated with different types of BM changes

1. BM innovation triggers

Among the patterns emerged in analysising the organisations' BMs at the beginning of the innovation diffusion cycle, the customers feedback and the marketing/support are two reasons that have a strong impact on the firms' BMI processes.

The existing literature on BMI triggers (e.g. Casprini et al., 2014; Demil & Lecocq, 2010; Dmitriev, et al., 2014; Johnson, et al., 2008), highlights that the change in market demand is most often the cause for a BM archetype change. In particular Dmitriev et al. (2014), who looked at early stage BMs for the commercialisation of technological innovations, identified internal (e.g. revenue estimations, network of partners and needed equipment), external (e.g. changes in the demand, technological advancements, geographic expansion) and contextual (e.g. the organisation's human resources, the target market and the nature of the invention) as main triggers that enhance the innovations in the BM. However, in addition to Dmitriev et al. (2014) I saw that a positive feedback given by the customers, which indicates the maturity of the technology, or its potential to move further along the innovation diffusion curve, can prompt a change in the BM. Further, the organisations that added an additional layer to the core business, this is usually driven by marketing needs when firms have limited resources and capabilities.

2. Degree of innovativeness in BMs changes

Another perspective to look at radicalness, different from the one highlighted in the previous section (6.1.2 – point 3), it refers to the radicalness of the firm itself. So, further considerations concern the degree of innovativeness associated with different types of changes in the BMs (Dmitriev et al., 2014). The identification of the degree of innovativeness of a BM is a very complex process. Some scholars (see for example: Brink & Holmén, 2009; Demil & Lecocq, 2010), look at the degree of innovativeness of the BM from an internal perspective (i.e. the more dimensions change in a BM, the more the innovation of the BM is radical). Other scholars look at the innovativeness of the changes in the BM with an external perspective (e.g. Johnson et al., 2008). In this case, the degree of disruptiveness of the BMI is identified according the impact of the new BM on the external environment. As seen above, even if important changes happen in the BM (e.g. introducing a new BM to the core BM), they do not initially necessarily reflect a great radical change. In a recent study, Rayna & Striukova (2016b) developed a conceptual framework (i.e. the inside-outside BMI framework) that merges the internal and external perspective of BMI process (see chapter two, section 2.4.2). However, their study is based on conceptual reasoning based on a small number of examples. This thesis contributes to advance the literature that talks about the degree of innovativeness when BMs change, by operationalising the Rayna & Striukova (2016b) inside-outside BMI framework. My cases show that the BMI cycles presented different combinations of inside-outside BMI according to the different types of BM changes. Overall, it emerged that, even if organisations change more than one BM dimension, the actual changes in the BMs are minor, as it is the impact on the external environment. Hence, as already observed for the influence of the technology on the BMs, also the innovations in the BMs do not lead to strong effects on the external environment.

6.4 Summary of discussion

This chapter outlined the insights on how BMs are framed in the commercialisation processes of a new technology in an established market. From this analysis a series of patterns emerged with regard to the links between strategic choices and specific business model solutions, the business model archetypes and the influence of the new technology on the business models, the role of collaborations in the above mentioned contexts. Additional patterns emerged concerning the business model innovation processes of emerging technologies ventures and their development mechanisms (i.e. triggers and degree of innovativeness). The patterns that emerged from the discussion are summarised in the following chapter (see section 7.2). Furthermore, the results emerged in this chapter have been used to provide empirically-driven results to implement the *a priori* framework developed in chapter two.

The next and final chapter of this thesis details the conclusions of the work. This chapter outlines the contribution to academia, the contributions of this research to practitioners as well as the limitations and the possible future developments.

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Chapter 7 Conclusion

7.1 Chapter introduction

The literature has taken several perspectives to explain how technological commercialisation happens: technology commercialisation, strategy, (collaborative) business model and business model innovation are all fields which concur to explain this phenomenon.
The commercialisation of emerging technological innovation in an established industry, typically resistant to changes and with high barriers to entry (Pellegrini, et al., 2014), has been understudied (Jia, et al., 2016; Probert et al., 2013).
This thesis has investigated how business models are framed in the commercialisation processes of a new technology in an established industry. More specifically, I have investigated organisations in the commercialisation processes of 3D printing-related innovations in the food industry. This is the case of firms which find themselves at the beginning of the innovation diffusion curve described by Rogers (1962).

In this chapter the contributions derived from the findings and discussions are divided into contributions to theory and contributions to practice. The limitations and suggestions for possible future research developments are then detailed.

7.2 Contribution to knowledge

The present study highlighted several contributions to theory with the aim to answer to the four main research objectives. Furthermore, the *a priori* framework initially developed in the literature part of the thesis (see chapter two, section 2.5) was implemented (section 7.2.1). A summary of the contributions to knowledge that this dissertation detected are highlighted in table 31. Table 31 shows: 1) the overall research aim, 2) the two expanded aims, 3) the research objectives derived from the gaps outlined in the literature (chapter two), and 4) a summary of the corresponding main theoretical contributions outlined in the discussion (chapter six).

Aim	*Expanded aims*	*Objectives*	*Contributions to knowledge*
How are business models framed in the commercialisation processes of a new technology in an established industry?	***1) Static RQ**:* What types of business models emerge when firms commercialise a new technology in an established industry?	**Ia.** Identify the links between strategic choices and specific business model solutions within the collaboration frame (Baden-Fuller & Haefliger, 2013; Bogers, et al., 2016a; Datta et al., 2015; Spieth et al., 2016)	1. The literature on the BM-strategy link confirmed that the BM is related to the execution of the firm's strategy (Cortimiglia et al., 2016). However, new technology ventures often adopt interim strategy to achieve the ideal one (Marx & Hsu, 2015). In addition to the existing literature, I observed that interim strategies are used also to identify the ideal strategy. To this are associated two types of BMs: knowledge service (consultancy) and product provider (digital ICT).
			2. According to the literature on the BM-strategy link, business strategies use collaborations either as an open innovation (OI) activity or to develop a form of open business model (OBM) (Vanhaverbeke & Chesbrough, 2014). My findings contribute to this literature, by indicating that that OI (2+3) and OBM (5+6) (Vanhaverbeke & Chesbrough, 2014, pp. 54) could be developed at different times and might take different strategic roles. This depends if they are supporting the design or the execution of the firms strategies (Cortimiglia, et al., 2016) (how OI/OBM activities are developed is detailed in objective Ib at point 2).
		Ib. Identify the business model archetypes and their revolutionary potential within the collaboration frame (Bogers et al., 2016a; Bogers, et al., 2016b; Ford et al., 2016)	1. The literature on technology commercialisation focuses mostly on the whole process or on specific aspects of it (e.g. Datta et al., 2015; Garcia & Calantone, 2002), but it does not show the BM typologies for innovations' commercialisation at the beginning of their diffusion process. My cases show the different type of BM associated with particular stages of the commercialisation and diffusion of innovation processes.
			2. The literature on collaborations in BM development provided a series of definitions of the OBM concept, but there are not empirical evidences on how firms combine OI activities with either open or closed BMs (Bogers, et al., 2016b), especially in the context of digital technologies commercialisation (Bogers, et al., 2016; Ford, et al., 2016). My research contributes to fill this gap by providing empirical evidence on the role of collaborations in BM development (OI/OBM).

			I have operationalized the Vanhaverbeke & Chesbrough (2014, pp. 54) OI/OBM classification and identified an additional class: the coupled linked OBM (5+6). Furthermore, I have observed that specific collaborative activities (OI/OBM) are associated to different types of BMs. For instance, the coupled-linked BM is used to: explore business opportunities, develop knowledge and create platforms.
			3. Most of the literature on the BM development for the commercialisation of emerging technologies is conceptual (see for example: Bogers, et al., 2016; Jia, et al., 2016; Rayna & Striukova, 2016b). My cases add empirical evidence to the theory. I observed that the diffusion of the technology (i.e. 3D printing) is not sufficient to allow the development of BMs that present great novelty in comparison the traditional BMs already existing in the food industry. The BMs based on 3D printing technology in food will might have a more disruptive impact when they will reach the scale of mass-customisation of food.
	2) Dynamic RQ: What are the BMI dynamics in the commercialisation process of an emerging technology in an established industry?	**IIa**. Identify the patterns in the process of BMI (Achtenhagen, et al., 2013; Cavalcante et al., 2011)	1. So far the literature on the BMI process separates the BM design (BMD) from the BM reconfiguration (BMR). The first is typically associated to new ventrues, while the second to existing firms (Massa and Tucci, 2013). In contrast to the literature, my cases show that BMR can happen also for new ventures and that BMD and BMR can sometimes co-exist and run in parallel.
			2. So far the literature has highlighted a series of patterns concerning the process of BMI (see for example: Aversa, et al., 2015; Casprini, et al., 2014; Cavalcante, et al., 2011). However, the literature did not show the BM dynamics in BMI of organisations that are trying to diffuse their innovations in an established industry (Achtenhagen, et al., 2013; Cavalcante, et al., 2011). My cases contribute to this gap. I have observed four patterns: i) single BM archetype evolution path, ii) multiple BM archetype evolution path, iii) changing BM archetype evolution path, and iv) the multiple-changing BM archetype evolution path. In the latter pattern, ventures switch from seeking funding from innovation to find early adopters.
			1. The literature on the BMI triggers, highlighted a series of factors that enhance the changes in the commercialisation process of emerging technologies (Dmitriev et al., 2014). My study contributes to

		IIb. Identify the triggers and the degree of innovativeness associated with different types of BM changes (Dmitriev et al., 2014)	the literature on BMI triggers, by having identified two further triggers: customers feedback and marketing/support.
			2. The literature which talks about the degree of innovativeness of the BMI tend to present either an internal or an external perspective. Rayna & Striukova (2016b) conceptualized an inside-outside BMI framework that merge the different perspective. My cases have added empirical evidence to their framework. In my cases, even though great changes take place in the BM dimensions, they are not reflected in major changes of the BM neither present a disruptive impact on the market.

Table 31 Summary of the contribution to knowledge

7.2.1 Implementation of the a priori framework

This study provides a framework to help understanding of how the themes analysed can be linked together with the ultimate aim to provide a support for new organisations in their commercialisation processes. For this purpose, I have used the observations emerged from the findings (chapter five) and from the discussion (chapter six) to conceptually reconfigure the *a priori* framework developed in chapter two (section 2.5).

In the process of commercialising an emerging technology in an established industry, such as 3D printing in food, organisations usually decide the strategies needed to get into the market during the 'Development' stage. In this phase it has been shown that new ventures tend to adopt niche strategies to get into the market (Christensen, 1997; Christensen & Rosenbloom, 1995; Davidow, 1986), concurring, with what was stated by one stream of the innovation literature, and supported by the analysis on AM technologies (De Jong & De Bruijn, 2013). However, this finding was contrasting to the market entry strategies for commercialisation in mature industries (i.e. differentiation strategies), suggested by (Grant, 2016).

The literature on emerging technologies commercialisation describes these processes as often being characterised by high technology and market uncertainty along with scarce resources and capabilities. Organisations operating in these complex contexts are keen to reduce the risks generated by uncertainties through strategies that rely on the support of other actors (alliances, joint ventures). Within this context, Marx et al. (2014) and later Marx & Hsu (2015), highlighted that new ventures can adopt co-operative interim strategies to achieve the ideal one.
From the case studies analysed here, it emerged that between the 'Development' and the 'Deployment' stage of the technology commercialisation process, new ventures can develop interim strategies to achieve the final one (Marx, et al., 2014; Marx & Hsu, 2015) but also occasionally to identify the ideal one. In this case, firms tend to adopt two types of flexible BMs: a knowledge service BM (consultancy) or a product provider BM (digital ICT).
In addition to the literature on technology commercialisation and innovation diffusion (Datta et al., 2014; Rogers, 1962), my cases show that organisations at their commercialisation developement stage tend to adopt a research BM that is used to seek 'innovators' users. Within the 'Deployment' stage of commercialisation, usually the BM finds its definition. In this phase the organisations tend to adopt supportive BMs to find early adopters and to convince them to use their technology. As many scholars in the technology commercialisation literature have highlighted, collaborations play a crucial role in a new venture's capability to reduce the risks generated by uncertainties (Maine & Garnsey, 2006). Within the BM context, the role of collaboration is expressed through the influence that the network

(i.e. the value network dimension) has on the other elements of the BM. In addition to what was highlighted in the *a priori* framework, based on Vanhaverbeke & Chesbrough (2014), whereby the openness of the BM can include only the BM dimensions of: value delivery, value creation and value capture, I have observed that organisations can open up all the BM dimensions. Some organisations open up all (or almost all) their BM dimensions, when they are exploring new business opportunities, enhancing knowledge or developing platforms (these are the cases of coupled-linked OBM 5+6). In other cases, such as the 3D printed food providers, where the firms involve the customers in the supply chain, they open up the value creation and value delivery dimensions (OBM 6).

To work out the complexity of the environment and successfully commercialise innovation, ventures need to be able to change and adapt their strategies and reflect these changes in their BMs. So, the BMI is placed in the 'Deployment' phase of the commercialisation process. I have observed that once organisations have defined the first BM, they constantly reconfigured their BMs according to different patterns (i.e. complete reconfiguration, small constant reconfigurations, reconfigurations with the addition of a new BM layer). Thus, contrasting with the existing literature, I have observed across the sample that BM reconfiguration (BMR), which typically is attributed to incumbent firms (Massa & Tucci, 2013), can also be found in new ventures. Furthermore, sometimes both BMI processes (BMD and BMR) can co-exist for BM extension and revision (Cavalcante, et al., 2011).
Often the changes in the BMs of new technology ventures happen according to a 'trial and error' processe (Lubik and Garnsey, 2015). In addition to the literature on the BM dynamics of BMI, the patterns observed in the BMI process lead to identify four main types of BM changes across the 3D food printing organisations: single archetype (i)(Casprini, et al., 2014), multiple archetype (ii) (Aversa, et al., 2015), changing archetype (iii)(Casprini, et al., 2014), but also a multiple-changing archetype (iv). By considering the existing literature, the multiple-changing archetype that I have observed is new. It takes place when organisations include a supportive BM to the core BM. However, when the organisation, for various reasons, changes the BM archetype, the firm adds to the new core BM an additional layer. Organisations often use the supportive BM to seek early adopters who are willing to use the organisations' technologies.

Each BMI process is set off by either endogenous or exogenous triggers (Casprini et al., 2014; Demil & Lecocq, 2010; Dmitriev, et al., 2014; Johnson, et al., 2008). I have observed that different triggers can be associated to different types of BM changes. For instance, among the organisations that changed their BM archetype over time (iii), the triggers are usually related either to the failure of the previous BM (as highlighted by (Demil & Lecocq, 2010)), but also to a positive feedback given by the customers, which indicates the maturity of the technology, or its potential to move further along the innovation diffusion curve. Furthermore, the organisations that added an additional layer to the core business are usually driven by marketing needs in limited resources and capabilities regimes.

The changes in the BMs (i.e. ΔBM) can have different degrees of innovativeness (i.e. more radical or incremental), depending on how many BM dimensions change at the same time, their degree of change in the BM (internal view), and the impact of the new BM on the external environment (external view) (Rayna & Striukova, 2016b). Adding empirical evidence to the Rayna & Striukova (2016b) inside-outside BMI framework, I have observed that even when great changes in the BM dimensions take place, these changes do not necessarily imply a great change in the external innovativeness of the BM itself. I have observed among the various cycles of BMI in the sample, that the innovations in the BM did not generate a disruptive impact on the external environment.

7.3 Contribution to practice

The research provides practitioners in large companies and entrepreneurs a better understanding of three main aspects:

1. Possible commercialisation strategies and BMs for new technologies such as 3D food printing

Organisations in the early stage of commercialisation activities for new technologies have limited resources, but they can consider adopting interim strategies and BMs. These interim strategies can be used by practitioners not only to achieve an already defined ideal strategy, but also to identify a suitable one. In these cases, organisations tend to adopt flexible BMs, such as a consultancy BM or a BM related to the provision of digital solutions.

Regardless of whether organisations are adopting interim strategies or not, if they are at their early stage of the innovation diffusion process they use different type of BMs depending on their innovation diffusion and commercialisation stage. Thus, organisations that are developing their products, at the beginning of their innovation diffusion cycle, they tend to use a research BM to find 'innovators' (i.e. investors). When the technology is more mature, organisations need to switch from seeking innovators to finding lead-users. To do so, firms usually adopt supportive BMs (e.g. a food service BM, a consultancy BM) to the firm's core BM. By adopting supportive BMs organisations can, therefore, diffuse their business and at the same time make profits. The above described finding can be interesting for managers who want to have insights on the possible types of BMs that they can use depending if they are seeking for innovators or lead users.

Firms at the beginning of their commercialisation process often change and/or adjust their initial BM. This usually happens through a 'trial and error' learning process. By observing the BM dynamic of BMI, practitioners can enhance their understanding on the process through which a technology organisation can innovate its BM. From my observations, these BM changes can take place through

four main patterns: i) not changing the main BM archetype, just adjusting it; ii) adding to the core BM archetype a supportive BM; iii) changing completely the BM archetype; and iv) adding to the core BM a supportive BM, then changing the core BM archetype and adding a new supportive BM.

2. The role of collaborations

The role of collaborations can be of strategic importance for early stage organisations commercialising 3D printing in the food industry. Practitioners and/or entrepreneurs should consider collaborating either with other players within the supply chain, or with customers to enhance the commercialisation of their products/services. The type of collaborations that organisations can adopt can vary, depending on whether they are at the initial stage of their innovation diffusion cycle seeking for innovators, or if organisations have a more mature technology. In these latter cases firms are more advanced in their innovation diffusion cycle and are looking for early adopters to convince them to use their innovation. In terms of collaborations, organisations at the initial stage of their diffusion cycle can use a coupled-linked BM (the research BM) whereby they can develop with partners new innovation and they can collaborate with the same partners also to develop the commercialisation process. Organisations can use a coupled-linked BM also to identify new business opportunities (the consultancy BM). To do so, organisations can also use a closed BM to provide clients with the firm's own knowledge to help them in the realisations of their innovations (outbound OI). When the technology is at a more mature stage, firms can use an open linked-BM to develop platforms (the competence assembler BM). In these cases, organisations can collaborate with partners to reach a greater number of lead users (i.e. early adopters) and commercialise a joint offer to the end customers. New ventures seeking for early adopters can use also different types of OBM depending on their main aim. For instance, an outbound OBM can be used when organisations offer to customise their own technology for clients. In this case organisations, collaborate with clients to tailor the technology according to the clients' needs. This type of BM can be used by organisations also to scope new business opportunities. On the contrary, an inbound OBM can be used by organisations when they want to involve the end customers in the commercialisation ecosystem, by making them the designer providers of the ventures for 3D food printed products. Finally, ventures looking for early adopters can also use a closed BM, but can rely on, and/or have relied on, OI activities to develop of a new offering (inbound OI). This is usually the case of organisations that provide the 3D food printer appliance.

3. Commercialisation of AM in food industry

3D food printing organisations often commercialise their innovations in niche markets. However, until the BMs are deployed by mass producers of food for food mass-customization, the new-digital technology does not have a great impact on the degree of radicalness of the BMs in the food industry.

Therefore, practitioners can consider to partner up with other actors of the supply chain, and/or with larger players within their target market to facilitate the processes needed to reach the food mass-customisation.

7.4 Limitations

This thesis work was exploratory in nature and this lead to mainly empirically-driven results. It adopted a grounded approach to provide insights on how BMs are framed in the commercialisation processes of AM technologies in the food industry.

The sample of this study was selected to understand how BMs are framed under the specific circumstances mentioned above. However, at this stage it is hard to define with certainty what a 'successful' BM is, since the case studies analysed are at their early stage of development.
Furthermore, as the case studies have been selected as representative of a 3D food printing ecosystem, however, they may not encompass all of the possible variations of the BM in the field.

Another limit of the research is the fact that the interviews were conducted mainly with one informant in each firm; therefore, it was possible to capture only one perspective of the BM evolutions of the firms. Additionally, through direct interviews, I cannot exclude that I could have indirectly influenced the informant on his/her BM and strategies.

As the analysis is focused on a very niche and emergent market, the results, therefore, may not be generalisable to other contexts. This can open up further paths for new studies.

7.5 Future research developments

From the present research it is possible to detect some useful indications for the near future research avenues. Hence, it would be important to extend and compare the results that have emerged here with other markets, in order to make the results obtained in this thesis more generalisable. As well as other markets, it would be interesting to extend and compare the research with other emerging digital technologies in the food industry (e.g. near field communication in food traceability).

Furthermore, the novelty of applications of AM in the food industry seems to have not yet displayed its potentialities, that would be expected to take place once the technology would reach the mass-

customisation level. Therefore, an interesting path for future studies would be to do a longitudinal study on the evolution of AM in the food industry.

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