Business Models for the Commercialisation of Digital Technologies in Established Markets: 3D Food-Printing

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ABSTRACT

Seeking an understanding of the use of open innovation and open business models to support commercialization strategies, this paper reviews the business models choices of 11 business that are trying to establish themselves in the food industry through the commercialization of digital (additive manufacturing) technologies. We find that, although the advantages of the digital technologies (e.g. flexibility and possibility to deliver food customization) are encompassed in the majority of BM configurations and implemented through open business model choices (e.g. via the involvement of communities of users in the delivery of designs and recipes), in this industry these BMs do not constitute a substantial departure from those traditionally available via non –digital technologies. We further draw conclusions on the configurations of (open) business models to deliver on commercialization and growth strategies of firms in established markets.

1. Introduction

The coming of age of a range of digital manufacturing technologies, such as additive manufacturing (AM), is offering firms new opportunities for creating and capturing value (De Jong and De Bruijn 2013, Thiesse, Wirth et al. 2015, Bogers, Hadar et al. 2016, Rayna and Striukova 2016). These technologies are being developed and commercialized in various industries, both emerging and established. In these latters, the new possibilities offered by AM are expected to force new manufacturing and consumer-centered logics in both innovation development and in the commercialisation of the innovation. Hence, the expectation is that AM will be able to break the established business rules, especially in established industries such fast moving consumers goods, where digital manufacturing could deliver the innovation required to support the delivery of future sustainable products and services, which comply with the emergent market needs and social trends (De Jong and De Bruijn 2013, Bogers, Hadar et al. 2016). This is particularly the case of the food industry, a very well established sector where traditionally products are commoditized, innovation is incremental (Zairi M. 1995) (Garcia Martinez, 2013), and the tendency is to seek manufacturing cost-savings along the very long and complex supply chain (Jia, Wang et al. 2016). The food industry is changing under the pressure to adapt to new market requirements and is eager to seek opportunities for product customization (Jia, Wang et al. 2016), which specifically addresses customers' individual nutritional health needs and taste predilections (Sun, Zhou et al. 2015). These innovative solutions can only be achieved through the management of collaborations across actors in a complex supply chain, through open innovation (OI) and open business models approaches (OBM) (Bigliardi and Galati 2013). AM, not only offers potential technical solutions, but also new opportunities for establishing both OI and OBM approaches, by managing collaborations across an extended range of innovation and commercialization partners (Chesbrough and Bogers 2014).

Therefore, the study of how AM is being commercialized in the food industry can provide a great opportunity to complement the current theoretical understanding of different inter-related phenomena:

- It might be able to enhance the understanding of how technology commercialization processes for emergent technologies are shaped (Datta, Mukherjee et al. 2015), in particular in established industries. This is a context which has often been neglected in previous studies (Probert, Dissel et al. 2013).

- It allows to appreciate how the technology commercialisation process works for digital technologies and the particular role that open innovation (OI)(Chesbrough 2003) and open business models (OBM)(Vanhaverbeke and Chesbrough 2014) approaches play in the shaping of these pathways (M. Bogers, Darwin, Zobel, & Sims, 2016; Ford, Mortara, & Minshall, 2016). In doing so, it helps knitting together the emerging field of open innovation, whose routes are in the innovation management literature, with those of strategy (Vanhaverbeke, Cloodt et al. 2014)
- It has potential for assisting the understanding of the links between technology strategies and business model choices (Baden-Fuller and Haefliger 2013).

Seeking an understanding of the use of open innovation and open business models to support commercialization strategies, this paper reviews the business models choices of 11 business that are trying to establish themselves in the food industry through the commercialization of additive manufacturing technologies.

2. Theoretical background

The commercialization 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, Mukherjee et al. 2015). This capacity is often the prerogative of new firms who try to establish themselves in new or existing markets by exploiting their technological knowledge. Throughout the commercialization process firms develop strategies to penetrate the designated market and define appropriate business models that describe how the value from the innovation is going to be captured (Lubik and Garnsey 2016). Business models explain the target market and the appropriate value proposition, the resources needed, and the placement of a firm in a value chain, playing a crucial role in the creation of competitive advantage (Casadesus-Masanell and Ricart 2010). Firms that are commercialising new technologies face complexity in managing this process independently, because they have to face a wide variety of market and technological uncertainties (Maine & Garnsey, 2006). Collaborations with other organizations can help in the sharing of risks, and hence reduce the complexity of technology commercialisation for these new ventures (Chesbrough, 2003). Hence, firms often manage the commercialization process across a group (ecosystem) of innovation participants. This happens through both open innovation (OI) and through the design of open business models (OBM). Whilst the first describes particularly the development of the innovation, whereby organisations match internal and external resources to develop an innovation (Chesbrough 2003), for the launch of the technological innovation on the market companies often need complementary innovation and for that purpose they need to orchestrate "value constellations" and design open (or linked) business models with partners (Iansiti and Levien 2004, Vanhaverbeke and Chesbrough 2014). Hence, the management of collaborations becomes of strategic importance for firms to gain competitive advantage (Iansiti and Levien 2004, Spithoven 2013). Through collaborations firms can identify new ways not only to develop innovation, but also to appropriate value in more ways (Vanhaverbeke & Chesbrough, 2014). These themes have all been debated in literature. However, due to their origins in different theoretical backgrounds which bridge across the strategy, innovation and entrepreneurship traditions, these issues are still substantially disconnected. We present an overview of these contributions and the existing gaps below.

2.1 The commercialisation of new technologies: process, strategies and business models

Past literature has taken a dual view of technology commercialization. Some see this as part of the innovation process (Burgelman, et al., 2004), others as part of the diffusion of these into the market (e.g. Nambisan & Sawhney, 2007; Nerkar & Shane, 2003). Taking an innovation management perspective (Datta, Mukherjee et al. 2015) identified six main steps that lead the technological innovations into the market, based on three main phases of the innovation process: ideation, development and deployment (Teece, 1986; Teece, et al., 1997). Whilst 'Ideation' consists of the discovery, the idea generation and the market recognition, the last phase, 'Deployment', concerns the launch of the product into the market. It is during the 'Development' stage that decisions on the strategies needed to gain entry in the market, and the process of protecting the innovation, take place (Datta, Mukherjee et al. 2015). In terms of the outcomes of this phase, the strategy literature suggests contrasting commercialization strategies for new technologies to be adopted: whilst, as anticipated in the studies on disruptive innovation, it is harder for large firms to take up opportunities where the market is yet to be completely defined, according to some, small firms should choose niche strategies to identify their competitive advantage, away from the area of influence of incumbents (Christensen 1997) This is particularly appropriate for innovation based on emerging technologies (Davidow, 1986). However, for generic technologies, sometimes the highest value part of the market might present opportunities for the new firms (Lubik and Garnsey 2016). In contrast, (Nerkar and Shane 2003) suggest that technology-based venture should diversify in several markets to have more chances to survive, although (Maine and Garnsey 2006) point out how this strategy can be difficult to follow for young and resource-constrained firms. (Maine, Lubik et al. 2012) and (Lubik and Garnsey 2016) suggest a tradeoff between the two.

Often the risks for the commercialisation of one technology include those for the commercialisation of other complementary innovations, current or future. Independently from their experience, firms face challenges in dealing with the intrinsic complexity in technology commercialisation due to cognitive biases and structural constraints. For instance, established organisations might underplay value emerging from new technologies and might become trapped in their established ways (path dependencies) (Demil, Lecocq et al. 2015). In contrast, new firms, particularly those involved in establishing commercialisation for generic technologies, find themselves unable to choose amongst the great number of market options available (Maine, Lubik et al. 2012), suffer from lack of legitimacy and, as a result, struggle to access the necessary resources for new venture creation. Facing these uncertainties, firms interpret the future in different ways: some see a clear-enough future, others a range of futures, a set of alternative futures or true ambiguity (Courtney, et al., 1997). However, companies have mostly stopped managing this process independently, facing market and technological uncertainties alone (Maine and Garnsey 2006). Collaborations with other organizations can result in the sharing of risks and hence reduce the complexity (Chesbrough, 2003). In fact, recently, Marx et al.

identified that startups who commercialise their technologies and lack the complementary assets to develop directly their 'ideal strategy', develop subsidiary co-operative strategies to access key complementarities and to gain legitimization in the eyes of incumbents (Marx, Gans et al. 2014, Marx and Hsu 2015). Hence, as part of the deployment phase (Datta, Mukherjee et al. 2015), sometimes well before products or technologies reach complete maturity (Lubik and Garnsey 2016), the ecosystem of partners (Iansiti and Levien 2004, Adner and Kapoor 2010) - i.e. the actors contributing to define the value of a new technology, including suppliers, complementors, downstream players and final customers and policy, support and regulatory institutions – are defined in the business models (BM) which could deliver on the strategy (Casadesus-Masanell and Ricart 2010) (Fig. 1).

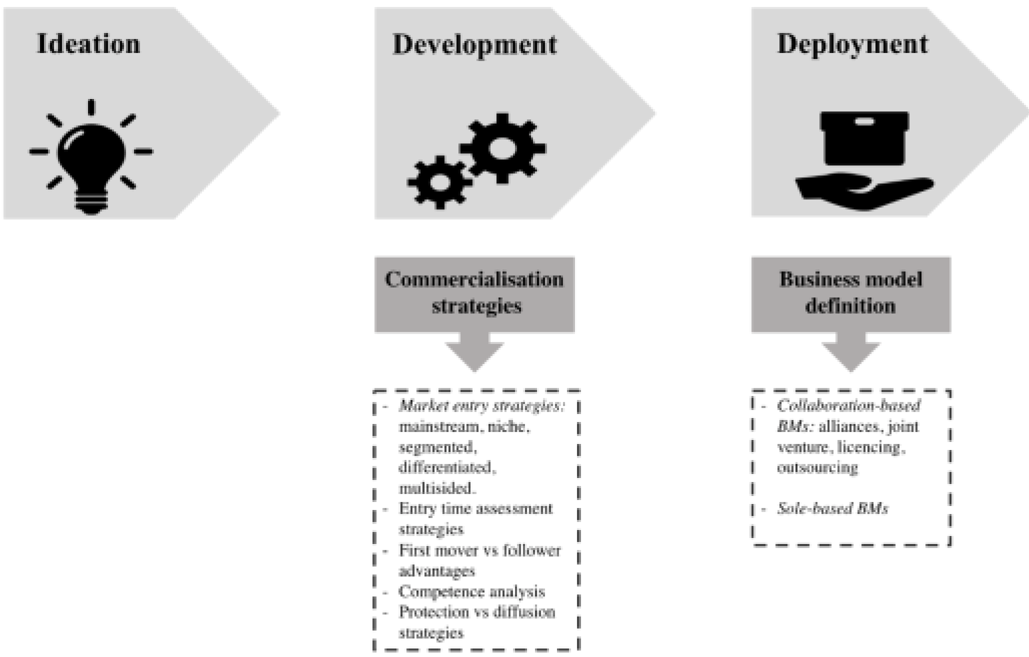

Fig. 1: Technology commercialisation process: strategies and business model definition stages
Source: adapted from (Casadesus-Masanell & Ricart, 2010; Datta, et al., 2015; Osterwalder & Pigneur, 2010)

The BM represents an organisation's essential activities in simplified form (Teece 2010 . The BM specifies the key elements of the commercialisation strategy, including the intended market and value proposition for the intended users, the internal and external resource requirements, the value capture method, and the position of the firm in the value chain and often firms develop and follow more than one BM at any one time. The BM is sometimes is explicitly outlined whilst at other times it remains implicit (Baden-Fuller, 2013)

Despite the breadth of different definitions, a system view of BMs is generally taken, confirming that BMs link the key elements of a business (see Fig 2.): (1) the value proposition for the market, (2) the value capture mechanisms, (3) the value creation resources and the (4) means for the delivery of value (Zott, Amit et al. 2011). However, considering that, particularly in technological innovation, “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”, (Vanhaverbeke and Chesbrough 2014) the (5) value network is often a necessary component of a BM (Fig. 2).

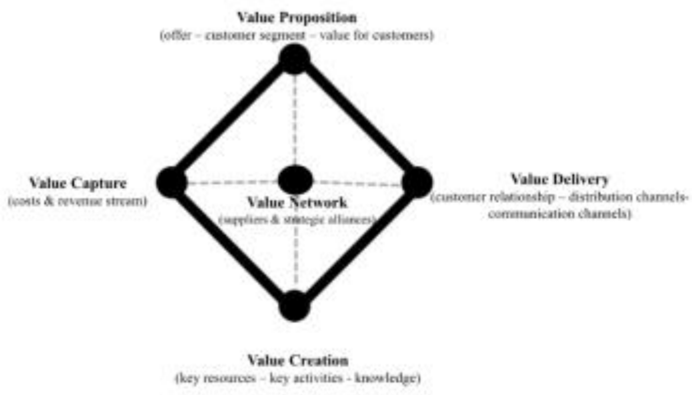

Fig. 2: Network-centric business models

The resulting shape of BMs can be classified to identify typologies and BM archetypes (Massa & Tucci, 2013). An archetype can be understood as a general example of a BM and many categorizations of BM archetypes exist (e.g. (Gassmann, Frankenberger et al. 2013)). An example of an archetype is "the Razor-and-blade BM", which relies on ‘selling cheap razors to make customers buy its rather expensive blades’ (Zott & Amit, 2010, p. 218). The particular forms of BMs, dependent on others' capabilities and complementary innovations for the delivery of value, are defined as Open Business Models (OBM) (Vanhaverbeke and Chesbrough 2014). However, even in cases when the BM is defined as closed, the company can access external knowledge via open innovation processes (inbound, outbound)

(Vanhaverbeke and Chesbrough 2014). In this sense, these authors have developed an initial classification of BMs types (Open or closed), linked with the OI processes which deliver them (see table 1).

Business Models Outcomes → **Open Innovation process ↓**	**Stand Alone BM** **(value of the offer achieved independently. Complementary assets are offered through vertical integration or/on transactional basis)**	**Linked BM** **(product/services marketed through availability of complementary assets which are offered via collaborative agreements)**
Inbound	3. Look for other people knowledge to develop product/service which is offered without the help of others	6. look for others knowledge to for a new BM
Outbound	2. Offer internal knowledge to others for them to develop new product /service which is commercialized without our help	5. offering internal knowledge to develop a new BM
(none) Closed	1. Develop & commercialise a new product/service with our own knowledge without the need of complementary offers (value is generated internally)	4. Launch of a product/service internally conceived whose value is obtained via the complementarities offered by others

Table 1: OI & OBM classification. Adapted form: (Vanhaverbeke and Chesbrough 2014)

Although the understanding of BMs is increasing, many gaps still exist. For instance, we still do not know how (1) strategic choices link with specific BM solutions; (2) how collaborative (OI) approaches support the commercialization of emerging technologies and (3) what types of BMs (open or closed BM (Vanhaverbeke and Chesbrough 2014)) emerge as a result of the availability of particular technologies (Baden-Fuller and Haefliger 2013). For instance, it is thought by many that the exploitation of new digital technologies, such as Additive manufacturing (AM) supports firms in the opening up their boundaries (Thiesse, Wirth et al. 2015) and hence might encourage both OI to involve a variety of partners in the co-creation of products and new (O)BMs for capturing value from innovation (Rayna and Striukova 2016). This AM affordability allows companies to develop new strategies and provides opportunities for firms to create new industries, or to serve potential or unsatisfied customers of existing industries (De Jong and De Bruijn 2013). Across the various streams of literature, some potential traits of the AM-enabled BM solutions have been prospected by few scholars (e.g. (Rayna and Striukova 2013, Holmström and Partanen 2014, Bogers, Hadar et al. 2016, Holzmann, Breitenecker et al. 2016, Jia, Wang et al. 2016, Rayna and Striukova 2016)). Based on (Piller, Weller et al. 2015). Fig 3 describes a generic value chain for AM whereby the technical elements/perspectives which aligned can deliver the industrial system (AM-value chains). Every player that commercializes innovation in an industry needs to assemble a value chain and highlight through the BM how the elements are brought together (with closed or network-based (O)BMs) to deliver value and how the participating organisations are going to take part in the process.

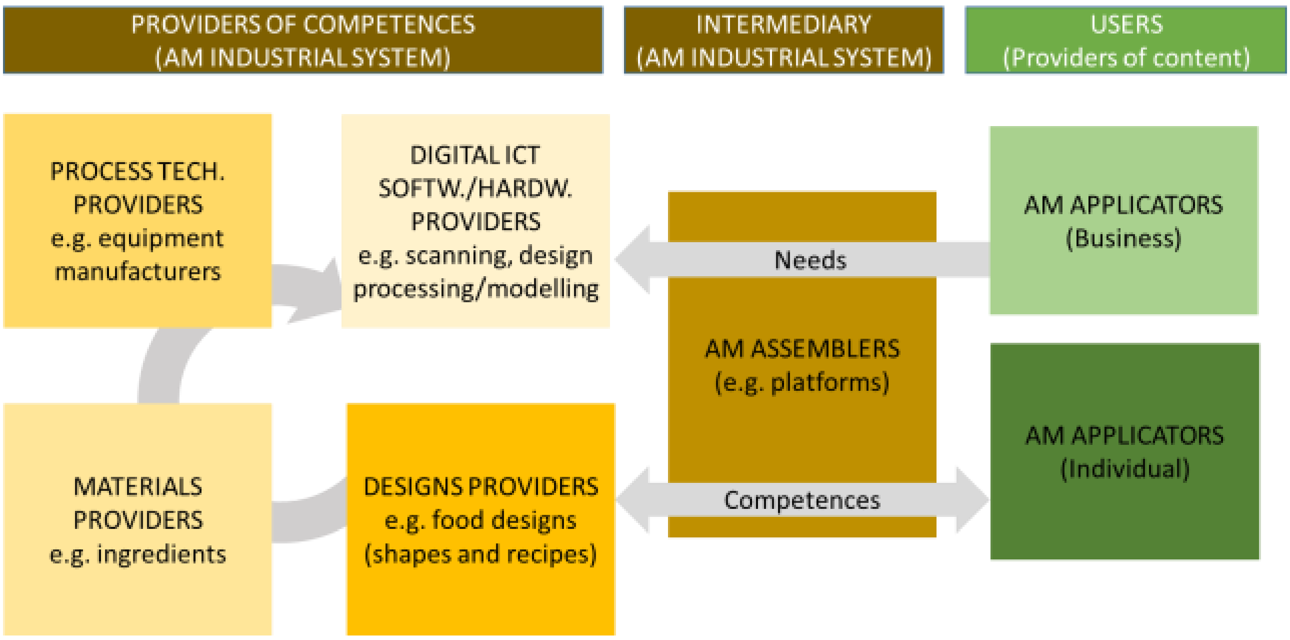

Fig. 3: AM value chain based on (Piller, Weller et al. 2015).

Bogers et al. (Bogers, Hadar et al. 2016) and (Piller, Weller et al. 2015) highlight the opportunities for the customer (or users) to become an integral part of the value chain with the provision of the competences (e.g. designs or personalized combinations of needs) to make the BM work. Bogers highlights how AM pushes industries towards decentralized supply chains where the consumer effectively takes over the productive activities of the manufacturer (Bogers, Hadar et al. 2016). Rayna et al. suggest a range of BM options including these customer-centred-BMs (Rayna and Striukova 2016) amongst the most radical. However, as these AM supply chains, BMs through value networks are being assembled, we still do not know what shapes are they taking in the real world, and how do they complement or substitute other business models. We also are not yet aware of how the OI processes are used to achieve them.

1. Methodology

The commercialization of new technologies has been mainly studied within emerging industries (e.g. (Maine and Garnsey 2006, Maine, Lubik et al. 2012)). However, less is known about the introduction of emerging technologies in established markets. The Food Industry is one of the largest manufacturing sectors in Europe (Bigliardi & Galati, 2013), traditionally characterized by scarce innovation, but where social trends and market demands are forcing the consideration of alternative innovation sources. Hence the application of AM in this sector has the potential to generate a significant impact, especially through the application of co-creation activities (Bigliardi & Galati, 2013a; Bogers et al., 2016; Sun et al., 2015).This paper reviews the strategies and the BMs of emerging in new ventures in 3D-food-printing (3DFP) in 2014 - 16. A cross- case study methodology with a grounded approach is the most suitable to investigate of such an emerging phenomenon (Yin 2009)(Eisenhardt, 1989).

Sample	**Born/or started activities FLM**	**Type of Organisation**	**Technology Commercialisation Stage**	**Product/service** (less relevant in brackets)	**3DFP Activity** (Wegrzyn et al. 2012)
A	2009	Startup	Deployment	Distribution and consultancy services for 3D-food printing	3DFP related services
B	2011	R&D firm	Development	Knowledge on 3D food shaping and personalisation to be commercialised via consultancy or outlicensing	Personalised nutrition
C	2014	Startup	Development	Customised 3D printed confectionary.(Food)	Customized Food Design
D	2012	Startup	Deployment	3D printing appliance for professional and home kitchen use.	Personal Food Factory
E	2014	Startup	Deployment	3D printing appliance ingredients/recipes for home kitchen use.	Personal Food Factory

				Consultancy on 3D food-printing	
F	2015	Startup	Deployment	3D printer/ingredients and recipes system for professional uses 3DP Confectionary	Customized Food Design
G	2013	Startup	Deployment	Customisable 3DP software	3DFP related services
H	2014	Startup	Deployment	Customised 3D printed confectionary. Consultancy on 3DFood Printing	Customized Food Design
I	2013	Startup	Deployment	Consultancy on 3DFood Printing & open knowledge diffusion	3DFP related services
J	2016	Startup	Deployment	3DFood Printing-based food provider (restaurant)	3DFP related services
K	2014	Startup	Deployment	3DFood Printing appliance/ingredients/recipes for professional and home use.	Personal Food Factory

Table 1: Case study overview

The sample has been selected from the most up-to-date database on applications of 3D printing (http://3dprintingindustry.com/). From an initial group of 50 ventures identified, we could only find the contact details for 25 and, by applying the "variety and contrast" principle (Eisenhardt, 1989) and we identified 11 organisations, based the 3DFP typology (Wegrzyn, Golding, & Archer, 2012) - personal nutrition, customized food design, personal food factory, food fabricators and 3DFP-related services. Except in one case, at least two projects for each 3DFP application categories, have been selected. Table 1 provides a first general overview of the anonymized sample. The cases are reported following the interviews order. As for precedent studies in the field under observation (e.g. Dmitriev et al., 2014), we used a multiple- case study approach to link theory with practice. Hence, taking a retrospective perspective, in-depth semi-structured interviews have been conducted with at least one informant per firm. The interviewees were either founders or technology ideators of the new ventures. Over two rounds of interviews were collected, for a total of 750 minutes of face-to-face or telephonic interviews, which were transcribed and complemented with archival data.

The analysis has been conducted through latent content analysis (Mayan 2009), through five iterative phases (coding – categorizing – theme formation – vertical analysis per each case - cross-case integration). Two researchers went through two iterations. The first one, was realized to understand the overall history of each case. While the second one was designed to enable a deeper understanding and characterization of the sample's BMs.

2. Findings

Table 3 highlights the main strategies adopted by the sample of organisations to commercialised their products and / or services. These strategies have been labelled according to the possible customers segmentation strategies highlighted by Osterwalder and Pigneur (2010). The strategies identified are further detailed following two main perspectives: short term and long term.

Sample	**Commercialisation Strategies** **Short Term and Long Term** (target market in brackets)
A	*Short term strategy*: <u>Diversificaiton</u> Consulting on 3DFP (tech and market opportunities). Through these, identify further strategic goals (**B2B**) *Long term strategy*: Distribution of 3DP equipment in educaiton and food.(**B2B**)
B	*Short term strategy*: <u>Niche</u> Research on 3DFP for food personalisaiton (**B2B**). *Long term strategy*: <u>Niche</u> Consulting and licencing for the diffusion of universal 3D printer for food personalisation (**B2B**).
C	*Short term strategy*: <u>Niche</u>. 3DFP customised confectionaries business (**B2B**). *Long term strategy:* <u>Niche</u>. 3D customisable confectionaries through e-commerce (**B2C**).
D	*Short term strategy*: <u>Niche</u>. Commercialisation of the 3D food printer (**B2B**). *Long term strategy*: <u>Niche</u> Commercialisation of the 3D food printer (**B2C**).
E	*Short term strategy*: <u>Niche</u> Commercialisation of the 3D food printer (**B2C**). *Long term strategy*: <u>Niche</u> Commercialisation of the 3D food printer (**B2C**).
F	*Short term strategy*: <u>Niche</u>. 3DFP system to develop customied confectionaries for end custoemrs through confectionary shops in specific locations (**B2C**). *Long term strategy*: <u>Niche</u>. 3DFP system to develop customied confectionaries for end customers through confectionary shops in specific locations and via e-commerce and or direct store. (**B2C**).
G	*Short term strategy*: <u>Diversification</u> Commercialisation of the software through customisation (**B2B**) *Long term strategy*: Not yet defined.
H	*Short term strategy*: <u>Niche</u>. 3D customised confectionary for end-customers. (**B2B**). *Long term strategy*: <u>Niche</u> Online platform for of 3D printed customised decorations for bakeries. **(B2B).**
I	*Short term strategy*: <u>Niche</u> Consulting on 3DFP.(**B2B**). *Long term strategy*: Not yet defined.
J	*Short term strategy*: <u>Niche</u>. 3DFP restaurants around the world & 3DP platforms in several inductries (**B2C**). *Long term strategy*: <u>Niche</u>. 3DFP restaurants around the world & 3DP platforms in several inductries (**B2C**).

K	*Short term strategy*: Niche Commercialisation of the 3D food printer via e-commerce (only in few countries**) ((B2B & B2C).** *Long term strategy*: Niche Commercialisation of the 3D food printer via e-commerce (**B2B & B2C)**.

Table 3: 3D food printing commercialisation strategies

Across the sample, AM was mainly conceived as a way of satisfying particular lead-users in established markets (Niche strategies) such as 'foodies', chefs, or nutritional experts or health cares in the food and kitchen appliances industries. Table 3 shows that, in the short and long term, most firms tend to adopt niche strategies to commercialise their product and or service. The only exceptions are: cases A and G that adopt a diversification strategy in the short term. A is at an inquisitive stage and aims to identify the long term strategy by commercializing through consultancy its knowledge of 3D Printing. For this, A has developed a BM with a flexible element (Value Capture) through which they can switch between a transactional OI model (2) whereby it sells knowledge to others to an OBM (6) where the relationship with the partner changes with the aim to collaboratively define and seize the market opportunity. A's final ambition is however to identify an opportunity where it could take the role of distributor for 3D Printing equipment. G has developed an internal platform which is making use of an inside out OBM (5) to commercialise and adapt its software to the client's needs. B has the long term objective of realizing the knowledge for a 3D food-printer (3DFP) system able to offer fully personalized food for a variety of uses. The firm is systematically seeking public/private funds through a chain of research projects to develop this knowledge which it aims to eventually commercialise through out-licensing (5) and co-creation of the supply chain through consultancy (6), in collaboration with the range of partners who contributed to the research projects. Hence, in contrast with (Marx and Hsu 2015), we 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 that want to implement.

Table 4 illustrates the various firms' value propositions and the type of BM according to Vanhaverbeke and Chesbrough. (Vanhaverbeke and Chesbrough 2014). The business model archetypes classification has been done according to the current main business model offer (i.e. value proposition) and, in second instance, according to the main revenue model, as suggested by prior work (e.g.(Gassmann, et al., 2014)). Following a similar logic to the one used by Cabage & Zhang (2013). Four main BM archetypes emerged: manufacturers (either of 3DF printer (D, E, K) or of 3D printed food (C, F, H)), knowledge service providers (e.g. consultancies (A, B, I)), providers of 3DP competences (e.g. software (G)), competences assemblers (e.g. industry platforms (J)).

Sample	**Commercialisation Strategies Short Term and Long Term** (target market in brackets)	**Short term BMs**	**Type OI/OBM**	**Long term BMs**	**Tpye OI/OBM**
A	*Short term strategy*: Diversificaiton Consulting on 3DFP (tech and market opportunities). Through these, identify further strategic goals (**B2B**) *Long term strategy*: Distribution of 3DP equipment in educaiton and food.(**B2B**)	*VP:* consulting on technical/market applications of 3DP in education and food. *VD:* Direct to customers *VCr:* Internal knowledge *(closed innovation 1)* *VN:* hierarchical or networked *VCa:* A uses a different value capture model depending on the potential of the busienss opportunities: Transactional or co-development of business opportunity	*6*	*VP:* distribution of 3DP equipement in education and food. *VD:* Direct to customers *VCr:* Internal knowledge (3DP equipment) *(closed innovation 1)* *VN:* Hierarchical *VCa:* Margin per asset sold	1
B	*Short term strategy*: Niche Research on 3DFP for food personalisaiton (**B2B**). *Long term strategy*: Niche Consulting and licencing for the diffusion of universal 3D printer for food personalisation (**B2B**).	*VP:*Step forward in the knowledge (IP) on the development of 3DFP *VD:* Direct to the funding provider. *VCr:* Shared: projects partners (*insiede-out OI 2)* *VN:* Networked: projects partners *VCa:* Value is captured through project funds.	5+6	*VP:* Consulting and licencing of universal 3D printer for food personalisation *VD:* Direct to custoemrs (licensor). *VCr:* Shared; projects and clients partners (*insiede-out OI 2)* *VN:* Networked projects and clients partners *VCa:* Value is captures through IP licencing sales.	5+6
C	*Short term strategy*: Niche. 3DFP customised confectionaries business (**B2B**). *Long term strategy:* Niche. 3D customisable confectionaries through e-commerce (**B2C**).	*VP:* 3DFP customised confectionaries . *VD:*Direct to funding institutions. *VCr:* Internal:recipe, ingredients and desgn (*closed innovation 1*) Shared: looking for external knowledge (3DFP technician) (*outside-in OI 3*) *VN:*Hierarchical: with ingredients suppliers and 3DFP technician. *VCa:* Value is captured through external funds for the business development.	3	*VP:* 3DFP customised confectionaries *VD:* direct to clients (e-commerce) *VCr:* Internal:internal knowledge recipe, ingredients (*closed innovation 1*) Shared: external desing (co-developed with customers) *VN:* Hierarchical: ingredients suppliers, distribution service, custoemrs *VCa:* value will be captured through the sales of each confectionary item.	4
D	*Short term strategy*: Niche. Commercialisation of the 3D food printer (**B2B**). *Long term strategy*: Niche Commercialisation of the 3D food printer (**B2C**).	*VP:* 3DFP system to develop new food shapes for professional kitcken users *VD:* Direct to customers *VCr:* Internal: 3DFP equipemnt *(closed innovaiton 1)* *VN:* Networked: Chef knowledge (3D customies food). *VCa:* value is captured by payment up front for each 3D food printer sold.	6	*VP:* 3D food printing system to personalised food for home kitcken users *VD:* Direct to custoemrs *VCr:*Internal: 3DFP equipemnt *(closed innovaiton 1)* *VN:* Networked: end-custoemrs knowledge (3D customies food). *VCa:* value is captured by payment up front for each 3D food printer sold	*6*

E	*Short term strategy*: <u>Niche</u> Commercialisation of the 3D food printer (**B2C**). *Long term strategy*: <u>Niche</u> Commercialisation of the 3D food printer (**B2C**).	*VP:* 3DFP system to develop new food shapes for home kitcken users *VD:* Direct to customers *VCr:* Internal: 3DFP equipemnt, pre-filled food capsules and chef recipes (are considerable as consultants). *(Outsied-in OI 3)* *VN:* Herarchical: manufacturer, pre-filled food capsues provider, chef recipes. Networked: End-customers (3D customies food). *VCa:* value is captured by payment up front for each 3D food printer sold and or pre-filled food capsules.	6	*VP:* 3DFP system to develop new food shapes for home kitcken users *VD:* Direct to customers *VCr:* Internal: 3DFP equipemnt, pre-filled food capsules and chef recipes. *(Outsied-in OI 3)* *VN:* Herarchical: manufacturer,pre-filled food capsues provider, chef recipes. Networked: end-customers (3D customies food). *VCa:* value is captured by payment up front for each 3D food printer sold and or pre-filled food capsules.	6
F	*Short term strategy*: <u>Niche</u>. 3DFP system to develop customied confectionaries for end custoemrs through confectionary shops in specific locations (**B2C**). *Long term strategy*: <u>Niche</u>. 3DFP system to develop customied confectionaries for end customers through confectionary shops in specific locations and via e-commerce and or direct store. (**B2C**).	*VP:* 3DFP system to develop customied confectionaries for end custoemrs *VD:* Indirect, through franchising *VCr:* 3DFP ingredients. Internalfood ingredients and recipes *(closed innovation 1)* *VN:* Herarchical: 3D food printer manufacturer,software, distributor (franchiser). Networked: end-customers (3D customies food). *VCa:* renting 3D food printer – licensing software - value captured through each confectionary sold.	6	*VP:* 3DFP system to develop customied confectionaries for end custoemrs *VD:* Indirect, through franchising. Direct through e-commerce and phisical store. *VCr:*3DFP ingredients. Internalfood ingredients and recipes. (*closed innovation 1)*, *VN:*Herarchical: manufacturer,software, distributor (franchiser). Networked: end-customers (3D customies food). *VCa:* renting 3D food printer – licensing software - value captured through each confectionary sold.	6
G	*Short term strategy*: <u>Diversification</u> Commercialisation of the software through customisation (**B2B**) *Long term strategy*: Not yet defined.	*VP:* embedded software for 3DP (3DFP) *VD:* Direct to customers (B2B). *VCr:* Shared: customers (B2B) (*inside-out OI 2*) *VN:* Networked: customers (B2B) *VCa:* fee for software and maintenance use.	5	*Not yet defined*	-
H	*Short term strategy*: <u>Niche</u>. 3D customised confectionary for end-customers. (**B2B**). *Long term strategy*: <u>Niche</u>	*VP:* 3DFP customised confectionaries for end-customers *VD:* direct to customers and through workshops and demonstrations. *VCr:* Internal: design, and ingredients *(closed innovaiton 1).*	4	*VP:* 3DFP customised confectionaries for professional *VD:* direct to custoemrs (e-commerce) *VCr:* Internal:design, ingredients . *(closed innovaiton 1)*	6

	Online platform for of 3D printed customised decorations for bakeries. **(B2B).**	Shared: customers (*ouside-in OI 3*) *VN:* Hierarchical: ingredients suppliers, packaging. Networked: customers. *VCa:* sales of each confectionary product		Shared: 3DFP technology (*ouside-in OI 3*). *VN:* Hierarchical: ingredients suppliers, packaging, distributor. Networked: 3DFP manufacturers *VCa:* sales of each confectionary product	
I	*Short term strategy*: Niche Consulting on 3DFP.(**B2B**). *Long term strategy*: Not yet defined.	*VP:* consultancy on 3DFP *VD:* Direct to customers *VCr:* Internal: internal knowledge *(closed innovation 1)* *VN:* Herarchical *VCa:* value is captured per consultancy/workshop activity (transactional)	6	*Not yet defined*	-
J	*Short term strategy*: Niche. 3DFP restaurants around the world & 3DP platforms in several inductries **(B2C).** *Long term strategy*: Niche. 3DFP restaurants around the world & 3DP platforms in several inductries **(B2C).**	*VP:* 3DFP dinners around the world & 3DP platforms in several inductries (food, furnishing and soft furnishing, 3DP appliances) *VD:* direct to custoemrs (e-commerce) *VCr:* Shared: 3D printer manufacturer, chef, 3DP furnitures *(outside-in OI 3)* *VN:* Networked (two-sided)*:* 3D printer manufacturer, chef, 3DP fornitures. (advantages for the network in terms of branding) *VCa:*value is captured per experience sold.	5+6	*VP:* 3DFP dinners around the world & 3DP platforms in several inductries (food, furnishing and soft furnishing, 3dP appliances) *VD:* Indirect, franchised *VCr:* Shared: 3D printer manufacturer, chef, 3DP furnitures *(outside-in OI 3)* *VN:* Networked (two-sided)*:* 3D printer manufacturer, chef, 3DP fornitures (advantages for the network is in term of branding and sales throuh the paltform) *VCa:*value is captured per experience sold (platform Vca to be determined)	*5+6*
K	*Short term strategy*: Niche Commercialisation of the 3D food printer via e-commerce (only in few countries) **(B2B & B2C)** *Long term strategy*: Niche Commercialisation of the 3D food printer via e-commerce **(B2B & B2C).**	*VP:* 3DFP system to develop new food shapes for professional and home kitchen users *VD:* Direct to customers (e-commerce) *VCr:* Internal: 3DFP equipemnt, pre-filled food capsules and chef recipes (*ouside-in OI 3)* *VN:* Herarchical: manufacturer,pre-filled food capsues provider. Networked: professional kitchen users and end-custoemrs (3D customies food). *VCa:* value is captured by payment up front for each 3D food printer sold and or pre-filled food capsules.	6	*VP:* 3DFP system to develop new food shapes for professional and home kitchen users *VD:* Direct to customers (e-commerce) *VCr:* Internal: 3DFP head design 3DFP equipemnt, pre-filled food capsules (*ouside-in OI 3)* *VN:* Herarchical: manufacturer, pre-filled food capsues provider. Networked: professional kitchen users and end-customers (3D customies food) *VCa:* value is captured by payment up front for each 3D food printer sold and or pre-filled food capsules.	*6*

Table 4: 3DFP business models and the type of BM according to Vanhaverbeke and Chesbrough (2014)

All the BMs build strongly on the characteristics of the technology to deliver customisation and personalisation (Piller 2007) of food. This feature is typically enabled through an OBM, and the technology's affordability has been understood and exploited by the ventures who are developing ways to build knowledge repositories which encompass the preferences of the users and can provide personalised content (e.g. designs of food, recipes) to enable the personalisation of the outcomes for a variety of reasons (e.g. health) (C, F, H). Most BMs present in our sample are known in the food industry, such as the "food machinery framework" (Bigliardi and Galati 2013), whereby much of the model rely on a collaboration across partners to develop a new manufacturing process/new food (e.g. B, D, E, K). In these cases however, on the contrary of what illustrated by Bigliardi et al. 2013, the machine/process equipment manufacturers are central to the BM and try to extend the value network to involve develop the missing elements (e.g. ingredients, software and designs). One of the cases (J) who adopts a traditional BM in the food industry (service – experience through restaurants) has developed the model as a two sided market (Baden-Fuller and Mangematin 2013). On one side, the restaurant experience is delivered to customers in agreement with the partners in a value network comprising the Food 3DPrinter manufacturers and ingredient providers, chefs, soft and hard furnishing providers (6) on the other, the events are for the value network partners opportunities to market their products/designs and skills and (in the future) also to sell them (5). J's is hence a platform (Gawer and Cusumano 2014) which bridges across different industries.

Discussion

Our research helps to link the technology commercialization and strategy literature to the OI and OBM literatures. Across the cases, AM was mainly conceived as a way of satisfying particular users in established markets (De Jong and De Bruijn 2013)(Niche strategies), in two different established industries (food and kitchen appliances). Hence, we could concur with those suggesting that niche strategies are important in technology commercialisation (Lubik, Lim et al. 2013), in particular in established markets. However, as per (Lubik and Garnsey 2016), we occasionally observed also that new tech-commercialising ventures develop interim sub-strategies. These have been used either as subserving strategies to reach the end strategy (causal mode) or as opportunities to explore and define the final strategy (effectual mode) (Sarasvathy 2001). In particular, for these latter, A's model of exploring different markets though consultancy to identify a particular business strategic opportunity, making use of an OBM, illustrates the potential for OBM to support the growth of the firm and its renewal (Vanhaverbeke, Cloodt et al. 2014). Hence, our findings indicate that OI (2+3) and OBM (5+6) (Vanhaverbeke & Chesbrough, 2014) could be built at different times and might have different strategic roles, depending on whether they are subserving the design or the execution of the strategies (Cortimiglia, Ghezzi et al. 2016). However, whilst the classification developed by Vanhaverbeke & Chesbrough, (2014) shows the distinctions across the various open and closed BMs and the OI processes (Table 1), the use of these terms have been challenging in our characterization. In fact, to deliver on the value proposition organisations can make use of open innovation (2+3) or closed innovation with some of the partners, but could be building open or closed business models with others in the value network. Hence, the various terms in Table 1 cannot be used as descriptions of entire BMs, but of portions of it.

A further consideration, relates to the influence of the technology on the BM (Baden-Fuller and Haefliger 2013) and in particular to the degree of novelty achievable in the BM as a result of the adoption of a digital technology. In this context, the digital characteristics of the technology are not sufficient to increase the radicalness of the BMs across our sample. Whilst for other consumers good it is difficult to achieve a high level of personalisation and customisation via other means compared to those available through AM, via (traditional) kitchen appliances and tools anyone can develop an infinite number recipes and obtain personalised food. The food manufacturing is also in many cases already distributed to the users' premises, even in the absence of 3DFP. The main advantages of the AM-food technologies would hence include the reliability in obtaining the shapes of the 3D printed food and the opportunity to scale-up the delivery of professionally-looking food, typical of small establishments such as patisseries or special restaurants. The current range of BMs for 3D Printers include the collaboration of the users in co-creating recipes and designs for the food (OBM). These present a certain degree of novelty for mass manufacturers of commoditised food, but are not per se new.

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