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From rapid prototyping to home fabrication: How 3D printing is changing business model innovation

Thierry Rayna [a], Ludmila Striukova [b,*]

[a] Novancia Business School Paris, 3 rue Armand Moisant, 75015 Paris, France
[b] University College London, Gower Street, WC1E 6BT London, UK

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ABSTRACT

There is a growing consensus that 3D printing technologies will be one of the next major technological revolutions. While a lot of work has already been carried out as to what these technologies will bring in terms of product and process innovation, little has been done on their impact on business models and business model innovation. Yet, history has shown that technological revolution without adequate business model evolution is a pitfall for many businesses. In the case of 3D printing, the matter is further complicated by the fact that adoption of these technologies has occurred in four successive phases (rapid prototyping, rapid tooling, digital manufacturing, home fabrication) that correspond to a different level of involvement of 3D printing in the production process. This article investigates the effect of each phase on the key business model components. While the impact of rapid prototyping and rapid tooling is found to be limited in extent, direct manufacturing and, even more so, home fabrication have the potential to be highly disruptive. While much more value can be created, capturing value can become extremely challenging. Hence, finding a suitable business model is critical. To this respect, this article shows that 3D printing technologies have the potential to change the way business model innovation is carried out, by enabling adaptive business models and by bringing the 'rapid prototyping' paradigm to business model innovation itself.

1. Introduction

Disruptive technologies are bearer of radical changes in business models and ecosystems. Digital technologies, in particular, have led to major shifts in the industries that have adopted them. One of the key consequences of digitisation has been to turn tangible objects into intangible ones (e.g., a vinyl record into an MP3 file, a film into a digital video, a book into an e-book). For this reason, digitisation of products is also often referred to as a 'dematerialisation'.

Progressively, over the past 30 years, new digital technologies have enabled to turn an increasing number of physical products into intangible digital content. Yet, all these products had in common that their physical 'expression' generally mattered little if at all. A digital film is the same film whether stored on a Blu-ray disc, a flash drive, or streamed online, and it carries the same 'function' (albeit generally in a far better manner) as the equivalent film on film stock. Nowadays, most of such products have already been digitised and the goods that were not are those whose physical expression actually matters and, thus, cannot be made totally intangible (e.g., looking at the virtual model of a spoon is not the same as using one).

Yet, while such objects necessarily have to be 'made' in order to be used (thereby preventing 'total digitisation'), digital technologies have nonetheless taken an increasingly important part in their production. While the move towards digitalisation of manufacturing – or digital fabrication – started decades ago with the progressive adoption of CNC[1] machines and other computer-controlled manufacturing systems, the trend has significantly accelerated over the past few year, in particular because of the advent of 3D printing technologies.

Originally used mainly for (rapid) prototyping, 3D printing technologies have progressively taken a more important part in manufacturing processes. As the technology improved, it became possible to use 3D printers not only to prototype, but also to manufacture tools and moulds used for 'traditional' manufacturing. It then became possible and economical, in some cases, to entirely manufacture end-products with 3D printers. Finally, the advent of Personal 3D Printers has made it possible to directly manufacture at home, thereby bypassing the (physical) distribution stage.

Yet, the 3D printing 'revolution' is likely to differ quite significantly from the previous digital revolutions. Indeed, while movies and music are nowadays predominantly transferred over the Internet to be

* Corresponding author.
E-mail addresses: trayna@novancia.fr (T. Rayna), l.striukova@ucl.ac.uk (L. Striukova).

[1] Computer Numerical Control.

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'manufactured' at home, it is unlikely that all manufacturing will follow this path, with every single object being fabricated at home on a personal 3D printer. Indeed, while clearly advantageous for customised products, 3D printing is very likely to remain uneconomical for mass-consumed objects. Even assuming that affordable high-definition multi-material personal 3D printers become a reality, consumers might still find it easier to pick up a product at a store or have it delivered.

Although the co-existence of physical manufacturing with full digital production has also occurred in other 'digitised' industries (e.g., CDs and records are still being sold), this was most likely either transitory (CDs will eventually be phased out) or due to the existence of niches (vinyl records). In the case of 3D printing, this co-existence between various manufacturing and distribution models is far more likely to prevail in the long run. Thus, understanding the radical changes that 3D printing will bring about is a rather complicated matter because of the co-existence of diverse production models, in which 3D printing is involved to a various extent (from just prototyping to full manufacturing and delivery).

The aim of this article is to investigate the disruptive effect of 3D printing on business models and on business model innovation. Its main contribution is that it provides an in-depth analysis of the effects of 3D printing on all business model components and accounts for the different levels of involvement of 3D printing in productive processes. Furthermore, it demonstrates how, beyond changes in business model components, 3D printing changes business model innovation, by enabling to rapidly prototype and adapt business models. Finally, this article clarifies the relationship between business model innovation enabled by 3D printing technologies and the resulting innovative effect, whether radical or incremental.

In regard to the literature on business models, this article provides a comprehensive value-based business model framework that integrates the different value components identified in the literature. Furthermore, a business model innovation framework, which combines both 'inside' and 'outside' views of business model innovation developed in the literature, is introduced.

The article is organised as follows. Section 2 provides a brief overview of 3D printing technologies and their current level of adoption. Section 3 investigates the successive adoption stages of 3D printing and details the related involvement of 3D printing in production processes. Section 4 explores the impact of 3D printing on the key business model components: value proposition, value creation, value capture, value distribution and value communication. Section 5 demonstrates how, beyond changes in the components, 3D printing affects business model innovation itself.

2. An overview of 3D printing technologies and services

3D printing is a form of "additive" manufacturing, where a three-dimensional object is 'printed' (built) by adding layer after layer of a particular material, which differs from the more usual "subtractive" (when an object is carved out of a block of raw material) or moulding/die-casting (when a molten material is injected into a solid mould) forms of manufacturing.

The first stage of 3D printing involves creating a digital model of the object to be printed. This is usually done with Computer-Assisted Design (CAD) modelling software or using dedicated online services provided by some of the 3D printing platforms (e.g., Thingiverse, Shapeways or Sculpteo). 3D scanners can also be used to automatically create a model of an existing object (just like 2D scanners are used to digitise photos, drawings or documents). Besides actual 3D scanners, which remain to this day relatively expensive,[2] mobile applications such as Autodesk 123D Catch enable to generate 3D models using the embedded camera of a smartphone. When an object is printed, the 3D model of the object is discomposed into successive layers that are printed one at time.

Nowadays, the most common material used for 3D printing is plastic (ABS, PLA, Nylon), but metal alloys, ceramics, wood particles, salt and even sugar and chocolate can be used to print. Currently, most printers, whether industrial or consumer grade, can only print with one material at a time, but in the past few months, several printers that can print with several materials simultaneously have been brought to market. For example Stratasys Objet500 Connex (sold at $250,000) can already print from more than 100 materials (up to 14 simultaneously) and manufacture multiple-part objects that are at the same time rubber and rigid, opaque and transparent. The range of objects that can be manufactured with 3D printers is very wide and is constantly growing: prototypes, parts, moulds, tools, body parts (organs), prosthetics, toys, art, food items, musical instruments, furniture, clothes. 3D printers can be even used to print other 3D printers.[3]

While 3D printing technologies were, originally, intended exclusively for (heavy) industrial use, the constant decrease in cost has put them within reach of SMEs and individual entrepreneurs. With home 3D printers now being available for less than $1000 (the cheapest printer, the Buccaneer, costs $350), 3D printing is progressively becoming a technology any business, small or large, can afford and a number of companies have already started to integrate 3D printing into their business model.

Beyond being used by firms, there is a growing trend of using 3D printing in consumer markets. While originally home 3D printing was often dismissed as a hobbyist activity, the entry of major players in this market tends to demonstrate otherwise. In May 2013, Staples became the first major U.S. retailer to sell 3D printers. It was followed a few months later by Walmart. In the UK, High Street consumer electronic retailer Maplin also started to sell 3D printers, consumables and accessories in its 205 stores in July 2013. It was followed shortly after by its main competitors, Currys and PC World. Likewise, in France, FNAC, one of the leading electronics retail chains, started to sell 3D printers and related consumables and accessories in autumn 2013. Meanwhile, online (and worldwide), Amazon opened a 3D printing section, selling printers, plastic filament, books, software, parts and supplies in June 2013.

Apart from 3D printers sales, major players are also embracing 3D printing as a service. In July 2013, eBay announced its new iPhone application called eBay Exact which enables users to browse and buy customisable print-on-demand merchandise from three 3D printing companies: MakerBot, Sculpteo, and Hot Pop Factory. More recently, Selfridges, the UK high-end department store has opened, in partnership with the 3D printing service iMakr, a Christmas shop where customers can print in store, buy 3D printers and 3D scan objects. ASDA, one of the three UK supermarket giants (and Walmart subsidiary) has launched 3D printing services in 50 of its stores in January 2014 and its main competitor, Tesco, is also planning to open similar services. In France, La Poste (post office network) has opened in November 2013 a dedicated 3D printing service in a few of its stores.

Besides these 'household names', a growing number of services related to 3D printing (most of them online) are now offered to consumers and businesses. Companies like Ponoko (the first mover, opened in 2007), Sculpteo and Shapeways operate marketplaces where companies and individual designers can sell 3D models of their products directly to customers, models that can then either be printed by the marketplace and shipped to the customer, or directly printed by the customer at home. If consumers do not yet own a printer, Cubify Cloud, in addition to its marketplace and printing services, also offers to ship 3D printers directly to consumers.

Beyond these rather versatile services, there are also companies specialising in printing activities. Two of them, iMakr and Makerbot,

[2] MarkerBot Digitizer currently sells for $949. The recently announced 3D Systems iSense, which works with Apple iPad, is priced at $499.

[3] E.g. the Reprap 'self-replicating' 3D printer. http://reprap.org/.

even have physical stores and are, thus, the 3D equivalent of the traditional printshop. Most of these services offer users assistance with the creation of their 3D object (for instance by converting a 2D drawing into 3D). Services like MakeXYZ and AdditiveHabitat provide a marketplace for 3D printers, where users can locate 3D printers located near them and get a quote from the owner of the printer for the particular object they want to print.

Finally, online platforms, such as Additer and Kraftwürx, enable crowdsourcing of both design and manufacturing. Businesses and consumers alike can use these platforms even when they only have a vague idea of what they want to manufacture (and of how to manufacture it). The members of the 'crowd' will team up to offer designs and materials (Kraftwürx offers over 70 different materials), the result being printed at nearby location.

In addition to these services, an increasing number of consumers and businesses make the choice to lease or own their own 3D printers, a trend which has rapidly accelerated over the past months.

3. From rapid prototyping to home fabrication: the adoption stages of 3D printing

The adoption of 3D printing technologies is actually a 'multi-layered' adoption process that corresponds to different usages. The reason for that relates both to the technology itself (in particular the materials used) and to the cost of usage.

The first 3D printing technologies (stereolithography, selective laser sintering, fused deposition modelling, laminated object manufacturing) appeared in the late 1980s and began operational in the early 1990s. At the time, only plastics could be used. The level of details and quality of finish were rather low, which meant that only 'rough' looking objects could be printed. Printing was slow, expensive and restricted to small objects. Consequently, the first application of 3D printing technologies was *rapid prototyping*,[4] i.e., the ability to rapidly build plastic models of objects.

While rapid prototyping was at first (because of the cost) mainly used by large corporations, progressive decrease in price led to a wider adoption. Nowadays, all 3D printers in the $1000–4000 range (e.g., Cubify Cube, MarkerBot Replicator) are targeted at SMEs and entrepreneurs in need of rapid prototyping. Prototyping quality has also improved and, nowadays, upper range printers (costing $200,000 and above) are able to build multi-material fully functional prototypes in one go.

In the second half of 1990s, the advent of 3D printers using heat-resistant polymers and metal alloys triggered the second stage of adoption of 3D printing: *rapid tooling*. Manufacturing processes have always required customised tools: jigs and hardware and, more importantly, moulds that are used for the ubiquitous injection moulding and die casting manufacturing. Such moulds have traditionally been built by machining (subtractive manufacturing) blocks of steel or aluminium, an expensive (a single mould can cost well above a few thousands of dollars) and lengthy (from a week to above a month, depending on the complexity of the part) process. In this context, mistakes can be quite costly and there is little flexibility in terms of improvement or upgrades of the manufactured objects. In contrast, 3D printing technologies enable to print moulds in a matter of hours, often for a fraction of the cost of traditional tooling (Hiemenz, 2013; Zonder and Sella, 2013), thereby leading to significant savings and opportunities (e.g., low volume production and frequent upgrades).

In the late 2000s, the cost of 3D printing began to be low enough (and quality high enough) to start directly manufacturing final products with 3D printers. As noted in Gibson et al. (2010), "speed, quality, accuracy and material properties have developed to an extent that [3D Printed parts] can be made for final use.[5]" This led to the third wave of adoption, generally referred to as Direct Digital Manufacturing (or DDM) or simply *direct manufacturing*, and which implies an entirely digital production process, with end-products directly manufactured using digital (CAD) models and 3D printers, without moulds, casts or machining.

While already available for several years, the adoption of direct manufacturing has significantly increased recently, partly because of the rise of online 3D printing platforms. Some of these platforms, such as Materialise Onsite or 3DCreation Lab, enable users to upload CAD files, which are used to manufacture 3D printed objects that are then shipped to the users. Others, such as Sculpteo or Shapeways, operate online marketplaces where designers can upload 3D models of objects that users can buy, have 3D printed and delivered.

Furthermore, some companies have integrated direct manufacturing at the core of their business. This is the case, for instance, of Protos Eyewear (3D printed spectacles for end-users), ThatsMyFace (figurines that are customised with customers' face), or companies, such as Mymo, Chicago Charm or Zazzy, that offer 3D printed jewellery.

The fourth and final stage of adoption, *home fabrication* has just started. It involves consumers (or end-users) manufacturing objects themselves using 3D printing equipment they have at home. At the moment very few consumers own a 3D printer and those who do are mainly hobbyist and engineering students (Wholers, 2013). While the growth of 'personal 3D printer' (i.e., printers costing less than $5000) sales over the past few years has been very significant, with a yearly average growth of 346% between 2007 and 2011 and a yearly growth of 46% between 2011 and 2012 (Wholers, 2013), the sales of personal 3D printers still remain low (35,508 units sold in 2012) in comparison to other consumer electronics products.

However, a limited and slow adoption is to be expected at this stage, as prices are still high and the technology yet immature. To this respect, the current market for personal 3D printers could be compared to the '2D' printer market in the mid 1980s (when dot matrix printers were the only affordable option) or to the personal computer market before the advent of cheap 'Wintel' PCs in the late 1980s.

Still, the question remains of whether 3D Printers will take the same place in people's homes as PCs and 2D printer did. While there is a large consensus about the value and potential of 3D printing technologies in general, there has been much debate about whether the 'home manufacturing' revolution is indeed on the cards. The arguments against mainly rest on the unsuitability of the technology (e.g., that it is too expensive, that quality is too low, that only one material can be used) and on the lack of need for a regular use of the technology (who needs to manufacture objects often enough to justify having a 3D printer at home?). To this respect, it can be noted that very similar arguments were used in the past in regard to technologies, such as personal computers or the Internet, which are now in every home. This, in turn, is the very argument used by those who believe in a widespread home adoption of 3D printers: 3D printing, as a disruptive technology, follows the same adoption pattern as other disruptive technologies.

Table 1 summarises the different adoption stages of 3D Printing technologies. It is important to note that each new phase does not make the previous one 'obsolete', but instead extends it (e.g., 3D Printing is still being used for rapid prototyping). Also, the last stage, home fabrication, extends the role of 3D Printing beyond

Table 1
Adoption stages of 3D printing technologies and resulting involvement in production.

Adoption stage	Started	Design	Tooling	Manufacturing	Distribution
Rapid prototyping	Early 1990s	✓			
Rapid tooling	Late 1990s	✓	✓		
Direct manufacturing	Late 2000s	✓	✓	✓	
Home fabrication	Early 2010s	✓	✓	✓	✓

[4] Before '3D printing' emerged as name, all these technologies were referred to as 'rapid prototyping'.

[5] From this point onwards 'additive manufacturing' became a popular designation for 3D printing technologies.

manufacturing, as home printers enable to use 3D printing as a means of product distribution.

In addition to these four clearly defined stages, an intermediary stage between direct manufacturing and home printing has started to emerge. *Local fabrication* refers to direct manufacturing that takes place not at home, but at a local printshop. As discussed in Section 2, while fairly rare until a few months ago, many of such services have recently opened.

The emergence of this intermediary stage is not really surprising, as it enables to bridge the gap between technology maturity and large installed consumer base. This is in fact very similar to 'Internet cafes' or 2D 'print-shops'. It remains to be seen whether, like the latter, such local facilities will disappear as home adoption increases or if, instead, the nature of 3D printing technologies is such that they are here to stay.

4. How 3D printing is disrupting business models

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). As noted in Baden-Fuller and Morgan (2010), business models are often hard to define, since they can serve at the same time as scale models, role models and ideal models. Likewise, business model construction often results from both a taxonomy and a typology.

Although there are differences amongst scholars about what constitutes a business model, there is a broad consensus around four critical components: value proposition (Voelpel et al., 2004; Casadesus-Masanell and Ricart, 2010; Chesbrough, 2010; Teece, 2010), value creation (Zott and Amit, 2002; Voelpel et al., 2004; Chesbrough, 2007), value capture (Chesbrough, 2007; Holm et al., 2013), and value delivery (Osterwalder et al., 2005; Abdelkafi et al., 2013; Holm et al., 2013). A fifth component, value communication, is also often considered as a critical aspect of a business model (Abdelkafi et al., 2013). These components, as well as their respective sub-components identified in the literature, are synthesised in Fig. 1.

As noted in Makadok and Coff (2002), the term 'value creation' is often used incorrectly in place of 'value capture'. While the two may occasionally coincide, this is not always the case and companies may well end-up capturing more (or less) value than what they actually created (Pitelis, 2009). Value creation requires increasing the consumers' perceived worth of consuming a particular product (Priem, 2007). Once it has happened, consumers' willingness to pay normally increases. However, that does not necessarily means that the company that originally created the value is able to raise its prices to capture it. Consequently, capturing value can be considered as the key objective of any firm (Pitelis and Teece, 2009).

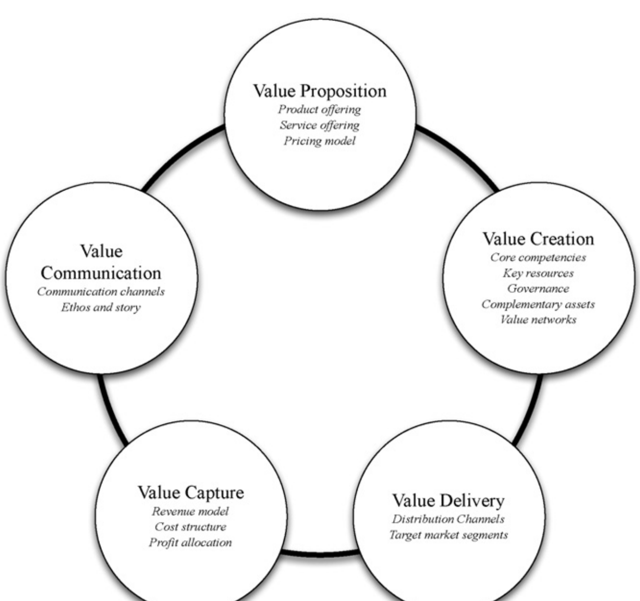

Fig. 1. Key components of business models.

As a technology, 3D printing will undoubtedly lead to significant value creation. The question is, however, of how business models will need to evolve in order to enable value capture, which is critical to obtain a competitive advantage.

As noted in Baden-Fuller and Haefliger (2013), the role of business models in enabling a new technology to create a competitive advantage has often been underplayed in the literature. Thus, in order to understand the interplay between 3D printing and business models, the changes 3D printing brings about to each business component will be reviewed in this section. In particular, the effect of each of the four distinct stages of adoption of 3D printing in the manufacturing process identified in the previous section (rapid prototyping, rapid tooling, direct manufacturing and home fabrication) will be considered. Since, 3D printing technologies are not expected to have a significant impact on value communication (e.g., they do not enable new communication channels), the following section will focus on the four other components.

4.1. Rapid prototyping

While novel at the time, the introduction of rapid prototyping, only had a marginal effect on the way companies planned and carried out their business activities. Indeed, the main purpose of a prototype is to identify design flaws, in particular compatibility or usage issues. With the introduction of rapid prototyping it became possible to significantly cut down the process of building a prototype from weeks (sometimes months) to a matter of days or even hours. Speeding up this stage of production has, therefore, effected the *value proposition* component as it allowed to release new products more quickly (*product offering*). The greater prototyping speed also marginally affected *service offering*, as it enabled to set up new 'priority' services alongside traditional prototyping services.

Considering the sub-components of *value creation* and *value delivery*, it is rather clear that rapid prototyping had little impact (if at all) on any of them. The effect on *value capture* is more ambiguous as, in some cases, rapid prototyping might have changed the *cost structure*. Bearing in mind the time it takes to manually build a prototype, 3D printing in its early stage might have led to some cost reduction. Yet, the problem at the time was that 3D printers were very expensive and rare, which made rapid prototyping only affordable to large companies, as smaller companies (especially those located in rural areas) were far less likely to be able to access (both financially and geographically) rapid prototyping services.

Thus, originally, the introduction of rapid prototyping did not have a significant impact on business model components and did not result in any significant changes in the way companies do business. For both large companies and small companies, it was 'business as usual', for the former because rapid prototyping simply sped up existing processes and for the latter, because the technology was simply too expensive for them. As noted in (Brean, 2013), the aircraft and automotive industries had been the first to use 3D printing to perform rapid prototyping, but the high cost of using this technology had kept the practice from going mainstream until the late 2000s.

The situation began to change in 2007,[6] when online platforms, such as Ponoko and Shapeways, started to offer 3D prints at a much lower cost and removed the necessity to own a 3D printer to build rapid prototypes. This gave access to rapid prototyping to anyone, firms, designers or even individual entrepreneurs. This democratisation

[6] The first 3D Printing service bureaus, such as Materialise, opened in the 1990s, but widespread usage of rapid prototyping was hampered by high costs, complexity of tools and lack of online integration.

trend was further accelerated by the ever-decreasing price of 3D printers (this is particularly the case for FDM printers, which can nowadays be purchased for less than $1000).

Bringing rapid prototyping to the 'masses' will most likely have a large effect on creativity, innovation and competition (as it enables would-be entrepreneurs to test their ideas). With regard to business models, however, it is important to note that this does not imply further disruptions in components, but, instead, that the changes identified above (mainly related to *value proposition*) will apply at a greater scale. Yet, in some cases, cheap access to prototyping might enable businesses to acquire *core competencies* that they did not previously have (for instance, a smartphone accessories store might decide to get involved in smartphone case design or customisation). Rapid prototyping services may also be considered as additional *complementary assets*. So, potentially, rapid prototyping can also lead to more *value creation*. Because rapid prototyping has become affordable, it could also be argued that this changes the *cost structure* and, hence, *value capture*. However, it should be noted that prototyping costs are usually small (if not negligible) in comparison to the overall cost of production.

4.2. Rapid tooling

Rapid tooling, the second stage of technology development, also has a moderate impact on business models. Indeed, just like rapid prototyping, rapid tooling accelerates the production process, but does not radically change it. Rapid tooling is still an integral part of a 'traditional' manufacturing process.

Thus, similarly to rapid prototyping, rapid tooling had an impact on *value proposition*, as the lower cost of tooling and, subsequently, production means that a greater variety of products can be offered (*product offering*). While still not really economical for very small volumes, rapid tooling nonetheless enables some limited elements of product customisation, as it makes it more affordable for companies to produce customised and/or personalised products (*service offering*).

For instance, according to Zonder and Sella (2013), it takes 30 days and $1400 to build an aluminium mould enabling to mass manufacture a set of six ice-cream spoons by injection moulding. Instead, the exact same mould (albeit in polymer) can be 3D printed in less than seven hours and about half the cost ($785). Likewise, 3D Printing enabled to shorten the production time of pump castings for U.S. nuclear submarines by 43 weeks and reduced the cost by 60%.[7]

Hence rapid tooling can clearly enhance *value proposition*. However, because rapid tooling does not significantly alter the production process, it is not expected to have a significant impact on *value creation*. Yet, because 3D printed tools and moulds, besides being faster to produce, are also significantly cheaper, they make lower volume of production economical. Hence, rapid tooling can affect *value delivery*, by enabling to serve more *target market segments*. Indeed, the increased simplicity to modify and personalise products means that companies now have an opportunity to cater for new niche markets that were previously left aside due to the high cost of adapting the product to the needs of a particular segment.

For instance, while the optimal quantity manufactured with a traditional mould is well over 10,000 units, 3D Printed mould are optimal for smaller series as small as 10 units (Zonder and Sella, 2013). Hence, instead of producing tens of thousands of identical ice-cream spoons, it is economical to produce smaller series that are particularly fit for a dedicated market segment (e.g., for toddlers, to eat ice-cream safely on the go). In fact, many objects can be better tailored and render ergonomically fitter and, hence, address the needs of potentially largely heterogenous market segments. As noted in Campbell et al. (2007), the lower cost of rapid tooling enables the development in parallel of several versions of the same product, which makes possible to target at the same time numerous market segments.

As the cost of rapid tooling is generally significantly lower than the cost of conventional tooling (though, of course, the fact the life of the tool can be sometimes shorter than if produced using traditional methods should be taken into account), it is expected to affect *value capture* as it may change the *cost structure*. However, just like in the case of rapid manufacturing, while significant, the tooling cost might still account for a small proportion of the manufacturing cost.

Finally, as a part of a traditional manufacturing process, rapid tooling is, generally, invisible from the outside and can hardly be expected to cause any change in *value communication*.

Nowadays, rapid tooling is mostly used in niche markets by companies who need intermediate tooling to produce a small number of prototypes or functional test samples for evaluation and market. However, it has got potential to be adopted more widely. As rapid tooling can potentially change the way companies compete, it can impact the *value creation* component of a business model. Indeed, the ability to quickly produce custom moulds means that certain *core competences* within the companies might become non-core and certain non-core competencies might gain more importance.

For example, rapid tooling can be used to design custom-engineered jewellery items. Forming tools (punch and die) can be produced to design stretch-formed jewellery with alphabet letters as jewellery patterns. The facility to integrate an initial or a name on rings, pendants, bracelets, earrings, etc. can give a personal touch to the jewellery (Gulati, 2011). In this case, knowledge of CAD becomes a new core competence for the company manufacturing jewellery, while other competencies that were previously critical might become less important.

4.3. Direct manufacturing

As the technology matures and becomes more widely accepted, new business models emerge (Sabatier et al., 2012). Whereas the impact of rapid prototyping and rapid tooling on business models component is rather limited, the next stage of development – direct manufacturing – has the potential to profoundly disrupt business models. The main reason for that is that it enables to completely reconfigure the production process. Furthermore, whereas rapid tooling is intrinsically limited in terms of adoption (not everyone is going to start ordering 3D printed moulds to manufacture at a large scale), direct manufacturing has a far greater adoption potential.

Of course, it should be noted that when direct manufacturing is integrated in existing manufacturing processes it may not significantly alter business models (e.g., a company that was using injection moulding to manufacture a product switches to 3D Printing, without changing the process). At the moment, however, the cost of manufacturing with 3D Printing still remains (in most cases) higher than traditional manufacturing. Thus, companies that are using 3D printers to manufacture do so because they intend to leverage the unique advantages of 3D printing (and not just as straight replacement).

Just like rapid prototyping and rapid tooling, direct manufacturing has an impact on *value proposition*, as it enables to improve both *product offering* and *service offering*. Furthermore, because the use of 3D printers to manufacture products enables full customisation, new *pricing models* are also likely to appear.

However, unlike the two previous stages, direct manufacturing is expected to have a critical impact on the *value creation* component, in particular its *value network* subcomponent. Indeed, one of the key aspects of direct manufacturing is that it enables large-scale mass customisation. As a result, any consumer engaging in a co-creation process with the firms becomes part of the firm's *value network*. As a result of this co-creation process between customers and firms, the value of the resulting product is likely to be significantly higher than for a mass-produced item. By taking an active part in the creation

[7] http://exone.com/sites/default/files/Case_Studies/sand_USNavy1.pdf.

process, customers become a far stronger element in the *value network* and enable more value to be created.

A second key element related to *value creation* that is particularly affected by direct manufacturing is *complementary assets*. Direct manufacturing enables to manufacture (with minor adjustment) with any 3D printer, whereas traditional manufacturing processes are generally tied to a particular plant or factory. Thus, any 3D printer that fits the manufacturing requirement (e.g., materials, precision) can become a complementary asset, regardless of its location. Instead of one or a few manufacturers, a firm potentially has thousands of manufacturers to work with. It is important to note that besides the sheer number of opportunities this creates, this also means more choice in terms of workflow, logistics, quality and materials. While 3D printer mass-adoption is just beginning, this does not necessarily impede the development of new business models. Indeed, as noted in Desyllas and Sako (2013), the complementary assets that are required to implement a new business model are not always available ex-ante, but often become available as the innovation process unfolds.

With regard to *value networks*, direct manufacturing actually enables to bring the crowdsourcing paradigm to the realm of manufacturing. Crowdsourcing has already led to significant business model innovation, in some cases even to an entirely new form of business models (e.g., Kickstarter, Threadless). Direct manufacturing enables to take this concept one step further. Indeed, so far crowdsourcing has been restricted to the idea/design stages of the production process. Direct manufacturing makes it possible to extend crowdsourcing to the manufacturing stage of the production process. For instance, online 3D printing services such as Additer, Kraftwürz and MakeXYZ enable businesses to crowdsource the manufacturing of their products using various materials and finish qualities (printers available through these services range from the basic plastic home printer to industrial grade alloy printer). To this respect, the network of 3D printers available to firms can act as a valuable *complementary asset* and be integrated fully into the business model. In fact, such technological innovation networks are critical because they can provide the necessary resources to change the business model and increase competitiveness (Calia et al., 2007).

Direct manufacturing also significantly changes *value delivery*. With regard to *target market segments*, using 3D printers to manufacture entirely removes volume requirements related to production.[8] Whereas, until now, niche market segments were often neglected, because of the high initial cost of manufacturing (one does not set up a production line just for a few units), direct manufacturing enables to serve any niche regardless of how small it is. It enables, in a way, to monetise the 'long tail' (Anderson, 2008). Indeed, set-up costs for 3D printing manufacturing are very low and it is only when a significantly high number of (presumably standardised) units needed to be produced that mass production becomes more economical than 3D printing.

Furthermore, direct manufacturing increases *value delivery* by creating new *distribution channels* that can be used alongside existing ones. For instance, accessories (e.g., smartphone cases) companies can, in addition to having their products mass-manufactured, use one of the many online 3D printing services (e.g., Cubify Cloud, i.Materialise, Ponoko, Sculpteo, Shapeways) to sell their products directly to consumers. In this case, no transportation or physical storage is involved until the consumer decides to purchase the product, whereupon the product is 3D printed and shipped to the consumer. Instead of shipping the product, one of the growing 'brick-and-mortar' 3D printing services (e.g., Asda, MarkerBot, iMakr) could be used as distribution channel.

As more value can be created with direct manufacturing, it is important to consider the question of *value capture*. The clear positive aspect of direct manufacturing on value capture is that it radically alters the *cost structure*. With traditional manufacturing, fixed costs (set-up costs, machinery, transportation costs, storage costs) are significant, while marginal cost is often fairly low. In contrast, manufacturing with 3D printers generally involves significantly lower fixed costs, but higher marginal cost. Thus besides the actual cost of manufacturing, it is indeed the structure of these costs that is radically changed.

Whether this change is globally positive or negative essentially depends on the volume of production, which, in turns, depends greatly on market demand. Large companies will most likely carry on using mass-manufacturing processes unless it is clear that there is a real demand for mass-customised products (in which case the higher cost of manufacturing can be passed onto consumers who see a higher value in a customised product). Yet, for low value items or infrequently demanded ones (e.g., spare parts), it may be the case that manufacturing cost is, in fact, negligible in comparison to distribution and storage costs. In such a case, even large companies may find an interest in using direct manufacturing.

In contrast, direct manufacturing creates large opportunities for SMEs, startups and individual entrepreneurs, as they often have difficulties accessing mass-manufacturing facilities either because of a volume of production that is too low (in which case they do not meet the Minimum Order Quantity) or a lack of sufficient funds to kickstart production (and, beyond manufacturing, transportation, storage, distribution).

To this respect, direct manufacturing has the potential to radically affect *value capture* as it enables positive cash flows. Instead of the company having to pay upfront (which for SMEs often means borrowing money) for the production, transport and storage of a product, hopping it will sell and recoup its costs, direct manufacturing enables objects to be manufactured on demand. In that case, the company gets the money upfront and then pays for manufacturing and (possibly) transportation (no storage being, of course, needed).

This is for example the case of companies that use 3D printing services, such as Materialise Online or 3DCreationLab, to manufacture their products. Indeed, they only place the manufacturing order once the payment has been received. Furthermore, online 3D printing marketplaces, such as Ponoko or Shapeways, fully automate the sales, manufacturing and delivery processes, thereby minimising the involvement of companies and individual entrepreneurs, who simply have to upload their designs, set a price and wait for their share of revenues to be paid after each sale.

However, although direct manufacturing can have a clear positive impact on *value capture* through changes in the *cost structure*, it also bears significant challenges and, possibly, negative effects. The first of these challenges relates to *profit allocation*. While large companies that use direct manufacturing as a substitute for traditional manufacturing may not see significant changes, the situation might be quite different for SMEs and individual entrepreneurs.

The main issue relates to *profit allocation*. Indeed, while direct manufacturing enables to create more value, in particular for smaller firms, the problem is to capture this value. For instance, using online 3D platforms may come at a significant cost, as those platforms, quite logically, want a share of the value created. While a few of these platforms, such as Ponoko or Shapeways, do not charge any commission on sales (they derive revenues from a markup above printing costs), most retain at least 30% of revenues and in some cases, commissions can even reach 40 to 50% (Cubify and 3DLT). Thus, unless firms are able to use 3D printers they own (which is unlikely for most small firms), they will have to relinquish part of their profits. However, it is important to note that this is not a problem intrinsic to direct manufacturing, but instead an issue that necessarily arises when intermediaries are involved (Giaglis et al., 2002).

The most challenging aspect of direct manufacturing, though, is very likely to be related to revenue models. Just like any previous digitisation episode, direct manufacturing is likely to trigger a fierce increase in competition, as it significantly lowers barriers to entry. Not only is it likely that many firms and individual entrepreneurs will start offering

[8] Rapid tooling enables to lower volume requirements, but as any mass-manufacturing process is still subject to Minimum Order Quantity.

similar products (in which case the question is how many of such products – for instance smartphone cases – can the market bear), but it might also be the case that successful products are (lawfully or not) copied.

In such a context, finding a good *revenue model* might become increasingly difficult. All the industries that have turned digital have been struggling with this issue, some of them for more than a decade (Rayna, 2008). While tangible objects are different from objects that can be made entirely intangible, there are little reasons to think that the sharp increase in competition that will follow a large adoption of direct manufacturing will not lead to revenue related issues, just like what has happened in other digitised industries.

This is certainly where business model innovation will be most critical and may involve radical changes in *profit allocation*. Consumers taking a significant part in the production process (from design to manufacturing and distribution), are likely to be reluctant to pay as much as before, unless they perceive that a significant value (e.g., full customisation) has been added to the product. Some companies may have to completely change their revenue model and move towards more added-value products (high-tech devices cannot be printed) or derive revenue from complementary services.

The challenges related to value capture will consequently require changes to communication component, in particular targeting customers who take part in co-creation and crowdsourcing practices.

4.4. Home fabrication

With regard to disruption of business models, home fabrication carries similar changes as direct manufacturing (as home fabrication is direct manufacturing that takes place at home), albeit, potentially, to a far greater extent.

Besides expected changes in *value proposition* (far more products and services can be developed when consumers have a 3D printer at home), *value delivery* (likewise, every consumer who owns a 3D printer becomes part of the *value network* and the printer becomes a *complementary asset*), home fabrication is expected to improve *value delivery* further, as each consumer who owns a printer becomes a potential distribution channel and even the smallest target market segment becomes economical.[9]

In fact, home fabrication may result in a positive feedback loop between *value creation*, *value proposition* and *value delivery* (Fig. 2). Indeed, both crowdsourcing and mass-customisation enable to increase value creation, which, in its turn, enables to improve value proposition and offer services that develop crowdsourcing and mass-customisation further. Changes in value proposition lead to changes in value delivery that can trigger a greater adoption of 3D printers (e.g., as more mass-customised products are delivered, there are more incentives for consumers to have their own 3D printer). Greater adoption of 3D printers can develop further opportunities for crowdsourcing and mass-customisation and, hence, increase value creation.

In regard to *value capture*, *cost structure* would be further improved, as consumers would solely bear manufacturing and distribution (if any) costs. However, this high consumer involvement is a double-edged sword. Indeed, as evidenced by what has happened in other digital industries, when consumers have the means of production and distribution, capturing value can become extremely difficult. This is likely to be even more the case when consumers engage in co-creation activities. If consumers have helped with, or even initiated, the design of an object and they manufacture it at their own expense, how much are they likely to be willing to pay for the right to do so? While the role of firms might remain critical (they might for instance ensure that the resulting object is printable), will this be perceived by consumers and how much will they be willing to pay for companies to play this role? Home printing, if it becomes largely adopted, will force companies to rethink both *revenue models* and *profit allocation*.

Beyond the question of the omnipresent role of consumers in the production process as customers, home printing also raises the question of consumers as producers. Indeed, over the past decades, the role of consumers in production processes has changed from an almost entirely passive role to a far more active and, in some cases, dominant role. As exemplified by Web 2.0 and social media, digital technologies have turned consumers into 'prosumers' (Tapscott and Williams, 2006) and enabled customers to have control over the design and production of their own original one-off goods (Fox and Li, 2012). While a massive involvement of consumers certainly has a significant positive impact in terms of creativity and market coordination, it also raises significant issues, as it tends to 'crowd out' existing businesses and makes finding alternative revenue and pricing models particularly challenging (Rayna and Striukova, 2010). Some companies may thus have to completely change their revenue model and move towards more added-value products (high-tech devices cannot be printed) or derive revenue from complementary services (for instance, validation and warranties).

5. How 3D printing is changing business model innovation

From the previous section, it is quite clear that 3D printing technologies have the potential to be highly disruptive and lead to significant business model innovation. One of the ways to carry out business model innovation is to make significant changes to the various business model components (Johnson et al., 2008; Abdelkafi et al., 2013). However, the effect of 3D printing on business model innovation goes far beyond that. Besides enabling business model innovation by changing business components, 3D printing technologies also have the potential to considerably change the way business innovation is carried out. The following two sections detail these critical changes.

5.1. Towards adaptive and 'mobile' business models

While business models naturally evolve overtime, firms sometimes need to shift from one business model to another either to leverage arising profit and growth opportunities (Willemstein et al., 2007), or to avoid the potentially lethal effects of technological shifts (Tongur and Engwall, 2014).

In either cases, the ability to move one's business model horizontally to existing or new markets is a key aspect of the necessary business model innovation (Giesen et al., 2007). However, such kind of move is often risky, because significant investments have to be made before even entering the market. 3D printing technologies make lateral moves less risky, because products can be manufactured on demand with minimal costs. Besides being used for entering existing markets, the same strategy may be used for entirely new markets.

In addition to sideways moves, 3D printing technologies can enable firm to rapidly move upstream or downstream. For instance, firms may relinquish manufacturing to customers and focus on design and service. In contrast, design firms that were dependent on intermediaries for the manufacturing of their products may decide to take manufacturing in their own hands. This also means that firms can more easily adapt the 'length' of their business model by taking on more activities (or by giving up some of them).

Hence, 3D printing enables to rapidly change the degree of vertical integration. As noted in Wolter and Veloso (2008), the variation in the degree of vertical integration as a result of innovation essentially depends on the nature of the innovation considered. While incremental innovation is not expected to lead to significant change, architectural innovation tends to increase integration and so does radical innovation (albeit not as clearly). In contrast, modular innovation tends to decrease the degree of integration.

[9] To this respect, Petrick and Simpson (2013) define the concept of "economies of one", when each consumer is his/her own market.

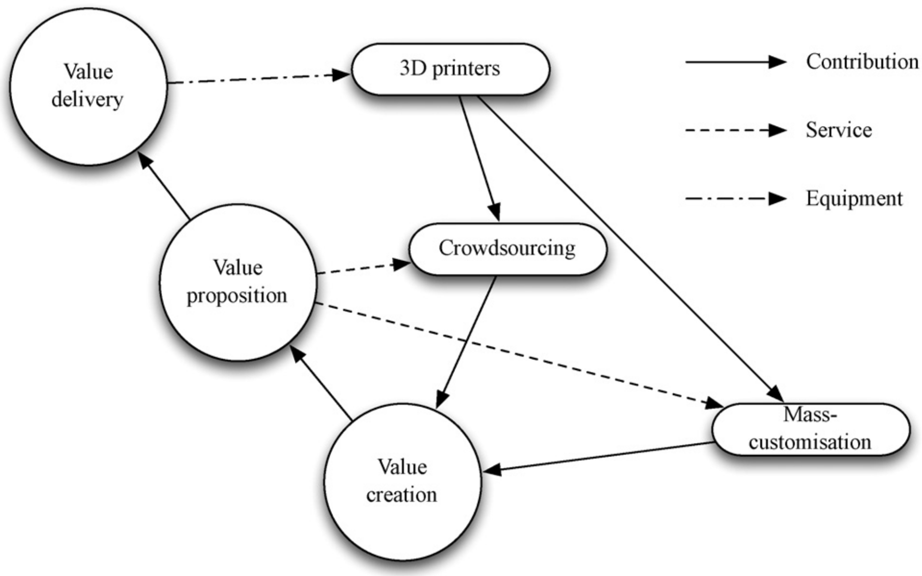

Fig. 2. Home fabrication and positive feedback loop between business model components.

In the case of 3D printing, the overall effect is, thus, ambiguous. Indeed, while Rapid Prototyping and Rapid Tooling are more likely to correspond to incremental and architectural innovation, Direct Manufacturing and Home Fabrication probably relate more to modular and radical innovation. Yet, the traditional rationale for vertical integration (transaction costs and competence) may not fully apply in the case of 3D printed objects because of mass customisation. For example, if consumers provide direct input into the conception of products and if they value personalised products, then competence may remain largely distributed (including amongst consumers) and accessible, and transaction costs may well be offset by the additional value created by customisation.

Overall, 3D printing technologies enable business models to become modular and adaptable. Firms can then decide, depending on the environment to adopt a narrow (focused on one particular market) or wide, long (e.g., design, manufacturing and distribution) or short (just design) business model. Furthermore, business models become fully 'mobile' and can be moved up/down or sideways, as needed (Fig. 3).

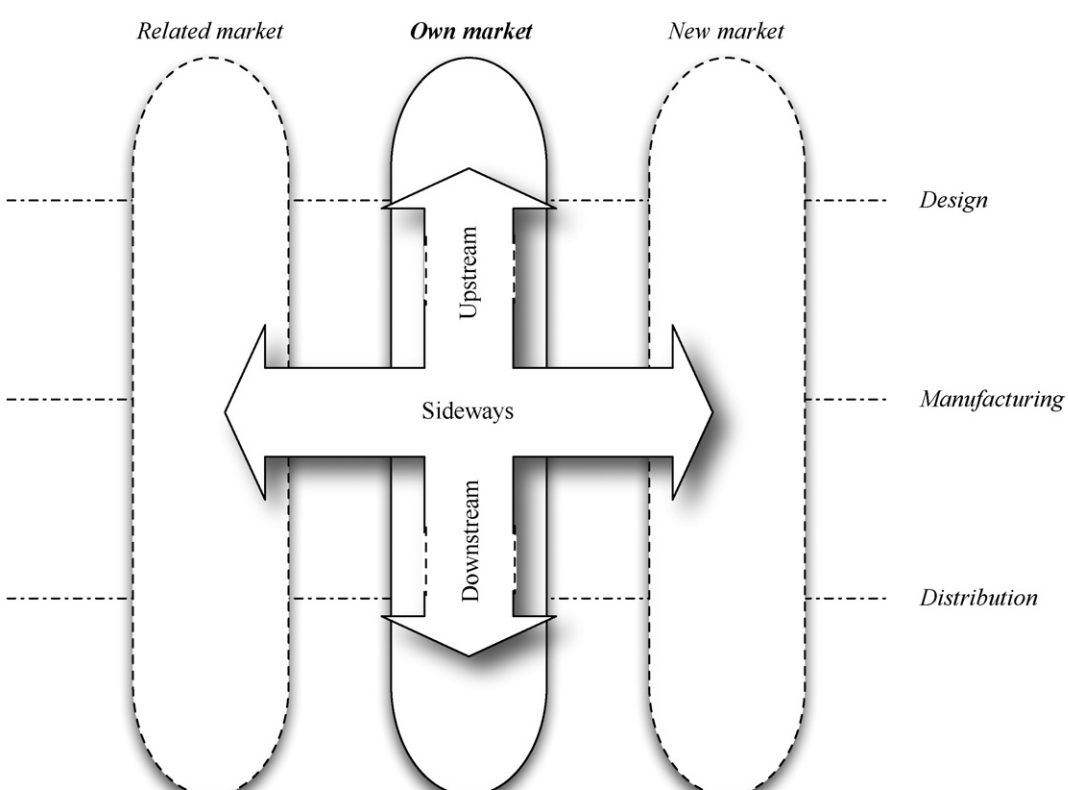

Fig. 3. 3D printing enables adaptive 'mobile' business models.

5.2. Rapid prototyping for business models

In regard to business model innovation, Sosna et al. (2010) mention that firms "plan, design, test and re-test alternative business model variants until they find the one that best suits their objectives". While for businesses there is often no other choice than trial and error when it comes to business model innovation, this heuristic process generally comes at a significant cost. As noted in Velu and Stiles (2013), this is particularly the case when a new business model is developed in parallel to the existing one, as there is a risk of cannibalisation.

Many businesses do not get a second chance to experiment and firms often choose to learn from the failure of other firms rather than from their own trial and error. Indeed, Desyllas and Sako (2013) found that, because business models can "hardly be tested in laboratory", conceptualising and implementing a new business model may not be sufficient to obtain a competitive advantage and above average returns.

In contrast, access to 3D printing technologies permits to try out various business models at a much lower cost, just like in a "laboratory". New ideas or design can be rapidly tested and the size of the testbed actually increases with the adoption of 3D printing technologies.

The recent foray of toy manufacturer Hasbro into the 'grown-ups' market provides a good example of 3D printing enabling to rapidly prototype and test business models. Since the 'reboot' of the "My Little Pony" franchise (targeted at girls aged two to 11) in 2010, Hasbro became progressively aware of a rather unexpected growing fan base of adults (including males, who refer to themselves as 'bronies' — or 'bro ponies') (Watercutter, 2011). Hasbro is a traditional toy manufacturer and, furthermore, had very little information about this entirely new type of fans. They knew adults like the TV show, but would that lead them to buy show-related toys and, if such, what kind and for what amount.

In this context, venturing into this potentially newfound market would normally seem highly risky, if not only because of the large costs (market research, designers, factory line) involved. What Hasbro did, however, is that they teamed up with Shapeways, one of the leading online 3D printing platform, so that 'grown-ups' My Little Pony figurines could be printed on demand. Unlike its usual toys, Hasbro chose sandstone 3D printing (instead of plastics), a fragile, but full colour and highly detailed material.

Hasbro actually chose to begin with a very 'short' business model. Not only did they not manufacture the products, they did not design them either. Instead, Hasbro called on fans to upload their own designs of Little Pony figurines, submissions that were screened by Hasbro before being made available on the Shapeways platform.[10] Hasbro even let designer-fans choose themselves the price of the products, while taking a cut on the proceeds. Hence most of the exploratory work related to this new venture has been done by fans themselves.

Had this prototype of business model not worked, it would have been very easy (and costless) to abandon it or to create a new one (for instance, Hasbro could have changed the pricing model at virtually no cost). In any case, the investment required to start this kind of venture is almost negligible.

The resulting business model is completely agile. Hasbro could 'lengthen' its business model by offering its own designs in replacement (or alongside) of those provided by fans. It could take the most successful designs and mass-produce them for adults, but also changing the materials, bring them back to their traditional child market. Hasbro could 'widen' the business model by enabling other objects than figurines to be contributed by fans. The scalability of 3D printing technologies enables in any case to subsequently 'shorten' or 'thin' the business model as needed.

Hence, 3D printing technologies, which were used at first for rapid prototyping of objects, can also be used for rapid prototyping of business models. The ability to rapidly try and test ideas has enabled the design and manufacturing industries to significantly increase the speed of product innovation. It may well be the case that 3D printing technologies will have a similar effect on business model innovation.

[10] http://www.shapeways.com/superfanart/mylittlepony.

6. 3D printing innovation: radical or incremental?

From the previous sections, it is clear that 3D printing can enable to rapidly change and reconfigure business model components, but what is the extent of the resulting impact of such changes? To answer this question, the impact of business model innovation in general (incremental or radical) has to be considered. To this respect, it is to be noted that, while this question has been addressed in the literature, this has not yet been done in a comprehensive manner.

Indeed, two different perspectives can be identified in the literature. The first focuses on the extent of the changes in the business models themselves, the other concentrates on the extent of the changes resulting from changes in business models. Hence, this section aims to integrate the two different perspectives in a joint framework in order to discuss the potential systemic effects of 3D Printing on business model innovation.

For Brink and Holmén (2009), radical business model innovation arises when the business model has changed "simultaneously within more than one aspect or dimension". Likewise, Abdelkafi et al. (2013) note that modifying more than one value component at a time can lead to more radical innovations.

Besides the number of components affected by the changes, the extent of the changes also has to be taken into account. For Ho et al. (2011), the difference between incremental and radical business model innovation relates both to the number of business model components affected, but also to the degree of innovation. When both are high, business model innovation is radical. When both are low, it is incremental. Brink and Holmén (2009) also note that radical innovation necessarily leads to many simultaneous changes in the business model. Likewise, Voelpel et al. (2004) mentions that radical business innovation is highly disruptive for the firm itself and its key components (core structure, governance, etc.).

The problem of this classification is that there is a large 'grey' area when one of these two criteria is high and the other is low (e.g., high degree of innovation affecting a few components of the model, low degree of innovation affecting many components). For this reason and in opposition to this 'inside view' of business model innovation (based on components), other authors consider, instead, the external aspects of business model innovation. In this case the radicalness of business model innovation is assessed based on its effect on clients, markets and industry.

Johnson et al. (2008) mention de-novo business models, which are not only new for the company, but also "game-changing for the industry or market". Likewise, Zott and Amit (2002) define radical business model innovation as a novel business model that leads to the creation of new market (e.g., eBay). However, radical business model innovation does not necessarily 'automatically' create new markets, but, instead, creating new markets may be needed because radical business model innovations are sometimes simply too radical for their own market (Treacy, 2004).

Creating new markets is not a necessary condition for business model innovation to be disruptive. Changes in existing markets are also a consequence of radical business model innovation. To this respect, Giesen et al. (2007) consider both redefinition of the industry in which the firm operates and horizontal move to new industries as critical aspects of business model innovation. Likewise, Koen et al. (2011) categorise business model innovation according to changes in the value network. Incremental business model innovation tend to keep the same customer base, while more innovative changes enable to capture existing customers which are not yet customers of the firm (clients of competitors). Finally, the most radical business model innovations enable to attract non-customers, hereby creating new markets.

When combining these 'internal' and 'external' views of business model innovation, it is important to keep in mind the difference between radical innovation and disruptive change. Indeed while market/industry disruption is generally associated with radical innovation, this is not necessarily always the case. Indeed, incremental innovation can lead to radical change, just as radical innovation can reveal itself as insignificantly disruptive (Rayna and Striukova, 2009). The same is also true for business model innovation. For instance, when moving horizontally to existing markets, a firm may become highly disruptive for the other firms on that market, although the core of its business model will not really change. Likewise, radical business model innovation may only affect the very same consumer base as before.

Fig. 4 presents a framework that integrates the two different views of business model innovation. The dotted arrows symbolise the loose relationship between radical innovation and disruption and the fact that business model innovation, whether incremental or radical, may lead to a wide range of outcomes on the market, some very disruptive, others not. Furthermore, profitability resulting from business model innovation has to be taken into account. Indeed, as noted by Amit and Zott (2010), subtle changes to business models might not be disruptive, but, nonetheless, be profitable.

Hence, even when adopting a more systematic view, it is very difficult to assess a priori the type of business model innovation enabled by 3D Printing technologies. Indeed, while *rapid prototyping* and *rapid tooling* do not, a priori, enable either numerous or deep component changes, the resulting effect might still be, nonetheless, highly disruptive. The ability to rapidly prototype and tool is likely to enable the entry of new companies on existing markets and while such companies may use very similar business models as the incumbents, the latter might nonetheless see their market position disrupted (one can think for instance about jewellery and accessories markets). In contrast, while *direct manufacturing* and *home fabrication* clearly enable to radically alter many business components, this does not necessarily mean that this will always lead to disruptive innovation. Indeed, direct manufacturing and home fabrication might just provide ways to 'do the same thing' differently. A typical example would be spare parts directly manufactured on demand instead of being manufactured ahead and stored.

Yet, logically, one can reasonably expect 3D printing to lead to highly disruptive business model innovation, especially as direct manufacturing and home manufacturing become more widespread. But that does not necessarily mean that all business models will be highly disrupted, or that those that are highly disrupted will be highly disruptive.

7. Conclusion

The aim of this article was to investigate the impact of 3D printing technologies on business models and business model innovation. Because 3D printing technologies can be involved at different stages and to a different extent in the production process, four different cases, which correspond to the four progressive stages of adoption of 3D printing technologies, were considered: rapid prototyping, rapid tooling, direct manufacturing and home fabrication.

As expected, rapid prototyping and rapid tooling were found to have a limited impact on business models, mainly because, placed within a 'traditional' manufacturing process, they merely speed up the process without changing it significantly. Although they may affect cost structures, their impact on value capture is unlikely to be significant. Yet, it was noted that the increasing affordability of 3D printers could, by bringing rapid prototyping to 'the masses', significantly increase competition.

In contrast, direct manufacturing (which corresponds to manufacturing end-use products with 3D printers) and home fabrication (on personal 3D printers) were found to be potentially significantly more disruptive, as they are likely to considerably increase value creation (because of an increase in complementary assets and value networks) and value delivery (because of the access to new delivery channels and market segments). However, while direct manufacturing and, in

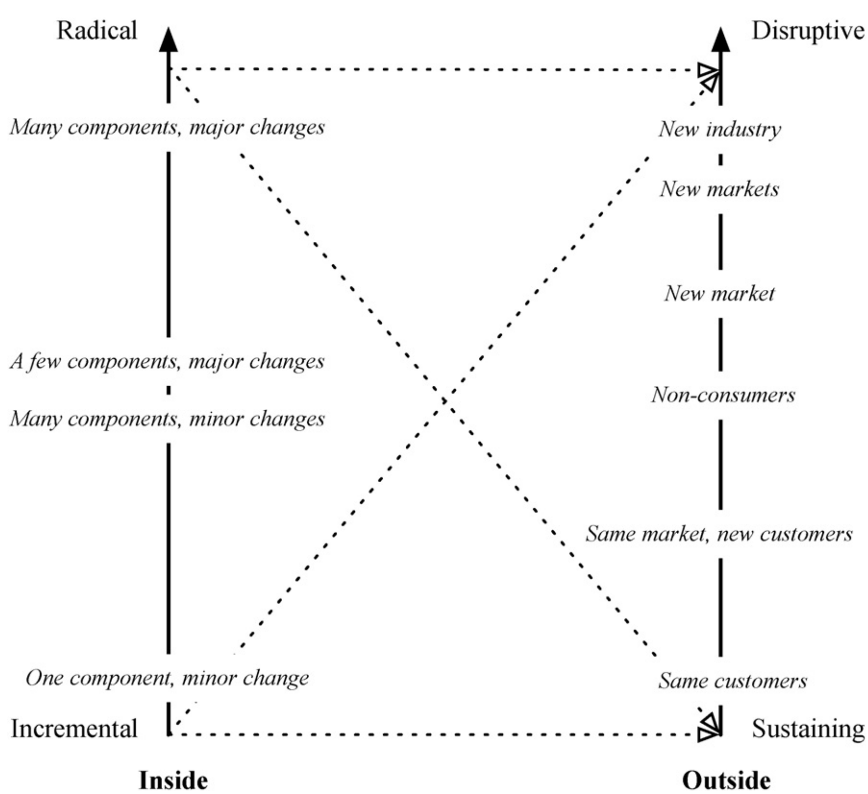

Fig. 4. Inside-outside view of business model innovation.

particular, home fabrication, can lead to much more value being created, they also make it much more difficult to capture value.

In both cases, one of the most critical effects is that 3D Printing will lead to a sharp increase in competition, from SMEs and individual entrepreneurs, but also from 'prosumers'. As noted in the article, such an increase of competition (whether legal or illegal) has been prevalent in all industries that have turned digital and has rendered, in many cases, past revenue and pricing models obsolete.

Yet, the article has shown that one of the key aspects of 3D printing technologies is that they enable to rapidly change and experiment with business models. Indeed, these technologies enable fully adaptive and 'mobile' (upstream or downstream, sideways, long or short) business models and bring the rapid prototyping paradigm to the world of business model innovation.

This new ability to have a very rapid rate of business model innovation creates new opportunities as well as challenges. As companies now have the ability to diversify or even change the focus of their business easily, so can competitors. Moreover, market structure is now more dynamic and key boundaries that used to exist tend to progressively disappear (e.g., consumers are becoming producers; niche market is becoming attractive to large players, not just to small ones). Chances are that the winners of tomorrow are those companies which, far from being blindsided by the new technology, will think first and foremost in terms of business model innovation.

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Thierry Rayna, PhD, is a Professor of Economics at Novancia Business School Paris. Beforehand, he spent ten years in the UK, where he held positions at Imperial College London, the London School of Economics, UCL, and the University of Cambridge. His research investigates the consequences of technological change and digitisation on strategies, business models and innovation ecosystems. He has served as an advisor for national and international organisations, as well as for major companies in the media, telecommunications and cultural industries. He also mentors start-ups.

Dr Ludmila Striukova is a Senior Lecturer at the School of Management of University College London. Her previous experience includes working as a market analyst for a statistical agency and as a researcher at King's College, University of London. She has published extensively in the area of innovation and technology management and her research work has been used in numerous EU and governmental reports. She also has used her telecommunications engineering background to mentor and advise technology based start-ups and multinationals.