The Impact of 3D Printing Technologies on Business Model Innovation

Thierry Rayna and Ludmila Striukova

Abstract. There is a growing consensus that 3D printing technologies will be the next major technological revolution. 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 model innovation. Yet, history has shown that technological evolution without adequate business model innovation is a pitfall for many businesses. The contribution of this article is threefold. First, it combines the existing literature on business model innovation in an integrated 'inside-outside' framework of business model innovation. Secondly, the changes brought about by 3D printing technologies to the business model components are investigated. Finally, this article shows that in addition to enabling business model innovation, 3D printing technologies have the potential to change the way business model innovation is done, by enabling adaptive business models and by bringing the 'rapid prototyping' paradigm to business model innovation itself.

1 Introduction

While everyone agrees on the critical importance of innovation, businesses often fail to innovate successfully because of a too narrow view of innovation. Indeed, when thinking about innovation, technological innovation (which results in product or process innovation) is often the first thing that comes to mind. Sadly, it is also far too often the *only* thing that comes to mind. Yet, technological innovation can only be valuable with an adequate business model. Countless firms with technological leadership have failed because of an unsuitable business model, while less

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innovative firms have achieved market dominance simply because of a better business model.

Furthermore, technological innovation might even sometimes endanger a successful firm (e.g. digitisation and the major record labels). Indeed, technological innovation often requires to completely rethink a firm's business model. Instead, technological innovation often provides firms with a false sense of safety, which might eventually be lethal. Meanwhile, technological followers often realise that the best way to catch up with the leaders is through business model innovation. Recent history has shown that business model innovation is, indeed, a powerful tool. The victories of Apple on the 'device' markets (iPod, iPhone, iPad) and online music (iTunes Store) are a testimony to the fact that a well thought business model innovation may be far more potent than market dominance or technological or product leadership (Rayna et al., 2009; Rayna and Striukova, 2009).

Amongst the recent technological innovations, 3D printing (or 'additive manufacturing') has been deemed as a very promising one. In 2013, U.S. President Barack Obama mentioned the critical role of 3D printing in strengthening manufacturing, scientific, defence and energy sectors[1]. Beforehand, Rich Karlgraad (Forbes) conjectured that 3D printing would become the "transformative technology of the 2015–2025 period" (Karlgraad, 2011). Likewise, Chris Anderson (Wired) forecasted that the "desktop manufacturing revolution [...] [would] change the world as much as the personal computer did" (Anderson, 2012).

Just like digitisation of other products (music, movies, books), 3D printing is going to be very disruptive, as it enables digitisation of objects. Just like what happened with other 'digitalised' industries, 3D printing is going to threaten the position of established firms and create opportunities for newcomers. In this context, business model innovation is going to play a critical role in the success or survival of firms affected by this new set of radical technologies.

This research investigates the role of 3D printing technologies in regard to business model innovation. In particular, emphasis is put on the business model components likely to be most affected by these new technologies. One of the objectives is to demonstrate that 3D printing technologies are not only enabling business model innovation, but also have the potential to considerably change the way business innovation is understood and carried out.

The first section of this article provides a classification of business model innovation and provides a novel framework which reconciles the 'inside' and 'outside' view of business innovation in the literature. The fourth section presents briefly 3D printing technologies and the main services that are currently available to businesses. Finally, the fifth section analyses the impact of 3D printing technologies on business model innovation.

[1] http://www.whitehouse.gov/state-of-the-union-2013

2 Categorising Business Model Innovation

Categorising business model innovation requires a thorough understanding of what business models are. The literature on business models is very abundant, with 110,000 academic works written on the subject between 2001 and 2013 and 12,500 new ones produced so far in 2013 alone[2]. Although there are differences among scholars, in particular between American and European (De Reuver et al., 2013), there is a broad consensus around four critical components of a business model: 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), value delivery (Osterwalder et al., 2005; Abdelkafi et al., 2013; Holm et al., 2013). A fifth component, value communication, is also often thought as a critical aspect of a business model (Abdelkafi et al., 2013). The components as well as their sub-components identified in the literature are summarised in Figure 1.

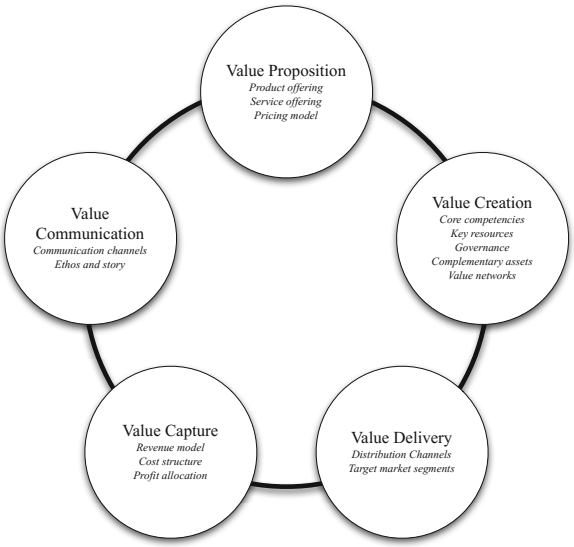

Fig. 1 Key components of business models

The most straightforward way to envisage business model innovation is to consider changes in any of these main components or sub-components (Johnson et al., 2008; Abdelkafi et al., 2013). In particular, Zott and Amit (2002), Giesen et al. (2007) and Koen et al. (2011) emphasise the role of value networks (which include all the firm partners, including customers).

[2] Data provided by Google Scholar.

One of the most common ways to categorise innovation is to distinguish between incremental and radical innovation (Banbury and Mitchell, 1995). The same distinction can be made for business model innovation. For Brink and Holmén (2009), radical business model innovation arrises 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 consideration. Indeed, according to 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 is 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 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.

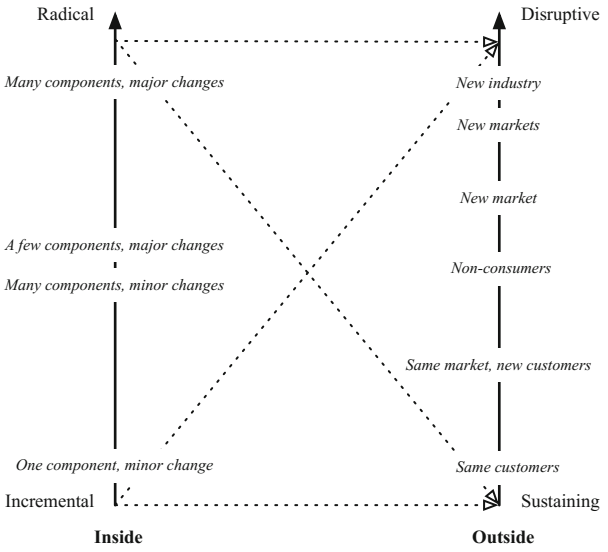

Fig. 2 Inside-outside view of business model innovation

Figure 2 integrates these 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.

3 A Introduction to 3D Printing Technologies

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. This differs from the more usual 'subtractive' (when an object is cut out from the raw material) or moulding/die-casting (when liquefied material is placed into a 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 generic 3D modelling software (some of which are available for free) or using dedicated software provided by 3D printing services (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). When an object is printed, the 3D model of the object is discomposed into successive layers that are printed one at time.

The most frequently used material for 3D printing is plastic, but wood, metal alloy, salt, ceramics and even sugar and chocolate can be used to print. Currently, most printers can only print with one material at a time, but it is only a matter of time before several materials can be used simultaneously. The Objet500 Connex (sold at $250,000) can already print from more than 100 materials (up to 14 simultaneously) and manufacture items which are at the same time both rubber and rigid, opaque and transparent. The range of objects that can be manufactured with 3D printers is very wide and is constantly growing: robots, body parts (organs), prosthetics, art, food items, musical instruments, furniture, clothes. 3D printers can be even used to print other 3D printers.

While 3D printing technologies were, originally, intended exclusively for 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 their usage 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. Amazon followed the trend in June 2013, when it opened a 3D printing section, selling printers, plastic filament, books, software, parts and supplies. In July 2013, High Street consumer electronic retailer Maplin also started to sell 3D printers, consumables and accessories in its 205 stores throughout the UK.

The same month, 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. Selfridges, the UK high-end department store will be opening, in partnership with the 3D printing service iMakr, a Christmas shop where customers can print in store, buy 3D printers and 3D scan objects. Tesco, the UK grocery chain and one of the worlds largest retailers, is also thinking about introducing 3D printing services, such as printing spare parts for items that customers had already bought while they are shopping in the store[3].

While not every business or home have (yet) their own 3D printers, a growing number of services related to 3D printing (most of them online) are offered to consumers and businesses. Companies like Ponoko (the first mover, opened in 2007),

[3] https://www.tescoplc.com/talkingshop/index.asp?blogid=124

Sculpteo and Shapeways operate a marketplace service where companies can sell the 3D models of their products directly to customers. The physical object can then either be printed by the marketplace for the consumer or directly by the consumer at home. If consumers do not have yet their own printer, Cubify Cloud, in addition to its marketplace and printing services, also offer to ship 3D printers directly to consumers.

In addition to these rather versatile services, there are also companies specialising in printing activities. Two of them, iMakr and Makebot, even have physical stores and are, thus, the 3D equivalent to the traditional print store. 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 market place for 3D printers, where users can locate 3D printers located next to 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 consumer alike can use these platforms even when they only have a faint idea of what they want to manufacture (and of how to manufacture it). The elements of the 'crowd' will team up to offer designs, 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.

4 How 3D Printing Can Revolutionise Business Model Innovation

Over the past few years, it has become clear that 3D printing technologies will have a very large (and disruptive) impact on the economy. Additive manufacturing will, undoubtedly lead to significant product and service innovation. However, this should not hide the fact that these same technologies have the potential to considerably affect business model innovation.

There are, in fact, two broad ways in which 3D printing can have impact on business model innovation. The first one relates to how this new set of technologies can change the different business model components (presented in Fig. 1). The second one, probably more subtle, but potentially more radical, is that 3D printing technologies have the potential to actually change the way business model innovation is done.

4.1 Innovation in Business Model Components

In section 2, it was shown that a key aspect of business model innovation relates to changes in the different business model components. Both the extent of changes in

the components and the number of components being changed can result in radical innovation.

In the case of many technological innovation, the principal business model component which is affected is *value proposition*, as technological innovation leads to product and service innovation. Although 3D printing technologies have already led to product and service innovation, their main impact is more likely to relate to the *value creation* component and, in particular its *value network* subcomponent. Indeed, one of the key aspects of 3D printing technologies is that they enable large-scale mass customisation. As a result of the co-creation process between customers and firms, the value of the resulting product is higher than for a mass-produced product. By taking an active part in the creation process, customers become a far stronger element in the Value Network and enable more value to be created.

A second element, which also relates to value network, is crowdsourcing. 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). However, 3D printing enables to take this concept one step further. Indeed, so far crowdsourcing has been restricted to the idea/design stages of the production process. 3D printing technologies make it possible to apply the crowdsourcing paradigm to the manufacturing stage of the process. For instance, 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 in the business model.

Another key business model component affected by 3D printing is, obviously, *value delivery*. Indeed, by enabling customers to manufacture at home (or in local print shops), 3D printing can potentially significantly alter *distribution channels*, creating new ones alongside traditional 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 to consumers. Consumers can then either print the product at home (if they own a 3D printer), have it printed and delivered by the online 3D printing service, or have it printed in a local printshop (such as iMakr in the UK, MakeBot in the U.S.). Some of these online services, such as Cubify Cloud, even develop distribution channels further, as they offer consumers to purchase 3D printers and print 3D objects at home.

A further change in value delivery brought about by 3D printing relates to *target market segments*. Indeed, 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), 3D printing enables to serve niche markets regardless of how small they are. It enables, in a way, to monetize the 'long tail'. 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 worthy than 3D printing.

A recent example of niche market enabled by 3D printing is Square Helper, a plastic widget which prevents the Square card reader[4] from spinning when the credit card is swiped. The entrepreneur behind Square Helper has now sold over 1,000 units, which were produced using his own home 3D printer, at $8 a piece[5]. Since it was impossible to know in advance what the demand for such a widget would be, it would not be possible to mass produce the widget, as it would require a pre-commitment on quantity, which would be far too risky.

The demand for niche products has been demonstrated over the past few months by the success of Kickstarter (and similar crowd-funding platforms) projects (some raising over a million USD for electronic devices and accessories). However, the key issues of these projects is their lack of scalability: a significant number of units have to be purchased before production starts and once the initial batch has been produced it is often impossible to order more units (except if a second project is launched and there is enough demand the second time around). 3D printing technologies enable remove these two constraints and to fully exploit niches.

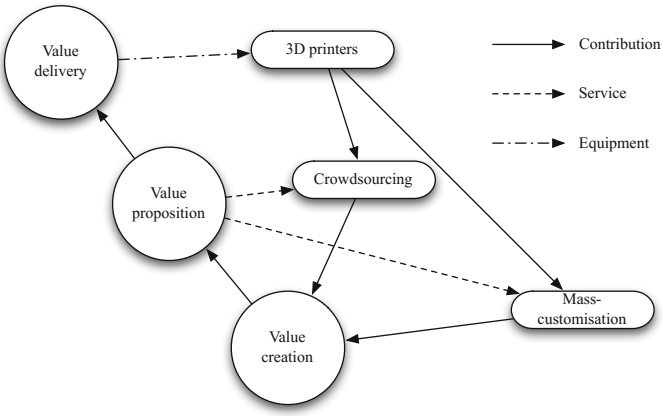

Fig. 3 Positive feedback loop between business model components

An important effect of 3D printing technologies on business model innovation is that they create a potentially positive feedback loop between value creation, value proposition and value delivery (Fig. 3). Indeed, crowdsourcing and mass-customisation enable to increase value creation, which, in its turn, enables to improve value proposition and offer services which develop further crowdsourcing and mass-customisation. Changes in value proposition lead to changes in value delivery

[4] Square offers a credit card payment solutions for small businesses that consists in a card reader device which can be attached to a tablet or a smartphone.

[5] `http://3dprintingindustry.com/2013/03/19/making-money-from-3d-printing-square-helper/`

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 of crowdsourcing and mass-customisation and, hence, increase value creation.

As more value can be created with 3D printing technologies, it is important to consider the question of *value capture*. The clear positive aspect of 3D printing on value capture is that it can significantly decrease the costs (*cost structure*). Indeed, as products can be manufactured on demand, transportation costs and storage costs can be decreased. Also, although the cost of manufacturing can be higher than with mass-produced techniques, the higher cost may be passed on to consumers, who will either see a benefit in a mass-customised product or will value a quicker access to the product. Furthermore, when products are home printed, the actual manufacturing cost of the product is actually borne by consumers.

However, beyond the improvement of cost structure, value capture is most likely the business model component that 3D printing will challenge the most. Indeed, while this new set of technologies will undoubtedly lead to far more value being created, this may also result in far greater difficulties to capture both new and 'old' value. Industries that had gone digital have faced the same problem, and required innovative *revenue models* to overcome it. This is certainly where business model innovation will be most critical and this 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.

4.2 Innovation in Business Model Innovation

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.

4.2.1 Towards Adaptive and 'Mobile' Business Models

As discussed in Section 2, ability to move one's business model horizontally to existing or new markets is a key aspect of business model innovation (this corresponds to the 'outside' view of Fig. 2). 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).

Thus, 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, the business model becomes fully 'mobile' and can be moved up/down or sideways, as needed (Figure 4).

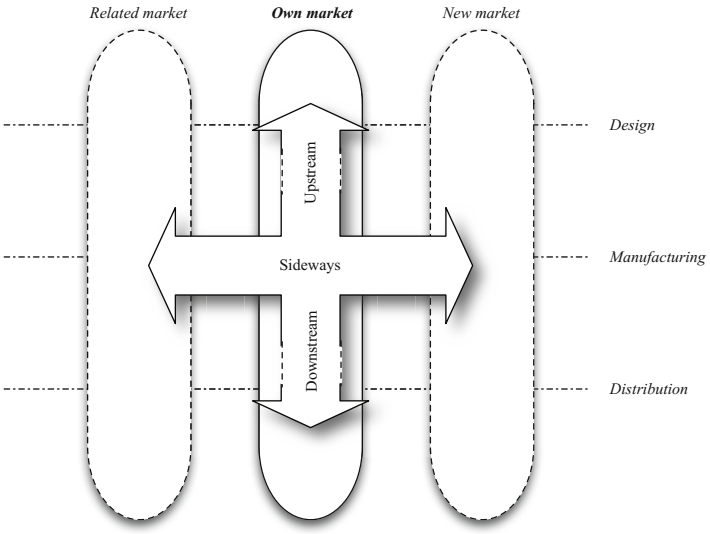

Fig. 4 3D printing enables adaptive 'mobile' business models

4.2.2 Rapid Prototyping for Business Models

Sosna et al. (2010) noted about business model innovation 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. 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.

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

Hence, such 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.

5 Conclusion

Drawing on the literature devoted to business model innovation, this article has provided an integrated framework which combines both the 'inside' and 'outside' views present in the literature. This framework was then used to discuss the effect of 3D printing technologies on business model innovation. Following the 'inside' view, the potential changes to the key elements of business models were investigated. It was found that although 3D printing technologies can potentially lead to a virtuous circle of value creation, firms might find it far more challenging to capture value.

But 3D printing technologies are not only a vector of business model innovation, they can also change the way business model innovation is done, in particular this article discussed how these technologies can enable fully adaptive and 'mobile' (upstream/downstream, sideways, long or short) business models. Finally, 3D printing technologies can bring the rapid prototyping paradigm to the world of business model innovation.

3D technologies are not only disruptive to similar technologies or to technologies *per se*. They are also disruptive to the current business models, models which, in many cases, have taken a lot of time and effort to be designed. Fortunately, 3D printing technologies make it much easier to try new business models and minimised the cost for companies change markets or even their place in the value chain.

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 being erased (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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