Technological Forecasting & Social Change xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

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

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ARTICLE INFO

Article history:
Received 23 January 2014
Received in revised form 25 May 2015
Accepted 28 July 2015
Available online xxxx

Keywords:
3D printing
Business models
Innovation
Rapid prototyping
Rapid tooling
Direct Digital manufacturing
Home fabrication
Value creation
Value capture

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

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http://dx.doi.org/10.1016/j.techfore.2015.07.023

'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/.

Please cite this article as: Rayna, T., Striukova, L., From rapid prototyping to home fabrication: How 3D printing is changing business model innovation, Technol. Forecast. Soc. Change (2015), http://dx.doi.org/10.1016/j.techfore.2015.07.023