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From material scarcity to artificial abundance – The case of FabLabs and 3D printing technologies

Primavera De Filippi & Peter Troxler

I. Introduction

Digital media allowed for the emergence of new artistic practices and innovative modes of production. In particular, the advent of Internet and digital technologies drastically enhanced the ability for multiple authors to collaborate towards the creation of large-scale collaborative works, which stand in contrast to the traditional understanding that artistic production is essentially an individual activity. The significance of these practices in the physical world is illustrated by the recent deployment of *FabLabs* (Fabrication Laboratories), that employ innovative technologies – such as, most notably, 3D printing, which is recently gaining the most interest – to encourage the development of new methods of artistic production based on participation and interaction between peers. By promoting a *Do It Yourself* (DIY) approach, *Fablabs* constitute an attempt to transpose the open source mode of production from the domain of software into the field of art and design. Yet, as opposed to the information realm (where scarcity has been added artificially – by legal means – to inherently abundant resources like software and creative expression), artistic and design production in the physical world is riddled by the problem of material scarcity: physical resources are inherently limited and cannot be reproduced without using, converting or otherwise disposing of others kinds of resources.

Specifically, we refer here to the notion of *artificial scarcity* to denote a situation whereby a resource that is technically non-rival (i.e. its consumption by one person does not prevent its consumption by another person) is turned into a scarce resource by legal or technical means. In the realm of information, this is achieved by means of intellectual properties laws (such as copyright, trademarks, or patent law) aimed at reducing the availability of resources to allow for monopoly pricing. This generally results into a deadweight loss for society, to the extent that some people can no longer afford to consume information.

Over time, open source practices have managed to ‘hack’ these provisions by means of contractual in-

struments designed to eliminate artificial scarcity so as re-instate the original state of abundance in the information realm. One has to wonder whether similar instruments could be conceived to eliminate – or, at least, reduce – material scarcity in the physical world. The underlying question that will be addressed throughout the paper is, therefore, ‘*how could we hack the law to turn technical material scarcity into artificial material abundance?*’

By analogy with artificial scarcity, we rely on the concept of artificial abundance to denote a situation whereby resources that are naturally scarce are made more abundant (or less scarce) by legal or technical means. While it is, of course, not possible to obtain an unlimited amount of resources – since physical resources are, by definition, scarce – we believe that it is nonetheless possible to reduce the scarcity of certain products by relying on recycled materials, alternative energy and digital manufacturing techniques in order to convert raw materials into finished products.

To substantiate this claim, we will first investigate the information realm (Section 2) to gain a better understanding of the properties of information as a quasi-public good (2.1), how the copyright regime effectively introduced artificial scarcity on a non-rival resource like information (2.2), and how the copyleft regime actually ‘hacked’ the law to get rid of such artificial scarcity (2.3). We will then look at the digital realm (Section 3), its specific properties (3.1) and, in particular, how the ‘meme’ of collaboration and sharing that established itself in the digital realm has led to the emergence of new, collaborative forms of artistic production (3.2) that are slowly spreading into the physical world (3.3). Finally, we will focus on the physical realm (Section 4) to analyse the mechanisms that could contribute to eliminating the three main barriers to abundance – raw material scarcity (4.1), exclusivity of production tools and facilities (4.2), and improper access to knowledge and skills (4.3).

2. The information realm

2.1. Information as a quasi-public good

Information is often assimilated to a public good¹, to the extent that it is both non-rival in consumption (i.e. the consumption of the resource by one person does not affect the consumption of the same resource by another person) and non-excludable (i.e. it is difficult, or impossible, to exclude anyone from accessing or consuming the resource). As such, information is inherently abundant, since, after it has been produced once, it becomes subsequently available for anyone to use, reuse or build upon.

Yet, given its non-rival and non-excludable character, information is affected by the same concern that characterises many other public goods: it is ultimately subject to free-riding, in the sense that people might

¹ In economics, a public good is a good that is both non-excludable and non-rival in that individuals cannot be effectively excluded from use and where use by one individual does not reduce availability to others (Varian, 1992).

benefit from it without covering the cost of production. The result is that, unless properly managed, the resource will end up being over-used and/or under-produced, because no one will have an incentive to invest in the production and/or preservation thereof.

Yet, as opposed to most *pure* public goods (whose characteristics cannot be changed), information is in fact a *quasi*-public good,² to the extent that its properties can theoretically be modified by either legal or technical means. This is the trend that we observed over the past few centuries, with the establishment of intellectual property laws and, in particular, with the gradual and steady extension of copyright protection.

2.2. *The copyright regime: Introducing artificial scarcity to a non-rival resource*

The main purpose of copyright law is to turn information – an inherently non-rival resource – into a commodity that can be traded on a market for information goods. This is done through the establishment of a series of exclusive rights over the content of information that allows authors to control the reproduction, distribution and exploitation of such content.

The underlying argument for copyright law is that authors need to be rewarded for their intellectual endeavours. Indeed, given the ease at which information can be reproduced, it is often argued that others can easily free ride on what has been previously expended in the initial production of a work.³ Authors are thus granted a temporary monopoly right over the exploitation of their works so as to acquire an incentive to produce more works. Yet, given the subjective value of creative works (which are essentially experience goods⁴) it is difficult to determine – objectively – the value that these works actually bring to society. Hence, the market is regarded by many as the best mechanism to correctly assess the value that the public can derive from these works (Besen & Raskind, 1991; Varian, 1999; Posner, 2005; Landes & Posner, 2009). Information is thereby turned into a commodity, which – albeit non-rival in consumption – nonetheless features the properties of a private good in terms of artificial scarcity and excludability.

The problem is, however, that – by virtue of artificial scarcity – the copyright regime ultimately reduces the opportunities for society to benefit from global and unconditional access to a large variety of cultural works; a ‘market failure’ or ‘externality’ that the (neo-classical) market is unable to account for.

2 Information goods (such as literary, dramatic, musical or artistic works) are commonly misclassified as public goods, even though they are technically classified – in economic terms – as quasi-public goods: although they do satisfy the characteristics of a public good, excludability is nonetheless possible (McConnell & al., 2009).

3 As clearly stated by Marx, in *Theories of Surplus Value*, “The product of mental labour [...] is far below its value, because the labour time to reproduce it bears no relation to that required for its original production.” (Volume I, p. 353). This idea of the ‘Tragedy of the Commons’ (Hardin, 1968) has been rejected widely as inaccurate and flawed (e.g. Ciriacy-Wantrup & Bishop 1975, Axelrod, 1984, Appell, 1993, Ostrom, et al. 1999).

4 In economics, an experience good is a product or service where product characteristics, such as quality or price are difficult to observe in advance, but these characteristics can be ascertained upon consumption (Nelson, 1970).

2.3. The copyleft regime: Removing scarcity from an artificially scarce resource

It is in response to this problem that the concept of *copyleft* (as opposed to *copyright*) has been elaborated by Richard Stallman (an American software freedom activist and computer programmer) as an attempt to limit the negative impact that copyright law had on the ability for people to freely use and modify software. More precisely, in the context of software licensing, the copyleft clause – first introduced in the context the GNU General Public License (GPL)⁵ – is a contractual provision stipulating that anyone has the right to access and modify the source code of a particular piece of software, but only provided that the modified software is made available to the public under the exact same conditions as the original software. This clause (also known as the ‘share-alike’ clause) has become, over time, a central tenet of many *Free/Libre Open Source Software* (FLOSS) licenses – even though it subsists alongside a number of more permissive licences (such as the *Apache* and *BSD* licenses) which rely on cultural and community norms, rather than strict legal enforcement, for ensuring the broadest availability and sharing of knowledge.

The geniality and originality of the FLOSS model is that it does not actually enter in conflict with the copyright regime. It does, however, flip it on its head in order to achieve a completely different result from what it was originally meant for. Indeed, as a copyright license, the GPL necessarily refers to the provisions of copyright law, which constitute the legal framework in which the license operates. Yet, as opposed to standard copyright licenses, the GPL only relies upon the exclusive rights granted under the law as a means to preserve – rather than preclude – users’ freedom to use, modify, redistribute and fork software (Stallman, 1998).

Initially deployed only within the FLOSS community, the copyleft concept has been later transposed into the realm of the arts with the emergence of the Open Content movement and its corresponding licensing schemes. While there is, today, a wide variety of licenses regulating the use and reuse of content (for a comprehensive overview, see Liang, 2005), the most popular are the ones elaborated by *Creative Commons*⁶, which developed a set of licenses specifically designed to encourage the dissemination and facilitate the reuse of original works of authorship protected by copyright or author’s rights – while nonetheless allowing authors to maintain a certain degree of control over the exploitation of their works (a move from ‘*all rights reserved*’ to ‘*some rights reserved*’).

As opposed to the traditional perception enshrined in copyright law, for which the creation of any original work of authorship is regarded as an individual act of genius (Rose, 1993; Lemley, 1997), the Open Content movement defends a much broader conception of creation, whereby the making of a work merely constitutes an intermediary step in the long and continuous process of incremental innovation (Van

5 The GPL license is the first license to implement the concept of copyleft. Its legal text is available at www.gnu.org/licenses/gpl.html.

6 *Creative Commons* is a non-profit organization devoted to expanding the range of creative works available for others to build upon legally and to share. See www.creativecommons.org.

Houweling, 2010) and distributed production (Elkin-Koren, 2011). According to the latter view, cultural production is always based on a more or less substantial reuse of prior works, which constitute – either directly or indirectly – the basis on which authors can build upon to produce new original works of authorship. Hence, it is often claimed that, in order for cultural production to flourish, it is important that information be freely available for use and reuse by everyone (Lessig, 2004). The legal excludability introduced by copyright law is, as such, seen as a threat rather than a support to creativity.

While the copyleft regime does not actually eliminate the artificial scarcity introduced by copyright law (i.e. it does not go counter the exclusive rights granted to authors under the law), it does, however, constitute an attempt at bringing back the properties of non-rivalry and non-excludability into information. The goal is not to turn information back into a public good, but rather to provide the legal means to turn information into a *commons*⁷ – or, more precisely, into an *information commons*:⁸ a resource belonging to the common cultural heritage, that is not owned by any single moral or legal entity but is, rather, held in common by all members of society (and can thus be freely accessed, consumed and reused by all).

3. In the digital realm

3.1. Properties of the digital world

Technological developments in the late 20th century have led to a fundamental shift in creative practices. Alongside the traditional tools of creative production – the pencil, the flute, the brush, the photo camera, etc. – digital tools have entered the studio and augmented or even displaced those traditional tools. Equally, the primary format of today's creative output (or at least its preferred form of distribution) is to a large extent digital, a binary code that through effective rendering takes the shape of text, music, images and movies.

Thus, underlying the legal properties of information, there are – in the digital realm – essential technical aspects that drive the need for readjusting the level of (artificial) scarcity imposed by the law.

First and foremost, the reproduction and distribution of creative works in digital format is fast, effortless, efficient and nearly lossless. Digital data allows for easy manipulation, modification, reconfiguration and transformation – and, what's more, it leaves the 'original' untouched. There is, therefore, no requirement to hold the 'original', as any 'copy' is basically identical.

Detached from a material manifestation – even not requiring materiality (except in the rendering engine) – digital content has all characteristics of information in general: technical barriers to reproduction

7 The term commons refers to all resources accessible to all members of a society, including natural resources (such as air, water, etc) and cultural resources (such as information). Although they might qualify as either public or private goods, the particularity of these resources is that they are not owned privately, they are held in common by the members of a particular community (Bollier, 2002).

8 Information commons have been defined as “information and knowledge resources that are collectively created and owned or shared between or among a community and that tend to be non-excludable, that is, be (generally freely) available to third parties” (Fuster Morell, 2010).

(such as the availability of materials) are no longer to be found, and given an existing and efficient distribution infrastructure, distribution of digital works comes at negligible costs.

As such, the digital world has become the breeding ground for many new forms of artistic practices based on collaboration and cooperation amongst peers – a new model of production which “*was mostly unavailable to people in either the physical economy (...) or in the industrial information economy*” (Benkler 2003, p. 1261).

3.2. Spreading the ‘meme’ of collaboration and sharing

Collaboration and sharing have always been at the core of human activity. Yet, this insight is only slowly making it into mainstream in the various scientific disciplines – from developmental biology to experimental economics, researchers are only now starting to accept cooperation as a fundamental paradigm of development; and competition is gradually being rejected as the only driver behind technological progress (Benkler, 2011).

In the artistic realm, there has been, for a long time, much emphasis on the idea of the ‘sole creator’ – the romantic, 19th century notion of the genius sitting in a closed-off studio, away from the general public or other artists creating yet another masterpiece. This vision is strongly reflected in how legislation defines and protects the value of creative output.

In practice, however, creative production is, in many cases, not an individual endeavour but a collective or cooperative effort. Even seemingly individual works often build on what has been created before as a result of inspiration, citation, parody, and so forth. But while inspiration is understood as a perfectly professional practice – just like citation and parody, which are legally accepted forms of reusing prior works – creating derivative works based on copies of pre-existing material without proper authorisation is generally regarded as ‘evil’.

Yet, this vision is progressively fading out, as social norms are rapidly evolving in the online environment, with collaboration and sharing being increasingly regarded as the genesis for creativity – even though the legal norms have remained essentially stable. Indeed, more and more users have begun to understand that much greater things can be achieved through sharing and collaboration than by relying exclusively on individual endeavour and competition.

Therefore, sharing digital artefacts and contributing to the production of large collaborative online works have become an increasingly popular and widespread practice nowadays, which is likely to benefit society as a whole. On the one hand, collaboratively producing, sharing and exchanging works amongst different communities provides authors with a greater source of inspiration, but also gives them more control over their productivity in a self-directed and more community-oriented way. On the other hand, the free availability of content that can be reproduced, distributed and built upon without restrictions gives users a

range of fundamentally different options to choose from, and, indeed, requires them to make active choices instead of passively accepting the mode of consumption that has been predetermined by the current “winners in the economic system of the previous century” (Benkler 2003, p. 1276).

In recent years, many dedicated online communities have emerged, whose goal is not primarily to facilitate the sharing and exchange of digital works (such as, e.g. most peer-to-peer file sharing networks), but, first and foremost, to encourage artistic dialogue and to promote collaboration or cooperation amongst a large number of individual users (see e.g. *Sourceforge* and *Wikipedia*). In the disciplines of photography and video, interesting developments with user generated content can also be seen on platforms such as Flickr, Vimeo and Youtube, where users are given the possibility to respond to a photo or video not only by writing textual comments but also by replying with another photo or video. Discourse is thus explicitly moved out of the domain of textual language and into the domain of the visual.

All of these practices can be regarded as novel forms of artistic exchange that – due to the material, spatial and temporal restrictions of the physical world – were hardly ever practiced before (Nardi 2005, Lange 2007). Early adoptions of this new form of dialogue can even be found on platforms for sharing physical ‘things’ as for instance on *Thingiverse*.

3.3. *The impact in the physical world*

Inspired by the open source model of production, the social practices of collaboration and sharing have taken a firm hold in artistic production, also in the digital realm. Indeed, with the advent of modern, computer-controlled manufacturing tools (such as 3D printing technologies or CNC machines), the open source model of production is being progressively transposed to the physical realm, where it can be employed for the production of physical works.

Indeed, in the physical world, the traditional approach to artistic production being the result of the creative endeavours of an ‘individual genius’ is more and more challenged by an alternative form of production based on a more collaborative peer-to-peer approach – a system whereby many individuals (professional, artists or amateurs) can contribute with their own skills, ideas or resources towards the practical implementation of an artwork in common.

Software programs for digital design form part of the tool-chain that creators use to gradually turn an idea into its material manifestation. Often these are the same programs that are used to produce digital output, and interim results are stored as digital datasets that differ in no way from the datasets of digital output. Computer-controlled production machinery – laser cutters, mills, 3D printers – are subsequently employed to generate physical objects from these datasets. The past decade has seen an exponential growth in the availability of such machinery. Professional service bureaus offer materialisation of digitally designed artefacts in almost any size, material, and quality. Publicly accessible shared machine shops such as *FabLabs* are spreading, offering the use of computer-controlled production machinery to everyone at affordable cost.

By providing a common platform for tools, materials, and technical training, *FabLabs* and public machine shops provide all physical means for experimenting with new models of production based on cooperation among peers. Indeed, if the model of peer-production can be easily employed for the production of digital content (which can be easily replicated and modified without affecting the original), it fits equally well with the digital tool chain and computer-controlled machines for the production of physical products. Several communities and platforms have sprung up to encourage collaboration and promote the sharing of (at least) the interim results of production (e.g. *Instructables*, *Thingiverse*, *Wevolve*). These platforms are not yet as common as those in the purely digital environment, since novel forms of artistic dialogue have yet to develop. However, we can already observe emerging movements around concepts such as ‘Open Design’ and ‘Open Hardware’ which aim to replicate the principles of copyleft in the physical world.

Yet, while the values of collaboration can easily be transposed into the physical world, the principle of sharing does not properly fit with one major constraint of the material world: the scarcity and limited malleability of (material) resources.

4. The physical realm

In contrast to information – which is inherently intangible – and the digital world, which can be regarded (for all practical purposes) as an intangible resource, the physical world is characterized by technical excludability and material scarcity. Thus, all resources that can be observed in the physical world are, by virtue of their materiality, both rival and excludable by default.

It is nonetheless useful to distinguish between three different types of resources, which distinguish themselves according to the role they play in the production chain. The first type comprises all raw materials that are used up in production (such as steel, wood, plastic, gas or electricity) and which are thus no longer available afterwards. The second type refers to all production facilities or infrastructures which are used in the process of production, but which remain available for further use and reuse (even though they might, eventually, deteriorate). The third type is the output of production: the resources that have been produced after a variety of raw materials have been assembled at one or more production facilities, where they have been processed with specific tools or machines and applying specific processing knowledge.

In this regard, it might be worth distinguishing between the ‘natural scarcity’ of materials, which is essentially due to their inherent characteristics as physical goods, and the ‘artificial scarcity’ that is created by technical means. Indeed, the current system of production based on capitalist principles introduces an additional layer of scarcity over certain types of products (mainly of the third type) by concentrating most of the knowledge and means of production into the hands of a few large corporations, so that people no longer have the ability to produce the products they need by their own means.

It is worth noting, however, that in the information realm, as copyright introduced artificial scarcity and

excludability over a non-rival good like information, specific legal tools (such as Creative Commons and other liberal copyright licenses) were able to eliminate such scarcity by legal and contractual means. The objective of this section is, therefore, to determine whether or not a similar effect could be achieved in the physical world. In other words, is it possible to turn a naturally scarce resource into an artificially non-rival resource, by either legal or technical means?

To answer this question, we will identify and analyse various mechanisms that could be employed to eliminate or, at least, reduce material scarcity and excludability from physical resources – taking into account that the preferred mechanism will always and necessarily depend on the type of resources that are being dealt with.

Thus, referring back to the three types of resources identified above (raw materials, production tools or facilities, and resulting end-products), we will investigate – for each of them – whether it is possible (and useful) to reduce the level of scarcity and/or excludability that they are naturally associated with.

In particular, we contend that – even though it is currently in an early stage of development – 3D printing could significantly reduce (and eventually eliminate) material scarcity for the third type of resources (end-products). Yet, this objective can be achieved only insofar as we can identify ways to (1) reduce material scarcity for the first type of resources (raw materials); (2) decrease the degree of excludability for the second type of resources (production tools and facilities); (3) provide free access to all the knowledge necessary to operate these tools and to produce the expected end-products.

4.1. Reducing Scarcity of Raw Materials

Beyond economic instruments such as fixed prices⁹ or discrimination amongst consumers¹⁰, various mechanisms can be employed to turn raw materials into a more abundant or less excludable resource.

In terms of excludability, abolishing property (or introducing temporary property rights) is a potential solution aimed at eliminating the *legal* possibility for the owner of a non-used resource to exclude others from benefiting from it. Although legally sound, this solution does not, however, encroach on the attributes of physical resources; they remain inherently rival. It does not, as such, resolve the problem of natural scarcity, nor does it eliminate the possibility for people to exclude others from accessing a resource by technical or physical means. Hence, while in the information realm resources are inherently non-rival in consumption and there is thus no incentive to fight over them, in the physical realm scarcity will necessarily

9 Imposing a fixed maximum price over certain raw materials, production tools or infrastructures can, to some extent, reduce the degree of excludability of these resources. Yet, although more people will potentially have access to these resources, this solution in no way constitutes a solution to the more generic problem of material scarcity and excludability.

10 Price discrimination consists in selling the same products at different prices to different customers, according to their corresponding willingness to pay for these products. The advantage for the suppliers is that price discrimination enables them to charge the maximum possible price for each unit sold, so as capture all available consumer surplus. While customers are thus left without any surplus, they are, however, all able to benefit from the consumption of these products, insofar as they are – at least – willing to pay for the marginal costs of production (Varian, 1989).

lead to people fighting over who does or should actually own every available resource. This is, indeed, one of the main justifications why the regime of property rights was implemented in the first place (Castle, 1978).

With regards to decreasing the scarcity of raw materials, one could imagine a situation whereby people could freely take certain types of materials from a common pool of resources whose ownership is shared amongst all members of a community, but only provided that they commit to giving back a similar amount of the same kind of materials in a given period of time (give-back provision).¹¹ The advantage of this approach is that it would make it possible to provide free raw materials to a certain community, while nonetheless preventing the common pool of resources from being depleted by guaranteeing a constant and gradual renewal of resources.

Finally, in the case of raw materials, perhaps the most obvious way to reduce material scarcity is to adopt material saving techniques. Additive manufacturing processes – commonly known as 3D printing – offer great prospects here as they allow to build structures that consist of the minimal amount of material in exactly those places where a structure would need it to respond to mechanical stress. Such geometries are hardly attainable with other manufacturing methods.

Material scarcity can also be reduced through extensive recycling or upcycling, i.e. by turning old neglected resources into raw materials, so as to produce a whole new set of resources without consuming any more raw materials.

Finally, it is possible to use alternative, naturally growing materials (such as bamboo and other bio-based materials) as a complement or, eventually, as a supplement to other resources which are either more scarce or more difficult to obtain.

4.2. Shared tools and production facilities

In the case of technical facilities, tools or infrastructures which persists over time, the focus is not so much on reducing scarcity, but, rather, on eliminating (or reducing) excludability – so that a maximum number of people can benefit from their use.

One possibility is to establish public *FabLabs* or high-tech workshops in a variety of cities so as to provide public access to tools and facilities that people might need, in the same way as we have public libraries providing public access to information. These facilities can be regarded, to some extent, as ‘libraries of peer-production’: shared spaces where anyone can come and learn new skills or use specific tools, whenever the need arises. Indeed, most people only seldom need a laser-cutter or a 3D printer – and, given the costs of these tools, they are unlikely to purchase them. Yet, in a few occasions, these tools could actually help people achieve a task that would, otherwise, only be achievable by delegation to large corporation or

¹¹ For instance, a pot-maker could take as much clay as allowed by community rules, but - after a determined amount of time (e.g. from 1 to months) – he would have to put back one kilogram of clay into the common pool for every kilogram of clay that has been taken from it.

industrial companies. The idea underlying the implementation of public *FabLabs* or workshops is, therefore, to gather a variety of tools into one single place or facility, to subsequently allow people to access these tools – under specific conditions – only when they actually need them.

These infrastructures can be provided either by the state (which already provides public libraries as part of its mission) or specific communities that believe in the idea that everyone from the community should have access to certain tools or facilities. Private actors might also engage in the provision of similar production infrastructures, to the extent that they are not concerned with profit-maximisation, but merely with the long-term sustainability of the service they provide. By analogy with the concept of *Infrastructure as a Service* (IaaS) for cloud computing, the provision of such production facilities and tools is akin to providing ‘*Resources as a Service*’ – a model whereby people only ‘pay’ for the amount of resources they actually need or use. Although this can be done through traditional renting or lending techniques, many *FabLabs* decided to experiment with a variety of different approaches, using traditional co-op or more innovative mutual strategies, covering expenses through membership contributions and bench fees, employing various types of voluntary contributions, establishing barter systems, or a mix of the above.

Decentralized options also exist. As people are increasingly realizing that most of the tools or machines they own are often significantly underused, various initiatives have been created (such as *Zipcar* for cars) whose goal is to bring excess capacity to a minimum. The goal is to maximise the access to and usage of specific resources by providing a platform encouraging people to share or lend the resources they own to others needing them (Sundararajan, 2013). This is the concept behind the emerging concept of ‘collaborative consumption’¹² – a concept initially coined by Felson & Spaeth (1978) and subsequently popularized by Botsman & Rogers (2010) in their book ‘*What’s mine is yours*’ – according to which people are increasingly consuming goods in a collaborative rather than individual manner, so that access to a resource is gradually becoming as important – if not more important – than property (Gansky, 2010).

4.3. Free access to knowledge and skills

Of course, public access to production facilities, even if combined with a large abundance of raw materials, is only useful to the extent that people have the necessary knowledge and skills to use the production infrastructure. Given that the underlying functions and functionalities of most products are hidden to the inexperienced eye, unless one wants to engage into reverse-engineering to try and figure out how a product is made and how it works, people need to be given exact instructions as to how to produce the products

¹² The term ‘collaborative consumption’ was first coined by Felson & Spaeth (1978) in a paper dealing with the practice of car-sharing as a means for car owners who make only occasional use of their vehicle to benefit from the lending of their car to people who only need occasional access to a vehicle.

they need. This is the mission that motivates initiatives such as Makezine.com¹³, Hackaday.com¹⁴, or Instructables.com¹⁵ where people can upload precise instructions to a variety of DIY projects, as well as to learn from and comments upon others' projects.

Yet, intellectual property laws, such as copyright or design rights, are restraining the exploitation of original works of art, including their models or designs. This is where the Open Design / Open Hardware movement comes in, as a way to ensure that – after it has been conceived and designed for the first time – a product can easily be reproduced by anyone else by simply feeding the digital manufacturing machines with the proper instructions.

FabLabs therefore encourage artists to share their knowledge and to ensure that their artistic productions are and remain available for the community to build upon them. Many require that artists release their works into the 'commons' (i.e. the common pool of resources that can be freely used and reused by the community) by means of specific licenses (such as the Creative Commons licenses) designed to reduce the default level of protection granted by default under the law. These licenses are meant to maximize the dissemination of works, while promoting the further development of cultural artefacts through the process of incremental innovation.

This can be regarded as a way to bring the values of the Open Source / Open Content movements into the digital world, encouraging people to collaborate towards the production of a design, which can then be reproduced indefinitely – by either reproducing the design, or 'printing' the product in the physical world, without any quality loss and at cost that – as technology develops – becomes closer and closer to the marginal costs of production.

But knowledge also refers to the way in which specific tools and machines work. While everyone knows how to use a hammer or a drill, a large majority of people still do not know how to use a 3D printer or a CNC machine. Access to manuals and instructions is therefore a key precondition to ensure that people can actually learn how to operate these machines, or even fix them, if the need arises. Hence, the Open design and Open hardware movement does not refer exclusively to end products, but also to the machines and tools that are necessary for the production of these products.

Besides, if one wants to get rid of the additional layer of scarcity that has been established as part of the capitalist system of production (i.e. depriving people from having access to the means of production), it is

13 *Make* is an American quarterly magazine published by *Maker Media* which focuses on *Do It Yourself* (DIY) and/or *DIWO* (*Do It With Others*) projects involving computers, electronics, robotics, metalworking, woodworking and other disciplines. The magazine is marketed to people who enjoy making things and features complex projects which can often be completed with cheap materials, including household items.

14 *Hack a Day* is an online magazine devoted to publishing and archiving "the best hacks, mods and DIY (do it yourself) projects from around web." Founded in 2004, *Hack a Day* publishes new hacks every day as well as a special weekly *How-To hack*.

15 *Instructables* is a website created in 2005 by Eric Wilhelm and Saul Griffith. *Instructables* is dedicated to step-by-step collaboration among members to build a variety of projects. Users post instructions to their projects, usually accompanied by visual aids, and then interact through comment sections below each *Instructable* step as well in topic forums.

important that citizens are able to produce their own infrastructure of production. This is the concept underlying various initiatives, such as, most notably, the *RepRap*¹⁶: a 3D printer that has been designed with the objective of reproducing itself. Again, this means that all plans and designs for such machines should be made freely available to the public, in a way that does not only allow for people to reproduce the piece, but also to create derivative versions thereof, so as to either add new functionalities or improve currently available ones, as well as to build upon it in order to create alternative version of the machine which are more tuned to one or another specific application.

Finally, beyond the design rights or possibly the copyright in the blueprints of a product, one important problem relates to the patentability of these products and/or the manufacturing processes and techniques that are necessary for the production thereof.

Innovation in 3D printing techniques is mainly covered by a dense mesh of US and international patents, and some 'open source' developments have already been challenged of infringing on those patents.¹⁷ As a result of market concentration due to big players buying up formerly open source projects¹⁸ there is an increasing risk that a number of patent applications could be filed or enforced over specific products or improvements,¹⁹ which may thus preclude others from innovating in a similar direction for the whole duration of the patent. This problem could be (partially) resolved by requiring patent owners to make the knowledge for production more readily available to all, e.g. by providing all necessary blueprints for the making of a product in digital format. That way, even though industrial production would be precluded by patent regulations until the patent expires, individuals could nonetheless have the opportunity to experiment with these products, and to – sometimes – produce them for personal use within their private sphere.²⁰

But the product itself is not the only element that can be subject to patent protection. Even if the design of a particular product has actually been released under an open license (and is thus available for everyone to produce and reproduce), patent rights might nonetheless subsist in the processes or techniques em-

16 The *RepRap* (short for *replicating rapid prototyper*) is low cost open source rapid prototyping system that is capable of producing its own parts and can therefore be replicated easily. More information available at <http://www.reprap.org>.

17 Most notably in the case of the *Formlabs Kickstarter* project, *3D Systems* (one of the few big players in the 3D printing market) filed a patent infringement suit on November 20, 2012 against *Formlabs* and *Kickstarter*.

18 *Stratasys*, also one of the few big players in the 3D printing market, bought the former open source project *Makerbot* for US\$ 604 million on June 19, 2013. *Makerbot* had abandoned the open source approach on September 20, 2012, after receiving US\$ 10 million in venture capital a year earlier.

19 For instance, in 2011, a patent application was filed for an 'Additive Manufacturing System and Method for Printing Customized Chocolate Confections' claiming that 3D printing with chocolate was sufficiently inventive to receive a patent, whose scope could potentially cover every thermoplastic material used for 3D printing. More information available on <http://www.google.com/patents/US20120251688>.

20 Most European countries introduced a 'research exemption' into their patent legislation, so as to allow the use of a patented invention for experimental purposes. Additional exceptions exist, such as those in respect of private and non-commercial use (see e.g. in the UK, Section 60(5) of the Patents Act). Similarly, in Japan, Article 69(1) of the 1959 Japanese Patent Law stipulates that "the effects of the patent rights shall not extend to the working of the patent right for the purposes of experiment or research". Finally, in the U.S., a series of exception for 'experimental use' have been established both in common law (first introduced in the case of *Whitmore v Cutter*, 29 Fed. Cas. 1120 (1813), and later narrowed down by the cases of *Roche v Bolar*, 733 F.2d 858 (Fed Cir 1984) and *Duke v Maye*, 307 F.3d 1351 (Fed Cir 2002), as well as in statutory law (see e.g. section 271(e) of 35 USC Patent Act).

ployed in the making of these products. Thus, even if all proper instruction were given on how to actually construct these products, third parties patent rights could potentially preclude the ability for people to undertake the necessary steps to actually implement these instructions, at least for commercial exploitation. Hence, it is important that – in addition to the actual design of the product concerned – every step of the manufacturing process be also publicly disclosed, so as to constitute prior art against the future patentability thereof.

5. Conclusion

This paper started with an ambitious objective: to identify ways to hack the law so as to turn technical or material scarcity into artificial abundance. We do not pretend to have found any ideal answer to that question. Rather, we have explored various mechanisms that could, when properly combined together, reduce – or, eventually, eliminate – scarcity for a particular kind of resources that we defined as belonging to the category of ‘end-products’.

We observed, however, that this objective can only be achieved if three other conditions are met: (1) raw materials have to be readily available; (2) production facilities and tools must be and remain freely accessible to all; and (3) all knowledge concerning the making and use of products or machines has to be open and free for anyone to build upon. Indeed, to the extent that knowledge and design instructions are available to everyone, people only need access to raw materials and production facilities or tools in order to be able to produce (almost) everything.

Ideally, anyone needing a particular product – such as a table, a chair, or a lamp to give a few examples – would only have to find or select a particular design for that object within the common pool of available designs, eventually adjust it to specific preferences or needs, and subsequently travel to a public workshop or *FabLab* in order to actually build that object with the tools and machines that have been made accessible to every community member. Thus, assuming that a sufficient number of FabLabs are deployed in every city or community, one could imagine that – sooner or later – products will only be as scarce as the raw material needed for their construction.

Although we are only at the early days of these technological developments, the advent of 3D printing and other self-fabrication technologies constitutes a paradigm shift in society that is likely to have a considerable impact on the way people perceive and consume most of the everyday products.

Most importantly, we are observing today the emergence of new social practices (mostly derived from the meme of collaboration and sharing that established itself in the digital world) aimed at encouraging collaborative consumption and the sharing of physical resources, which – despite being inherently rival in consumption – are increasingly held in common and shared amongst the member of a particular community (Betts, 2010) according to specific governance rules or social norms which prioritise *access rights* over *prop-*

erty rights as an alternative system for managing common property resources (Weitzman, 1974). Building upon Benkler's in-depth analysis of what motivates people to engage in commons-based peer production (Benkler, 2006), we can say that – as human beings tend to collaborate whenever there are incentives to do so (Benkler, 2011) – the growing popularity of *FabLabs* and the recent development of many initiatives oriented towards furthering the 'common good' is a proof that there is, nowadays, a general interest for people to engage in collaborative practices and cooperation (characteristics of the *homo reciprocans*), rather than focusing on either self-sufficiency – as the *homo faber* does (Ahrendt, 1958)– or self-interest and competitive behaviours which are generally assumed by the *homo economicus*.²¹

We observe, as well, the emergence of new methods of peer-production (similar to the methods employed by many FLOSS or Open Content communities) that significantly differ from the traditional system of production based on capitalist motives, such as profit maximization and accumulation of wealth. More and more, in the physical world, rather than relying on a centralised infrastructure of production, members of many online communities rely, instead, on a distributed and decentralized network of contributors who participate to the development or the design of a product in a collaborative and incremental way (Troxler, 2010). By analogy with the digital world, where – since the advent of Web 2.0 technologies and the consequent explosion of user-generated content – people are increasingly regarded as 'prosumers'²² – i.e. users who act both as producers and consumers of information (Toffler, 1980, Ritzer & Jurgenson, 2010)– with the advent of 3D printing technologies and the rise of the Open Design / Open hardware movement, many consumers are also evolving into 'prosumers' in that they now have the ability to produce the very same products they are consuming. This is clearly illustrated by the growing popularity of the DIY movement over the past few years, with electronics and personal manufacturing techniques becoming progressively part of people's basic education (Mota, 2011).

To the extent that they have been released under an open or free license, these products can subsequently be reproduced– either digitally (by making copies of the relevant designs and blueprints) or physically (by producing a physical instance of the design)– in a way that strongly resembles the production and reproduction of digital or information goods. Indeed, in spite of the inherent scarcity of physical goods, the deployment of 3D printing technologies and of an ever growing number of *FabLabs* has the potential of turning certain types of physical resources into artificially abundant resources, to the extent that it suffices to gather the necessary raw materials in order potentially replicate these products an indefinite number of times.

21 *Homo reciprocans* is the concept in some economic theories of humans as cooperative actors who are motivated by improving their environment. This concept stands in contrast to the idea of *homo economicus*, which states the opposite theory that human beings are exclusively motivated by self-interest.

22 The term 'prosumer' was coined by futurologist Alvin Toffler (1980) where he predicted that the role of producers and consumers would soon begin to blur and, eventually, to merge into the role of 'prosumers'.

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