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Additive manufacturing as global remanufacturing of politics?

Yannick **Rumpala**
Université de Nice / Faculté de Droit et de Science politique
Equipe de Recherche sur les Mutations de l'Europe et de ses Sociétés (ERMES)
Avenue Doyen Louis Trotabas - F-06050 NICE Cedex 01 France
rumpala@unice.fr

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Abstract:

There is a growing interest in 3-D printers because of the technical and economic implications they could have. The objective of this paper is to take the analysis even further by wondering if, as they could interfere in the material practices of production and consumption, they could not also have effects in a more political register. The first part of this contribution consists of re-examining the promises associated with this technology and highlights the implications of this technology as a possible way to restoring individual and collective capabilities (I). Secondly, the ways in which these machines could destabilize the industrial bases of contemporary societies, and therefore the economic order, are examined, along with the political implications of such a shift (II). Finally, the points of friction that these technological developments may encounter and that might affect future trajectories are clarified (III).

Keywords: 3D Printing, political change, technological change, socio-technical systems

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Introduction

3D printers (ie, three-dimensional, since they work by adding layers of material one on top of the other) are beginning to generate a lot of comments. They suggest potentially important changes in the way of making a range of everyday objects. But this is not the only possibility. Certainly, there are technical and economic implications (Lipson and Kurman, 2010), but beyond this, there could also be more structural and far-reaching political effects. It is these effects that this contribution aims to explore.

These technical developments, combining digital design and new modes of automated production, open spaces for experimentation, which are for the moment mainly visible in communities of technophile tinkerers like "fab labs" ("fabrication laboratories") and "hackerspaces". But, since these tools are designed to be eventually accessible to the broader public (Gordon, 2011), it would be useful to look beyond the still experimental nature of these initiatives. One can indeed make the hypothesis that changes in the political realm, and potentially profound changes, can also occur by the accumulation of dispersed practices even if they appear merely technical (just as computer connections over the Internet have not only opened up new possibilities of communication, but also catalyzed political changes).

Beyond the economic impacts that are increasingly being studied, it is this potential to transform the political order that also deserves consideration, especially insomuch as such an evolution could be even felt on a global scale. It is not a question of merely saying that there are political elements in technologies, which is now commonly accepted[1], but that some contain potentialities for change which go beyond their designers and the importance of which will be revealed in their conditions of actualization.

Three-dimensional printing is a technology that seems to open up a field of possibilities. It has all the appearance of a "disruptive technology"[2], because it seems to prevail over other established technologies in terms of performance, so as to significantly change the practices of its users, and as a result, the competitive conditions between economic operators. It also has all the appearance of a "general purpose technology", because it could affect the entire economic system and bring about profound and structural changes, from the working world to the domestic sphere (Helpman, 1998; Jovanovic and Rousseau, 2005).

In retrospect, another type of printing, printing on paper, shows the cumulative influences that a material technique can have on human activity, thus justifying its analysis as an "agent of change" (Eisenstein, 1979). But the underlying question of this contribution is more prospective. What is also at stake in this case is to know how to assess the potential effects of a technology that is not yet

[1] In line with the reflections of Langdon Winner, 1980. See also Herrera, 2003.
[2] To reiterate the concept that Clayton M. Christensen (2000) tried to develop.

developed, in other words, how to understand in what ways this technology can be used and the changes that may result from it. It is even more difficult to address this type of technology since it captures and feeds a whole sphere of imagination (which is sometimes close to the science fiction genre[3]). Since the ambition to analyze can easily drift into pure speculation, it is essential to keep in proper perspective the different types of discourse, both emphatic and critical, that may surround new technological developments[4]. These various accompanying discourses could justify a separate study, but the drawback would be no longer being able to comprehend these technological developments themselves and their potential impact.

More specifically, three-dimensional printing can also be a way to underline the relationship between technology and economic and political order. For the most part, the capitalist order was built upon machines. Could it be destabilized by a new kind of machine? In this contribution, it is precisely a question of identifying and analyzing these potentialities, especially as material factors that can also have a chain of effects and go as far as having political implications. The generalization of this type of machine, like computers now being in households, can lead to changes in practices, consumption patterns, and consequently in production systems. What kind of logic of deployment could such machines have? What uses do they make possible? What kind of resources do they offer for users? With what constraints? What type of reconfigurations could they bring about ?

The analysis in this paper stems from the hypothesis that a technical development can have systemic effects. Machines can have different and more indirect functions that those they were designed or planned for. Technical change could then contribute to social change, through joint and convergent development.

However, methodological precautions need to be taken when going forward with this type of analysis, namely "taking out the notion of machine from an industrial conception", which reiterates one objective defined by Frédéric Vengeon (2009: 177) in a program for the Collège international de philosophie. Machines that print in three dimensions incorporate both mechanical and digital/computational/informational factors (according to the preferred terminology). Both material and data are used by these machines: they are combined to assemble hybrid artefacts, which are taken from virtuality and are given materiality. Moreover, consideration must go beyond the tool or the machine to include the system in which it participates, meaning the elements it has inherited and the elements the machine helps to change. Therefore, for this type of investigation, there must be an interdisciplinary approach, including analyses from sociology of technology (Akrich, 1992), political economy[5], socio-economics[6], cultural studies (Slack and Wise, 2005), and political theory[7].

From these bases, this paper will study the potentialities and implications of three-dimensional printers in three steps. The first part of the analysis consists of re-examining the promises associated with this technology and highlights the implications of this technology as a possible way to restoring individual and collective capabilities (I). Secondly, the ways in which these machines could destabilize the industrial bases of contemporary societies, and therefore the economic order, will be examined, along with the political implications of such a shift (II). Finally, the points of friction that these technological developments may encounter and that might affect future trajectories will be clarified (III).

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[3] The book *The Diamond Age* by Neal Stephenson (1995) is often referenced in more or less speculative discussions, since it is about "matter compilers", machines that are in each household and allow any type of product, food, or object to be made, thanks to advances in nanotechnology.

[4] Along the same lines, see for example Caprotti, 2012.

[5] Especially for understanding the behavior of economic actors. See Hirschman, 2004.

[6] Matt Ratto and Robert Ree (2012) began studying these socio-economic implications.

[7] Especially for considering the dynamics that take place at a subpolitical level, according to the conceptualization of Ulrich Beck (1997).

I) Defining an underlying shift: some features of a new print culture[8]

What capacities do the new three-dimensional printers provide? Certainly they provide manufacturing capacities, but their social distribution seems to be different from the former industrial modes. Is technology then a possible vector of emancipation? The question can be posed anew. The use of these machines can indeed spread to spaces where they may allow for renewed activities. These printers become part of a supportive environment that can help develop their potentialities, and by contributing to the erosion of passive consumption logics, they can reactivate forms of autonomy in individual practices.

a) Technological developments that can renew manufacturing capacities

These machines are attractive[9] because they appear to have a set of relatively innovative physical properties, since they propose relatively new modes of manufacturing and they seem capable of carrying out certain actions that appeared to be more difficult to accomplish before[10]. This technology functions on the principle of addition, and not on molding or subtraction. The process does not consist in removing material (by grinding or cutting away for example), but applying successive layers of material to obtain the desired form. The model is provided in the form of a digital file, since advances in computer technology allow objects to be "digitalized".

Interest in three-dimensional printers has grown as the quality of their work has improved and the price has decreased. These machines are now become accessible for individuals and family budgets. The range of materials that can be used also seems to be increasing to include different types of plastic and metal. The use of this technology is even considered for constructing building and "printing" organs. Some three-dimensional printers, like the RepRap (REPlicating RAPid prototyper)[11], are designed to allow identical models of itself to be re-manufactured, thanks to an open source design and the lowest possible cost principle. Even if this technology does not seem to have reached maturity, it appears to be rich in possibilities for its users.

With the development of such tools, the use and mastery of productive technologies may no longer be limited to certain parts of society. This mastery would be transferred. This type of machine brings manufacturing opportunities back in the domestic realm and for non-professionals. Fab@Home, the project of Cornell Creative Machines Lab (Cornell University), is specifically designed in this perspective, in which available technical resources must be able to meet new capacities and new desires: « A consumer-oriented fabber, coupled with the networked educational and technical resources already available today, empowers individuals with much of the innovative facility that would otherwise require an entire R&D laboratory. This could potentially lead to economic innovations such as neo-cottage industry manufacturing, an "eBay of designs" where

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[8] The author has taken the liberty of adapting the title of the second chapter of Elizabeth L. Eisenstein's book (1979).

[9] The machines also prompt a great deal of interest in newspapers that represent the dominant economic thought, such as *The Economist*. See « The printed world: Three-dimensional printing from digital designs will transform manufacturing and allow more people to start making things », *The Economist*, Feb 10th 2011, http://www.economist.com/node/18114221 ; « Solid print: Making things with a 3D printer changes the rules of manufacturing », *The Economist*, Apr 21st 2012, http://www.economist.com/node/21552892 . The *New York Times* even talked about a "revolution" (See Ashlee Vance, « 3-D Printing Spurs a Manufacturing Revolution », *The New York Times*, Published: September 13, 2010, http://www.nytimes.com/2010/09/14/technology/14print.html?ref=ashleevance).

[10] Hence the possibilities of developing a rhetoric that can contribute to building the merits and benefits of this technology. See Sheridan, 2010.

[11] For a presentation of the origins and design of this machine, see Jones, Haufe, Sells, Iravani, Olliver, Palmer and Bowyer, 2011.

individuals can market unique product designs as digital instructions and material recipes for others to execute on their own fabbers, and millions of people inventing technology rather than merely consuming it »[12]. The development of three-dimensional printers would not only bring about an evolution in manufacturing methods, but could also affect the ways of consuming everyday objects.

If these machines became commonplace, production capacities would no longer be concentrated, but distributed. For certain products, people who begin far away from production activities could hope to compete with the world of professionals, even to the point of reducing their need to rely on them. In certain groups, there is a social awareness of these capabilities.

b) Emergence and development of a supportive environment : Fab labs and communities of users

The potentialities of this type of technology must also be linked to the social bases on which it develops. A large part of its development is indeed favoured by collaborations in networks, which allow individuals to exchange and share ideas, and compare experiences. Thanks to advances in the digital world and the various channels available through the Internet, this technology has a high rhizomatic potential, both in the way it can be spread and how it can develop by bypassing the current hierarchies and subordinations, especially those in the business world.

In this type of collaborative space, the ability to show what can be accomplished plays an important role, especially when visual presentations with photographs are used, and even more so when videos are made available on sites dedicated to this technology. Objects made from three-dimensional printers allow the possibilities of these machines to be shown more concretely and give credibility to the practices based on this technology. The Internet can then provide a wider audience and help construct a supportive environment, made of physical relationships or not, that can produce a reservoir of information and knowledge. At this time, which is largely experimental, the Internet allows not only technological know-how to circulate, but to be discussed and eventually supplemented. People who are interested in this technology can rapidly find communities, like those formed around Internet sites or forums such as Thingiverse, a site that allows files of more or less useful objects to be shared online, or the forum proposed by Shapeways, a start-up that offers on-demand printing services. The RepRap also has a community that lets users get help for assembling the machines. All that is necessary is to use any search engine to quickly access a “wiki” (http://www.reprap.org/wiki/RepRap) which makes technical information available, and allows the most motivated users to follow the evolution of the project and the many attempts to improve it.

In spirit, these initiatives are in line with the kind of rhizomatic project that took shape under the label of “fab labs”. Fab labs (fabrication laboratories) are workshops that are geared toward new technologies, but designed to be accessible to non-professionals. They make advanced tools accessible, which are generally more readily available in the industrial world, so that users can manufacture their own objects. This idea, which was inspired by the work of Professor Neil Gershenfeld of Massachusetts Institute of Technology (MIT) in the late 1990s, has been taken up in many countries[13], with an often present and strong interest for three-dimensional printing.

To some extent, the fab labs offer a way to materialize the idea of “vernacular workshops”, developed by thinkers such as Ingmar Granstedt (2007) or André Gorz. In this rather unexpected encounter, three-dimensional printers seem to bring the tool that was missing to strengthen the utopian idea of a “communal self-production cooperative” that André Gorz (2010) had imagined in his vision of society.

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[12] « Multi-Material 3D Printing », http://creativemachines.cornell.edu/Multi_material_3D_Printing , accessed May 31st, 2012.

[13] For a presentation and a perspective on the project, see Gershenfeld, 2007.

c) Blurring of individual roles: will everyone be a prosumer thanks to three-dimensional printers?

If three-dimensional printers become part of the domestic sphere, this technology will make it possible to self-produce objects that will then be directly appropriated. In doing so, it would tend to dissolve even further the boundaries between production and consumption activities, as innovations in information technology and other digital applications have already started to do (Ritzer, Dean and Jurgenson, 2012).

The term "prosumer" has been proposed and increasing used to refer to this phenomenon of the blurring of individual roles (Humphreys and Grayson, 2008). Three-dimensional printers could foster a new way to express this tendency, with different implications. With such machines available for use, it is consumers who can decide what is going to be produced (depending on their ability to explore the catalogue of possibilities). They are no longer necessarily excluded from the production cycle; they may participate in it for the objects they are interested in and if they have expertise in computer-aided design, they could even express their creativity by modifying the product. If the characteristics of this product allow for it, consumers can choose the materials used. The range of machines available even appears to be expanding, and this diversification could allow users to give priority to types of 3D printers with certain specifications, which are potentially better adapted to their expectations.

The possibility of making an object can also bring about a greater interest for the way it is designed[14]. Thanks to software than can be combined with three-dimensional printing, users may modify elements of design and re-work certain characteristics depending on what they consider to be their needs or tastes. The object becomes something other than a "black box", as many products and machines are today since they are impossible to open or modify. Behind its technological appearance, this tool also re-establishes a contact with the (almost) raw material and the possibility to modify it. In addition, the work that needs to be done may appear to be easier, less difficult, and less messy: indeed it is easier to handle powder in bulk or resin in cartridges than to chop wood or machine metal.

The implications could be felt at the source of the production chain. If access to such machines became as easy as accessing a personal computer, then the private ownership of production means (as Karl Marx criticized it) could be displaced or even dissolved. Adrian Bowyer himself, a professor at the University of Bath and founder of the RepRap project, suggests this situation could be on the horizon. He speaks of "Darwinian Marxism" when describing a process that could trigger the full realization of his project: "So the RepRap project will allow the revolutionary ownership, by the proletariat, of the means of production. But it will do so without all that messy and dangerous revolution stuff, and even without all that messy and dangerous industrial stuff »[15]. It is indeed a form of evolutionism that would select the most appropriate machines and allow their generalization. So, if this reasoning is followed through on, the consequences of this process will profoundly affect the economic infrastructure.

[14] If the link is made with David Gauntlett's point of view (Gauntlett, 2011), three dimensional printing would only be becoming part of a broader movement.

[15] « The Biology of Rapid Prototyping or Darwinian Marxism », the first version was published on 2 February 2004, http://people.bath.ac.uk/ensab/replicator/background.html , the text is also available under the title « Wealth Without Money », http://reprap.org/wiki/Wealth_Without_Money , accessed 28 June 2012.

d) Could machines give increasing autonomy? A reappropriation of production means and renewed possibilities for autonomy

This type of new technology appears to offer renewed capacities, such as the monitoring and controlling of techniques used and the openness to express creativity. And it also could allow these capacities to be integrated into social spaces that seem to have been deprived of them. Could this be qualified as a new form of empowerment through technology?

The advantage of this type of machine is that it can allow each individual regain control over his or her daily life, in this case through objects. Owning a machine or having one available nearby can reduce the anxiety of not being able to obtain certain goods. Thanks to these techniques, capacities seem to be given back to communities, like those who call themselves "makers".

If these technologies are examined through the lens of Ivan Illich's insights (Illich, 1973), they seem to offer possibilities of autonomisation, or at least they can restore a degree of autonomy. Ivan Illich, who was engaged in a critical reflection on the industrial society, was concerned that production was serving the people less and less and that the relationship between the two had become inversed, to the detriment of the latter. Therefore, human life would have been progressively subject to a form of "heteronomous" production over which consumers would lose all control, even though they apparently benefitted from a growing number of goods and services. The cost of this apparent comfort is an insidious dependence, while an "autonomous" production allows individuals to keep control over the basic tools that help them meet their needs. It is this "autonomous" form of production that Ivan Illich wanted to put forward and encourage, as a fundamental element to put society back on the path of "conviviality". It was for him a question of re-establishing the means to allow citizens to regain the knowledge and sense of direction of their own lives. Hence the importance of tools, which he considers in a broad sense, ranging from material objects to institutions such as schools, and for which he looked for criteria that would contribute to this conviviality. In his line of thought, convivial tools should be favored because they attribute use value to autonomous production rather than exchange value. As Illich explains, "Tools foster conviviality to the extent to which they can be easily used, by anybody, as often or as seldom as desired, for the accomplishment of a purpose chosen by the user. The use of such tools by one person does not restrain another from using them equally. They do not require previous certification of the user. Their existence does not impose any obligation to use them. They allow the user to express his meaning in action" (Illich, 1973: 22). From the perspective of Ivan Illich, convivial tools do not necessarily refer to a low level of technological development. His objective is not a technological regression, but a way out of systems that trap individuals and make them dependent. For Illich, the "convivial" society is one in which all citizens, and not only specialists, have control over their tools that serve the population and not the contrary.

From this point of view, three-dimensional printers have qualities that can be highlighted. They may be a way for interested individuals to find a sort of control over their life, by offering people another role than mere consumers. This type of custom manufacturing allows consumers to circumvent the passivity they are often forced into thanks to the reopening or expansion of spaces of creativity.

In his project of « social ecology », the anarchist theorist Murray Bookchin had also sought to show that certain technologies could have a "liberating" potential. He might have considered three-dimensional printers to be an example of these machines he aspired to, which would take production away from the increasingly overwhelming industrial machineries and at the same time, free up the life of individuals to complete tasks other than required and mindless labor[16]. To summarize the political ideal of Murray Bookchin, there would be a radically decentralized and

[16] See « Towards a liberatory technology », in Bookchin, 1986.

democratized society. Such a project, which is far from being incompatible with the accumulated technological developments throughout human history, could even benefit from it and find resources to facilitate it (White, 2008: 75-76). In his reasoning, the issue would no longer be setting humanity free from need, since the technical level reached would allow it, but using this potential to help improve the relationship between humans and between humans and nature. Rather, it would be a question of promoting technical innovations that have liberating potentialities, precisely those which would seem to be capable of developing outside of the logics of industrial capitalism.

The idea of a decentralized and small-scale production is also known to be defended by Ernst Friedrich Schumacher (1973), whose argument "small is beautiful" largely refers to the technological dimension. From this point of view, there should be a preference for "appropriate technologies", that is, taking into account the context of their use and being simple enough to make them manageable by people or groups who would use them.

A few decades after their death, three-dimensional printing technology seems to offer a possible way to materialize the ideas of a series of authors, who would probably have been tempted by this type of progress. These machines make conceivable the possibility for people to again take ownership of production means. In other words, this technology could give a large group of people the means to produce for themselves the objects they would like to have or judge to be a necessity. In addition, these goods could be produced at any time and people could spend as much time as they wanted on manufacturing. Therefore, in this configuration, the relationships of dependence would be transformed, especially since the ability to self-produce objects can reduce the pressure of earning an income.

II) Could new machines destabilize the economic order?

The register in which 3D printing has developed is not really one of frontal resistance against the dominant terms of the economic system, but the latter could nevertheless find itself destabilized. The socio-technical network that is established with the development of this technology could contribute to a substantial restructuring of a whole series of networks that were deployed with the economic globalization movement[17]. The changes in the production modes could impact industrial structures, the status of goods as merchandise, and ultimately global trade.

a) Demassification of production

Mass production was the basis for the development of industrial capitalism. In this model that became dominant in the twentieth century, producing high volumes became easier thanks to the combination of various efforts, especially the standardization of goods offered and the rationalization of how work is organized, which Taylorism took very far. During its expansion phase, this system absorbed a large number of workers who ended up finding themselves in a position of subordination in relation to industrial logics: these production agents were functional and interchangeable elements, and could only understand a part (usually a limited one) of the production process and usually only had a distant relationship to the final result, the finished and sold product. Producer and consumer became two distinct roles, on opposite ends of the flow of goods. Productivity of production and assembly lines benefitted from advances in technology and increased thanks to their automation, which thus allowed costs to be reduced. Large firms developed using this system and they were able to ensure their growth by selling large quantities to

[17] If we use a framework of analysis such as the one used by Dicken, Kelly, Olds and Yeung, 2001.

clients who were often treated as homogeneous masses and targeted by extensive advertising campaigns in the mass media. And outlets were also those of a mass consumption.

The generalization of three-dimensional printers could profoundly affect such a scheme. If individuals can make, rather than buy, a large part of the objects they need, then these new tools can bring a society out of a massified industrial model that is dependent on large production units. With the development of mechanization in the nineteenth century and the "industrial revolution", there was a tendency to have a concentration of production, both in terms of manufacturing structures and geographic zones. In comparison, machines like three-dimensional printers have a high potential for becoming widespread: they are small in size, can be taken apart and many have a modular design. Such machines allow for production to be dispersed in smaller units. They are not specialized in only one or a few products. This may not mean the end of large plants and factories, but these machines are likely to reduce their number. At the same time, they would have the potential to break the oligopolistic tendencies that characterize many sectors of consumer goods.

b) Could these machines disintermediate the existing system? A factor of obsolescence of industrial structures

For individuals, this technology could thus be presented as a way to reduce their dependence on the industrial system. This type of machines, *a fortiori* if they can print their own pieces and become self-replicating (like in the RepRap project), makes the presences of certain intermediaries almost unnecessary. This is particularly the case with regard to commercial outlets where offer is supposed to meet demand, or the part of logistics that ensures the transport of finished products.

In industrial capitalism, the development of the production process was built on the accumulation of fixed capital, in the form of machines installed on sites that were set up for this purpose. With the development of three-dimensional printers, there are now productive machines that are no longer in factories. Equipment costs are reduced. The issue is less about accessing products than accessing materials to make them, which shortens circuits.

The underlying logic of whole industrial sectors, especially those that mass-produce objects, may be affected to the point of making them obsolete. The simpler the product, the harder it may become to defend the usefulness of corresponding industries. But if some sectors of activity become obsolete, the result could be the same for employment in those sectors. Thanks to production capacities that could be recovered, the labor force of individuals could then be less likely to be exploited.

In addition, the machines being proposed allow for a glimpse of how the market logics could be destabilized. For the time being, many available machines are sold, assembled or unassembled, by companies such as MakerBot, Ultimaker, or more recently, Solidoodle. But regarding the machines that can self-replicate, there is no interest in trying to sell them. Adrian Bowyer, the RepRap project founder, expressed this idea in an almost provocative way: "[…] if you have a machine that can copy itself, you can't sell it. You'll only ever sell one! »[18]

The expansion of this technology can lead to a chain reaction in the entire economic system, from production to distribution, and vice versa, depending on the products that will adapt. In the last decades of the twentieth century, the productive fabric had experienced profound changes, in particular those related to the introduction and the functioning of mass distribution, which strongly contributed to reshaping the economic circuits on an intercontinental scale. Gary Gereffi (1994) had the opportunity to study the shift in economic power over the past forty years, from manufacturing

[18] Found on the page http://unit13.ortlos.info/?p=618 , accessed on September 10th, 2012.

to the retail sector. This power could weaken if there is a decrease in the quantity of products to be distributed.

c) Could these machines bring decommodification? Goods that no longer necessarily become merchandise

The proliferation of objects in everyday life is another element that fundamentally changed people's lives in the twentieth century (Cohen, 2001: 203). To a very large extent, these objects took the form of commodities. In other words, they were designed to be sold and bought, and thus subject to monetary exchange.

Can the generalization of tools like three-dimensional printers make the relationship with objects evolve? Yes, if one considers that self-producing objects can make individuals less passive, especially regarding consumption habits. The consumer would no longer be restricted to choosing based on a predetermined offer, but could almost build the offer he or she is looking for. That is to say, the consumer could not only identify the products and models available and assess their characteristics and properties, but also potentially modify them. With this decentralized mode of production, *a priori* adapted to the needs of consumers, another way of considering goods may also be favored, one in which the use value would tend to have greater priority over the exchange value, since each individual could manufacture the object he or she wanted and exchange would become less necessary (except perhaps if specific features must be added).

These products would no longer necessarily be intended to be commodities and have a market value. One could then see everyday use of three-dimensional printing as a possible way of decommodifying certain objects. If a large proportion of objects produced are no longer intended to be part of commodity exchange cycles, the monetary medium becomes less useful, at least for buying what was formerly a manufactured product. There is little justification for selling an object if everyone can make it at home. The idea of value itself can be destabilized and this new possibility of self-production may make indicators that are already challenged, like the Gross Domestic Product (GDP), even more obsolete.

d) Could these machines contribute to relocalization? Renewed forms of self-production and their effects on world trade

Could the extent of these transformations be world-wide? This is a possibility to consider, since the generalization of such tools (*a fortiori* if, at the same time, places such as fab labs become widespread in everyday environments) may disrupt the organization and circulation of physical flows, both for materials used and productions made possible.

It is obviously too early to say whether such tools can bring economic globalization to a halt, but at least one can suppose that they can contribute to relocalization dynamics and reducing the volume of international trade. The recent phase of global capitalism was marked by mobility and the release of the flow of goods. These flows both increased and developed in the global market starting in the 1970s, while at the same time participating in a rearrangement of the international division of labor[19]. Many studies have shown that economic globalization revealed itself through the distribution of production activities in new spaces. For a wide range of industries, in particular labor-intensive ones, the strategic choices were to "delocalize" to countries deemed more

[19] See "Globalization. 1973-2000", in Frieden, 2007.

advantageous from a labor cost standpoint. The combined effect was that transport flow increased for both raw materials and products at various stages of their fabrication.

From this point of view, three-dimensional printing technology could be compared to an innovation such as the container (Levinson, 2008), but with almost opposite effects. The container facilitated the handling of large quantities of merchandise for long distance exchanges. It enabled to streamline certain logistical tasks, so to save time, reduce costs and to better control the extension of transport chains. One could consider that the container facilitated the deployment of economic dynamics on a new scale, one that is more extensive in this case, and world-wide. If we make a connection between the two, three-dimensional printing is a technical solution that can contribute to a new destabilization of hierarchies, but in distinct forms, even contrary to what may have occurred with globalization[20]. Given the likely difference in cost compared to local production, it would not be rational to have products manufactured in remote areas of the planet and then import them. The development of this technology (in addition to other factors such as the rising price of oil) would contribute to a new phase in the spatial distribution of production and transportation needs. There would be fewer goods to be transported, since part of the exchanges would take place via digital files containing the necessary information for printing.

In other words, it would be logical that a large part of these exchanges of manufactured goods disappear if the fabrication of objects became possible exactly where the needs are, within a short period of time with respect to when the needs were expressed, and all without having to go through long circuits requiring a whole logistical chain to bring these goods closer to the places of use. The type of production that three-dimensional printing enables can make many infrastructures and logistical activities obsolete. There would also be fewer finished products to stock (and thus manipulate in warehouses). However, the management and distribution of materials (powders, resins, etc.) could create a relatively new field of logistics.

If three-dimensional printing tools allow objects to be made locally, anywhere, and brings production back to more decentralized bases, it will probably be difficult to speak of an international division of labor. Indeed, the comparative advantages of low-wage countries would be reduced.

Such machines could then be the answer that some alter-globalization groups have been waiting for, especially regarding wishes for “relocalization”, that is, making production return close to places of consumption. More than just an economic issue, this return may be seen as a way to possibly regain collective and democratic control over the production process. The origin of goods would no longer be lost in the opacity of production circuits that are expandable according to the interests of production firms.

Thus, these machines should not only be regarded as an innovation, one of many in an ever-increasing technological dynamism. They can profoundly affect the economic order, and therefore the resulting collective life. Common activities would no longer need to be connected to networks of exchange and would be removed from economic logics responsible for certain dependencies.

III) Friction points

In order not to give in to technological messianism, obstacles to the diffusion of these technologies must be kept in mind, starting with those posed by the different actors who have no interest in

[20] For a comparison with dynamics linked to globalization, see Sassen, 2006.

seeing them develop, and obstacles resulting from ecological constraints and the availability of sufficient resources. These conditions and constraints are likely to generate tensions and conflicts, and can significantly affect the future trajectory of three-dimensional printing.

a) Ecological issues and the place of the question of resources

Since three-dimensional printers are indeed machines that produce artefacts, they will not escape the ecological issues of "sustainability". These issues are related to the material impacts of resources used and environmental effects of the production process. On the one hand, these machines require materials that are not found in nature. On the other hand, they consume energy and can create waste.

Who is going to be able to produce these basic materials and how? Plastic, in various forms, is the most commonly proposed material for the time being. Depending on its method of production, its use may be problematic. The issues surrounding plastic are similar to those concerning how to replace petroleum-derived plastics by other types plastic made from "natural" and renewable raw materials. However, this technology is undergoing developments that encourage some of the interested actors to reflect on materials.

In other respects, this technology also has advantages from an ecological point of view. With products designed with an open source approach and the availability of three-dimensional printers to manufacture spare parts, repairing objects becomes more feasible. But this implies that products be originally designed to be easily repaired. Similar to product catalogues that are already online, this can lead to the development of spare parts catalogues, especially for products that have been discontinued. The possibility of repairing objects can give them a longer life and thus circumvent the planned obsolescence that some companies may have tried to carry out to maintain their market sales.

A lower level of consumption of materials is also an argument used by certain proponents of these machines. This production method reduces the amount of material scraps and waste that are produced with more traditional machines. The need for packaging can also be reduced, which would be another way to generate less waste.

However, the question arises as to whether this type of tool would encourage individuals to produce all kinds of gadgets, and throw away objects more easily. The desire to have an object can be satisfied (almost too) quickly ("I want it, so I'm going to print it out"). This tool finds itself in a consumerist society, one of whose motors is to stimulate the desire to obtain objects. So there is no guarantee that there would be a reduction in the quantity of goods consumed. The rising cost of raw materials may however curb frivolous use of this tool.

Even if goods become readily available (since they would avoid problems of commodified scarcity), objects at the end of their lifecycle still need to be dealt with. Reflections on recycling materials used in three-dimensional printers are at the early stages of development. Some go as far as suggesting to try to close the loops, by ensuring that materials from objects produced can be ground up and collected for future use[21].

Moreover, this technology does not make the question of resources any less important, but the question is displaced. With the generalization of this type of machines, the materials will become a major issue and controlling their production circuits will become strategic.

[21] This type of research has been undertaken at the Creative Machines Lab at Cornell University (see Hiller and Lipson, 2009). See also Baechler, DeVuono and Pearce, 2013.

b) Obstacles posed by regimes of ownership

Any technology that is likely to destabilize the established order experiences criticism and blockages, especially from those who could benefit from this order. With regards to three-dimensional printing, one of the fronts that have started to open up is the regime of intellectual property. Questions about intellectual property are important for businesses and economic actors who hope to make a profit from their production. Some industries may be afraid of suffering the same fate as the music and film industry following the development of file sharing technologies. Especially since three-dimensional scanner technology has also developed significantly, and thanks to this technology, it is possible to scan physical objects in the form of computer files (and even now from a smartphone). If the reproduction of objects becomes easier, making a profit from the sales of these same objects may become more difficult for the traditional manufacturers. In short, it will not be long before manufacturers denounce new types of "pirates"[22].

This kind of fear can be reinforced by initiatives such as the one on the site The Pirate Bay, which is known for letting its members easily share and download a large number of indexed files. In January 2012, the portal proposed a new category called "Physibles", which provides access to printable object files in three dimensions[23].

A part of the community of followers of three-dimensional printing, who foresaw blockages from certain economic interests, began thinking about more legal matters. The American organization Public Knowledge, whose work aims to keep the Internet open, published a "White Paper" at the end of 2010 to defend the possible innovations from this technology and try to prevent hostile use of intellectual property legislation (Weinberg, 2010). On April 28th, 2011, Public Knowledge, along with the founders of several start-ups, organized a meeting in Washington to try to raise awareness among policy makers and bring to light the strategic issues of three-dimensional printing.

The intellectual property issues could decrease when prototyped objects are proposed under licenses such as "Creative Commons" (Soufron, 2009). This system of licenses allows for a legal guarantee to be provided while leaving possibilities of free movement for works registered in this way. For example, they are used on the sharing platform Thingiverse. The organization Creative Commons has also begun reflecting on how to develop more appropriate licenses for material objects based on the model used for software. The community of supporters of three-dimensional printing remains indeed largely attached to the principles of open source, which allow licensees the possibility to improve the design of objects.

Conclusion

Three-dimensional printers offer exemplary proof that it is possible to produce differently, that is, other than mass, centralized, and standardized production methods. Of course, this technology is not yet fully developed, but it would not be judicious to neglect it on the grounds of its uncertain future, for it could have a larger impact than the current experiments and techy craft projects that its

[22] For insight into the legislative framework available, especially in the United Kingdom and Europe, see Bradshaw, Bowyer and Haufe, 2010.

[23] By making this conviction : « We believe that the next step in copying will be made from digital form into physical form. It will be physical objects. Or as we decided to call them: Physibles. Data objects that are able (and feasible) to become physical. We believe that things like three dimensional printers, scanners and such are just the first step. We believe that in the nearby future you will print your spare parts for your vehicles. You will download your sneakers within 20 years » (http://thepiratebay.se/blog/203 , accessed 12 September 2012).

designers and users are for the moment producing and trying to make work. These conceivable potentialities are all the more challenging to analyze that they revive questions about interrelationships between what is technical and what is political, including how technical advances can expand political capacities.

Certainly, the full list of potentialities offered by this technology is not yet actualized, but interesting trajectories are discernible. As it develops, three-dimensional printing technology also tends to transmit values, which can indeed, as we have seen, rally a community. These values contribute to emphasizing creativity and the capacity to make something oneself. These new tools seem to bring about new modes of production and consumption, and therefore potentially different relationships to goods. These possible changes would not be driven "from above", but in a diffuse manner. Technology would make new practices possible, and as they are generalized, they themselves could have systemic effects.

These effects are political, even if they stem from everyday life and the changes that are made possible. This type of tool is likely to destabilize work as a value that has accompanied the development of the industrial society. If there is a shift from consumption to self-production, this may encourage a certain number of people to reduce their level of income, *a fortiori* in an economic context where obtaining a well-paying and stable job is becoming increasingly difficult. It could even go as far as impacting the labor market, which could then enter into a phase of transition. In fact, the labor needs would be different, especially in manufacturing, where the market and thus the raison d'être would be lost[24]. And on an individual level, if everyone can make their own objects, this can reduce the need to have full-time employment. There would be a disintensification of commercial activity and a redistribution of monetary flows, and some of these flows may even disappear altogether.

The spread of this technology will go through experimental phases before being adopted by users. All the potentialities of a technology may not be realized, or not completely, or may be discovered over time. Just because this technology becomes accessible does not necessarily mean it will be integrated into current practices to the point of being part of everyday obvious facts (particularly for the lowest income bracket).

There may only be partial changes to the economic infrastructure. Printers did not make books and publishers disappear. Technology can also be used by powerful economic actors to adapt changing dynamics to their advantage. It is also conceivable that certain businesses see three-dimensional printing as a way to gain more flexibility in their production process, by establishing new forms of subcontracting.

The role of this technology will be judged primarily on how it will intervene in the relationship between human life and objects. In a world saturated with objects, what ultimately matters is not only the way to manufacture them, but also the artefacts that are created, as well as their nature, their quantity, the intentions that inspired their creation, the desires they meet... Three-dimensional printing is only a means which seems to leave undetermined the question of the usefulness of what will be produced, thus overlooking the ontology of objects.

[24] Some economic newspapers have gone as far as outlining an enchanted vision of employment, with a shift of labor towards more skilled jobs, like in this description: « Most jobs will not be on the factory floor but in the offices nearby, which will be full of designers, engineers, IT specialists, logistics experts, marketing staff and other professionals. The manufacturing jobs of the future will require more skills. Many dull, repetitive tasks will become obsolete: you no longer need riveters when a product has no rivets » (« The third industrial revolution: The digitisation of manufacturing will transform the way goods are made—and change the politics of jobs too », *The Economist*, April 21st 2012, http://www.economist.com/node/21553017)

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