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# The Next Industrial Revolution? The Role of Public Administration in Supporting Government to Oversee 3D Printing Technologies

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**Abstract:** *In recent years, developments in 3D printing have grasped the public's attention. There are a range of different applications for these technologies that have a number of social, economic, and environmental implications. This essay considers these advancements and what the role of government should be in overseeing these technologies. It argues that although these technologies have been absent from the public administration literature to date, there is an important role that the field can play in supporting governments in this endeavor. In illustrating this, the final section of the essay draws considers how a multilevel governance framework of technology might allow us to consider the broader implications of these technologies.*

Additive manufacturing—or 3D printing, as it is better known—is a new set of technologies receiving significant attention for their potential to change many facets of our everyday lives. Some have gone so far as to suggest that their advent signals that we are on the cusp of the next industrial revolution, with technological, social, environmental, and economic implications stemming from these innovations. If this is true, what role should government play in overseeing these technologies, and how can the field of public administration support this endeavor? Should government let the market flourish, or should it seek to control developments in a top-down way? This essay suggests that the reality, of course, is somewhere in between, and there is a critical stewardship role for government to play as we navigate the changes associated with these developments.

The argument is set out as follows: The first section provides an overview of 3D printing technologies and some early applications. The following section goes on to consider the argument that 3D printing represents the next industrial revolution and demonstrates some of the ways in which these technologies have potentially far-reaching and unanticipated consequences. The final section concludes by drawing on the public administration literature to consider how a multilevel governance framework of technology might allow us to consider the broader implications of these technologies.

## 3D Printing: An Overview

Although 3D printing is often viewed as a new concept, it has existed for more than two decades. Much of the early application of these technologies was in rapid prototyping, but advancements have seen this approach applied in mainstream manufacturing and even individuals owning their own printers to produce objects at home.

The first part of any 3D printing process involves creating a digital model of the object to be printed. This can be done by buying a model online, customizing an existing design, or creating your own. Approaches to creating digital models require varying degrees of skill in design, although we are seeing the rapid development of 3D scanners that allow the user to analyze a real-world object and use these data to construct a digital model. Once the design of the object is finalized, it is sent to a printer to produce the object. There are a number of approaches to 3D printing, including extruding semi-liquid material that builds up object layers, applying a laser to a vat of liquid photopolymer, spraying a liquid that is set with ultraviolet light, laser-fusing layers of powder, and sticking together sheets of cut paper, plastic, or metal. Each of these approaches differs in terms of the equipment required, materials used, quality of the end product, and price. At one time, the common material used for 3D printing was plastic, but it also possible to print using metal alloys, wood particles, ceramics, food substances, and even bacterial cultures.

This array of approaches and materials is attributable to the fact that there are many different applications for 3D printing. This is reflected in predictions about the global economic impact of these technologies, which has been estimated in the range of $230 billion to $550 billion per year by 2025 (McKinsey Global

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Institute 2013). For many, 3D printing is not a future aspiration but a daily reality. If you have had a hearing aid fitted in recent years, there is a good chance that it was produced using an additive manufacturing approach; more than 10 million 3D-printed hearing aids are in circulation worldwide. The field of health care offers a number of potential applications, from individualized prostheses to replacement teeth. 3D printing has become one of the major tools in the bioprinting industry. To date, human blood vessels have been produced through 3D printing processes, in addition to skeletal muscle, multilayered skin, vascular grafts, tracheal splints, cartilaginous structures, and bone and liver tissue (Mironov et al. 2008). The advantage of these products over artificial implants is that they are less likely to be rejected by host bodies, as they are living objects.

In the housing arena, 3D printing can be used to develop low-cost dwellings. A number of approaches are available to either print structures in situ or produce larger components that require less assembly than traditional modes. 3D printing is significantly quicker than standard construction techniques and cheaper because there are fewer labor costs and less waste is produced. Hostile environments, such as those associated with emergency relief, are also an area in which these tools are being used. Rather than arming teams with vast amounts of equipment, 3D printers can be used to create objects as they are required and customized to the specific situation. Lipson and Kurman (2013), for example, foresee miners using 3D printing equipment in the event of a collapsed mine shaft. NASA has already sent a 3D printer to the International Space Station to test how the technology works in microgravity for similar purposes.

## The Next Industrial Revolution?

Some commentators have argued that 3D printing is more than just an interesting development in manufacturing techniques—it represents the dawning of the next industrial revolution (Barnatt 2014). Certainly, 3D printing challenges a number of traditional characteristics of manufacturing. While most manufacturing approaches remove material during the production process, 3D printing techniques add material, building up an object. But the implications of this approach go further than this to a number of the principles underpinning contemporary manufacturing.

Since Adam Smith first described the principles of specialization and division of labor in *The Wealth of Nations,* these have remained central to ideas of mass production. A small amount of highly skilled labor is used to design products and set up production processes, and a larger body of unskilled labor is used to produce standardized components and assemble them. Such approaches produce many versions of the same product at low cost by (often) unskilled laborers. 3D printing approaches do not need to gain economies of scale through mass production. Single items can be produced and changes can be made to product designs without a substantial increase in costs. 3D printing techniques will allow manufacturing to move into an era of mass customization, making products that are more relevant and working more efficiently by reducing the volume of waste produced.

Campbell et al. (2011, 1) argue that 3D printing will have "profound geopolitical, economic, social, demographic, environmental, and security implications." In challenging the principles of manufacturing, we see changes in flows of people, power, and money. Some commentators have gone so far as to argue that 3D printing represents an attempt to "democratize" manufacturing (Barnatt 2014), as individuals can own the means of production in their own homes. However, as others note, large private sector firms and even nation-states dominate the 3D printing field to a greater extent than individual consumers (Daly 2016).

One example that demonstrates some of the broader dilemmas posed by 3D printing technologies is the production of weapons. The Liberator was the first successfully fired 3D-printed gun in 2013. Issues of safety and security emerge from this, and not just in terms of the availability of weapons. If there is a rise in the use of these kinds of weapons, we will need to see some changes in how we go about ensuring the security of the citizenry. Machines that detect guns in schools, courts, and airports typically sense metal, but many home-fabricated guns will be plastic. The manufacture of guns is not the only area in which we might be wary about the application of 3D printing technologies. The production of pharmaceuticals has also been flagged for concern. So-called chemputers allow individuals to print pharmaceuticals in their own homes, meaning that we may see a rise in the availability of illicit substances.

Of course, it is possible to make guns and some pharmaceuticals in our homes at the moment, provided we have access to the right sorts of materials and specialist knowledge. 3D printing enables specialist knowledge to be more easily shared. More than 100,000 people downloaded the Liberator files before they were taken down by the U.S. State Department. A recent court ruling will see these files made publicly available again, although in the intervening period, it has not been difficult to find designs for 3D-printed weapons online.

Such developments raise questions about what role government will play as technological advances are made. One of the ways that governments have traditionally regulated harmful weapons and substances is through their manufacture and sale. New technologies challenge this approach; if we are able to print these in our own homes, then this has implications for how they are regulated. Beyond the harm that pharmaceuticals and guns can do to individuals and communities, there are also concerns regarding health and safety regulations and issues of liability. Items that are printed at home may not be subject to the same sorts of safety checks as those that are mass manufactured and therefore subjected to well-developed regulatory regimes. Domestic production may increase the potential for injury and damage through bad designs or inappropriate production, and this poses issue for existing liability regulation.

Current intellectual property rights may also be challenged through the sharing of designs that could infringe on design rights, patents, and possible trademarks (Brean 2012). A key consideration for public administration practitioners will be to ensure that intellectual property rights are not violated in using 3D printing techniques to devise efficient service delivery methods. This issue is clearly not new, although practitioners will need to work in different ways to ensure that rights are not violated.

We find a further series of dilemmas in relation to bioprinting and applications in organ replacement processes. Although we have had the ability to perform live transplants of organs for many years, in many countries, there is a chronic shortage of live replacement organs. In the United States, more than 120,000 people are currently on the waiting list for a lifesaving organ transplant, and on average, 22 people die every day from a lack of available organs (American Transplant Foundation 2016). The ability to bioprint replacement organs could save significant numbers of lives each year. These impacts could be even more profound for particular ethnic groups. New technologies offer the *potential* to reduce significant inequities in health outcomes, although realizing them is contingent on access to health care. Medical technologies that reduce disparities between groups are likely to be highly welcome, particularly in the U.S. context, where we have seen growth in avoidable differences in health across ethnic and socioeconomic groups (Adler, Glymour, and Fielding 2016). However, these technologies could also have implications for health behaviors. If there is greater availability of replacement organs, might this mean that individuals will engage in riskier and unhealthier behaviors? As medical technologies develop, governments will have important work to do in ensuring access, but also in anticipating unintended consequences of their implementation and guiding behavior to prevent harm.

The emergence of 3D printing technologies has also attracted attention for their potential impact on employment. As these technologies do not need large amounts of unskilled labor, it is possible we could see companies bringing manufacturing bases back to countries such as the United States. Indeed, such a promise was made in President Barack Obama's final State of the Union address. However, it is unlikely that any such shifts will create low-skill roles and revitalize traditional manufacturing areas. 3D printing technologies could also mean the loss of jobs in other industries, such as construction. Such approaches have already been developed to produce low-cost dwellings, where savings are realized in terms of labor costs. 3D printing is not all bad news in terms of employment. The U.S. Postal Service predicts that increased delivery of single-item parcels containing customized products will lead to $485 million in new annual revenue (Office of Inspector General United States Postal Service 2014), but in a context in which some postal services are being delivered by drones, such estimations could prove optimistic.

As this brief selection of examples has demonstrated, many of the applications of 3D printing technologies have profound impacts beyond their immediate purpose. In addition to being hailed as a means to overcome a number of long-standing issues, they raise a number of governance dilemmas and pose challenges to conventional processes. There is, therefore, a need for governments to engage in thinking about these technologies, their potential applications, and the implications that may arise. Public administration can play a role in supporting this.

## The Technology Ecosystem and Multilevel Governance

There is a well-rehearsed argument concerning the role of government in relation to technology and innovation. Such a perspective is illustrated by the following quotation: "Governments have always been lousy at picking winners, and they are likely to become more so… governments should stick to the basics: better schools for a skilled workforce, clear rules and a level playing field for enterprises of all kinds. Leave the rest to the revolutionaries" (*The Economist* 2012). This view cleaves to the notion that governments kill innovation and should play a limited role in encouraging technological innovation, intervening only in cases of market failure. Not only is this a narrow perspective on the various roles that are important in innovation, it has also been shown to be significantly untrue. As Mazzucato (2015) demonstrates, governments have invested substantial amounts of money in financing innovation and creating entirely new fields such as biotechnology and nanotechnology. Governments play a critical role in creating and shaping new markets and driving technological advancements. Indeed, many of the applications of 3D printing set out here have been driven by public funding and/or government research applications.

Although these kinds of critiques of technological innovation do not hold up within the evidence base, it is clear that most governments have some way to go in terms of how they oversee these types of processes. Many governments around the world have changed aspects of their practice since the last great shift in technology, from mechanical to digital, but there remains a stubborn discourse that government has sometimes struggled to harness technological possibilities and that progress has been incremental at best (Norris and Reddick 2013). If governments are to avoid this criticism, there is a need to engage in careful thinking about these technologies and the dilemmas that they raise. Further, it is incumbent on the academic public administration community to support this process. As Pollitt (2016) acknowledges, the public administration academic community has often failed to give sufficient attention to aspects of technological change. Yet the public administration literature can offer some helpful insights into guiding the role that governments play in overseeing these technologies.

One of the challenges with new technologies, such as 3D printing, is they cross so many different domains of traditional government activity. Therefore, it is not unusual to see multiple agencies or organizations develop separate strategies and approaches around new developments, each in a rather narrow sense. As the examples here illustrate, this can pose dilemmas when the introduction of an innovation in one space has profound implications for safeguarding, regulation, or other processes of governance in another. Further, this activity needs to take place in advance of an issue or an event arising that triggers an inevitable investigation.

As Mazzucato (2015) argues, there is a need to consider the entire "ecosystem of innovation," the roles that actors play within this over time, and the implications of developments for various areas of policy. In this sense, the field of public administration provides a helpful lens through which to consider these technologies, drawing on the concept of multilevel governance. Multilevel governance is an approach that can be used to understand the dynamic interrelationship within and between different levels of governance and government (Bache and Flinders 2004). The application of a multilevel governance framework by practitioners seeking to consider the impact of 3D printing technologies within their jurisdictions would assist in understanding the various formal and informal actors at different levels of the system and aid in

identifying challenges that might arise and the opportunities to leverage change (Hovik and Hanssen 2014).

What is clear is that public administration practitioners and scholars are in need of approaches that will allow us to conceptualize new technologies and their full implications in a much broader manner than is often captured at present. The radical changes that 3D printing may bring is one example of a number of technological revolutions that are on the horizon (e.g., robotics, artificial intelligence, augmented reality, quantum computing). Enacting approaches such as multilevel governance will encourage consideration of the broader applications and implications of these technologies and help governments stay ahead of the curve.

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