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(UN)LOCK AND (UN)LOADED: REGULATING 3D-PRINTED FIREARMS IN THE OPEN-SOURCE ERA AFTER THE 2013 HYSTERIA*

by

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3D printing, or additive manufacturing, is a fast-evolving technology that is transforming the way humans create things. Anyone can buy a 3D printer for private usage, allowing them to produce totally personalized things in the comfort of their own homes. One 3D-printed commodity, unfortunately, is provoking a huge debate: firearms. Any person may build a completely functional firearm only with a 3D printer, the necessary designs and filament. Thus, bypassing governmental licensing, registration, and fabrication regulations. A surge of scholarships appeared

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nine years back, alerting people about the dangers of 3D-printed firearms. Following the widespread hysteria, this work offers commentary on the issue of 3D-printed firearms, as well as lessons learnt for a better regulatory framework for these firearms. To establish effective regulatory oversight over illicit ownership and usage of 3D-printed guns, existing law may have to be enhanced. Furthermore, any prospective regulations will almost definitely be closely scrutinized in order to strike a balance between public security concerns and personal liberty. Additionally, many conceivable technological regulations would be unfeasible and would contradict the public interest objective of safeguarding technological development. To better control 3D-printed guns while preserving basic freedoms and technological development, a three-pronged approach has been proposed.

KEY WORDS

3D Printing Technology, 3D-Printed Guns, Additive Manufacturing, Firearms, Ghost Gun, Regulation

1. INTRODUCTION

Three-dimensional (3D) printing, often known as additive manufacturing, is a fast-evolving technology that poses new legal implications. Among the most challenging issues is determining how to control 3D-printed guns responsibly.[1] Anybody with a 3D printer now has the ability to transform a digital design into an operational lethal firearm, circumventing various gun control regulations.[2] Regardless of the fact that 3D printing technology has been around since the 1980s, recent technological breakthroughs and lower costs have rendered these devices more affordable to everyday users.[3] Since the market for 3D printers is still so nascent, it is still yet to be effectively governed, and the legal ramifications of 3D-printed items have not been adequately assessed by the judiciary.[4] It is uncertain why 3D printing technology has not really been covered by current regulative frameworks up to this point. The far more likely answer is that the technology is not quite developed, and that it would be several years before it becomes a viable alternative to conventional production. Nonetheless, a number of recent advancements indicate that the technology may become feasible sooner than

[1] For the purpose of this article, any firearm manufactured with any 3D-printed component that serves to the firearm's operation, regardless of the material used, is considered a 3D-printed gun. See McCutcheon, C. (2014) Deeper than a Paper Cut: Is It Possible to Regulate Three Dimensionally Printed Weapons or Will Federal Gun Laws Be Obsolete Before the Ink Has Dried? *Journal of Law, Technology and Policy*, 2014 (2), p. 227.

[2] McCutcheon, C. (2014) *op. cit.*, p. 221.

[3] McCutcheon, C. (2014) *op. cit.*, p. 223.

[4] Berkowitz, J. (2018) Computer-Aided Destruction: Regulating 3D-Printed Firearms Without Infringing on Individual Liberties. *Berkeley Technology Law Journal*, 33 (1), p. 53.

expected.[5] As 3D printers are becoming more widely accessible, there is fear that users may utilize these devices to get around the law.[6]

Anybody with a 3D printing machine and Internet connection may make guns in their own houses, eliminating the need for license, registration and background checks.[7] There are currently minimal regulations concerning the ownership or production of 3D-printed guns. Thus far, 3D-printed weapons have largely sparked concerns about intellectual property, such as patent, trademark and intellectual property theft.[8] Nonetheless, once the technology has become more widely available, it will surely thwart existing gun-control measures and public safety concerns.[9] With tens of thousands of firearm-related violence annually,[10] 3D-printed firearms should be evaluated in the light of their potential to increase that numbers. Although it is unlikely that many people would manufacture their own weapons, 3D printers will help to increase the number of illicit weapons on the market and offer offenders with a novel way to get weaponry.[11] In addition, unskilled users may injure themselves when trying to manufacture and discharge a badly crafted firearm.[12] Nevertheless, regulators must be cautious not to let the innovation of 3D printing divert attention away from the real issue: public safety and preventing misuse of technology, while not stifling with technological innovation.[13] This is especially true for 3D printing, which has the potential to revolutionize many industries, from manufacturing, medicine to gunsmithing. However, there are potential risks associated with the technology, such as the potential for misuse, which regulators must be aware of in order to ensure public safety. Regulatory oversight is important for safety, but it must not stifle innovation. Governments must ensure that regulatory actions are reasonable and do not prevent the development of 3D printing technology for beneficial uses. It is similar to navigating a narrow path between two cliffs; too far to either side and one

5 Christopher, G. (2015) 3D Printing: A Challenge to Nuclear Export Controls. *Strategic Trade Review*, 1 (1), pp. 18-19.

6 Ferguson, C. (2013) *3-D Printed Guns Are a Boon for Criminals*. [online] Atlanta: CNN. Available from: `https://edition.cnn.com/2013/05/07/opinion/ferguson-printable-gun/index.html` [Accessed 25 April 2022]

7 McCutcheon, C. (2014) *op. cit.*, p. 221.

8 Berkowitz, J. (2018) *op. cit.*, p. 54

9 McCutcheon, C. (2014) *op. cit.*, p. 220.

10 Little, R. (2014) Guns Don't Kill People, 3D Printing Does? Why the Technology Is a Distraction from Effective Gun Controls. *Hastings Law Journal*, 65 (6), p. 1506.

11 McCutcheon, C. (2014) *op. cit.*, p. 237.

12 There are many other serious social consequences of firearms ownership that are unrelated to criminality, like the alarmingly high frequency of accidental gun-related injuries. See Stevenson, D. (2021) Going Gunless. *Brooklyn Law Review*, 86 (1), p. 184.

13 Little, R. (2014) *op. cit.*, p. 1510.

will fall off the edge. Regulatory actions must be balanced to provide enough protection without choking off the beneficial advances that 3D printing can bring. Therefore, finding the balance between protecting the public while still allowing innovators to explore technology's full potential is the key. Hence, the debate over merely removing digital data for 3D printing firearms off the Internet has little practical significance.[14] However, it raises the question of whether and how gunsmithing by means of 3D printing should be governed. This paper will examine the topic of 3D printing and its prospects for regulatory action. This will include an overview of the technology, its potential applications, and its potential security implications. Next, this paper's topic will also allow for examining existing regulatory approaches. From a legal and technological perspective, the paper's topic will then move towards discussion on what strengthens the raison d'être for regulating or non-regulating 3D printers. The ultimate aim of this paper is to explore the appropriate regulatory responses for 3D printing technology, in order to ensure its potential benefits are realized, while mitigating any potential security risks. Whilst this paper is theoretical in nature and therefore not bound by any particular jurisdiction, it aims to provide overall assessments that will be useful for policymaking. However, this paper was never meant to be the "overarching" and "one-size-fits-all" panacea, and to ensure effectiveness, further contextual and empirical research is definitely needed.

Unlike previous scholarships, the novelty of this paper lies on its focus on coming up with solutions that strikes a careful balance between preserving public safety and rights on the one hand, while avoiding unnecessary controls on 3D printing technology that would stifle the industry on the other. The concerns of clients of this technology, as well as the interests of other players in the technology, like 3D printer makers, government agencies, and hosting platforms, are considered. Furthermore, lessons learnt from several scholarships in response to the 2013 3D-printed gun hysteria,[15] as well as

[14] Jacobs, J.B. and Haberman, A. (2017) 3D-Printed Firearms, Do-It-Yourself Guns, & the Second Amendment. *Law and Contemporary Problems*, 80 (2), p. 137.

[15] When the downloadable designs (or digital design files) to build a 3D-printed firearm, called "the Liberator," were posted onto the world wide web by the US-based firm, Defense Distributed in 2013, it drew a lot of public and law enforcement interest. The new tech shocked the public, reaching more than 100,000 downloads within the first 24–48 hours, well before the US Department's Directorate of Defense Trade Controls (DDTC) advised the files' withdrawal from the Internet based on the pretext that the Liberator may be in breach of the Arms Export Control Act. See Daly, A. et al. (2021) 3D Printing, Policing and Crime. *Policing and Society*, 31 (1), p. 40; On the other hand, Hassan argues in his commentary that 3D-printed firearms are not a serious societal concern. As a result, alarmist reports about 3D-printed firearms may be perceived as a disservice to the wonderful influence that 3D printing is doing for our society—hence, an unwarranted manufactured hysteria. See Hassan,

current circumstances, are considered to provide up-to-date analysis on the subject matter.

This paper focuses on the challenge 3D-printed firearms poses to policymakers, with emphasis on the lesson learned from several scholarships in response to the 2013 3D-printed gun hysteria. It also suggests a way for the legal system to govern 3D-printed firearms with minimum interference to people's freedom and without impeding technological progress. Part II explains why 3D printing is vital for development, how it works, how anyone might use it to make weapons for themselves, and how 3D printers may revolutionize the way guns are procured, compromising or perhaps even rendering obsolete the archaic regulatory regime. Part III examines the present regulatory regime for 3D-printed guns and explains why the collision of technology and existing legal systems throughout the world provokes fearful regulatory response. Part IV explains why regulation is still the best step to take, elucidates the case against regulating 3D printers, and proposes a three-pronged approach that is deemed by far the most practical way of regulating 3D-printed guns while maintaining individual liberty and technological progress. Finally, Part V highlights and emphasizes the need to embrace 3D printing technology with minimal regulatory actions, while ignoring proposal for regulations requiring strict controls on 3D printers.

2. THE PROLIFERATION OF 3D-PRINTED FIREARMS: HOW TECHNOLOGY IS MOVING FASTER THAN THE LAW

3D printing technology, according to U.S. President Barack Obama in 2013, has the "potential to change the way we create practically anything."[16] 3D printing has already been revolutionizing several industries: the National Aeronautics and Space Administration (NASA), for example, uses this technology to make parts for its spaceships.[17] They has even launched 3D printers into space onboard its spacecraft in case a component fails and has to be replaced swiftly.[18] At Boeing, about 200 distinct parts for ten separate aircraft models are manufactured using 3D printers.[19] Furthermore,

K. (2020) Three-Dimensional Printed Hysteria. *3D Printing and Additive Manufacturing*, 7 (2), p. 47.

16 Blackman, J. (2014) The 1st Amendment, 2nd Amendment, and 3D Printed Guns. *Tennessee Law Review*, 81 (3), p. 483.

17 McCutcheon, C. (2014) *op. cit.*, p. 221.

18 Lewis, A. (2014) The Legality of 3D Printing: How Technology Is Moving Faster than the Law. *Tulane Journal of Technology and Intellectual Property*, 17, p. 304.

19 Willcocks, L., Venters, W. and Whitley, A. (2014) *Moving to the Cloud Corporation: How to Face the Challenges and Harness the Potential of Cloud Computing*. Hampshire: Palgrave Macmillan UK, p. 187.

this technology is utilized on a daily basis in the healthcare industry to make products such as hearing devices, prosthetics, orthopedic implants, and dental fillings.[20] Surgeons could even construct replicas of a patient's body to rehearse surgery before it is executed using this technology. The 3D printing technology permits a relatively pleasant production process that is both more efficient and waste-free than existing conventional production techniques.[21] Numerous critics, however, are worried that as 3D printing technology is becoming more widely used, certain people would exploit it to advance illicit activities.[22] The laws are left behind technological progression. Therefore, the capacity to successfully control 3D-printed firearms is at the top of this list of concerns.[23]

2.1. 3D PRINTING OR ADDITIVE MANUFACTURING

Additive manufacturing[24] is the catch-all term for 3D printing and its related technologies.[25] What sets 3D printers apart from earlier technologies would be that they enable people to recreate anything efficiently and quickly.[26] 3D printing is a fabrication technique that involves the process of construction by assembling tiny sheets of solid or liquid substances in

[20] Jensen-Haxel, P. (2012) 3D Printers, Obsolete Firearm Supply Controls, and the Right To Build Self-Defense Weapons Under Heller. *Golden Gate University Law Review*, 42 (3), pp. 451-452.

[21] McCutcheon, C. (2014) *op. cit.*, p. 222.

[22] Although the advantages of having a 3D printer are enormous, the potential of a 3D printer to quickly transform a CAD file into a lethal item, such as a gun, allows printer availability to the regular populace, especially those with malicious intentions, a national security issue. See McMullen, K.F. (2014) Worlds Collide When 3D Printers Reach the Public: Modeling a Digital Gun Control Law after the Digital Millenium Copyright Act. *Michigan State Law Review*, 2014 (1), pp. 196-197.

[23] McCutcheon, C. (2014) *op. cit.*, pp. 235-237.

[24] Additive manufacturing is not the same as subtractive manufacturing. The former creates objects by depositing material layer-by-layer, whereas the latter creates objects by removing material layer-by-layer. Thanks to their overlapping variety of applications, additive and subtractive manufacturing technologies are frequently utilized together, despite their key distinctions. A computer numerical control (C.N.C.) milling, is an example of computerized subtractive manufacturing. This method does what 3D printing cannot: it makes an object by subtracting materials instead of adding them.

[25] Christopher, G. (2015) *op. cit.*, p. 19.

[26] In general, 3D printing outperforms conventional manufacturing techniques in terms of efficiency and speed, particularly for smaller and customizable runs of production. One can argue that a 3D printer may construct objects more slowly than a conventional manufacturing line. However, there are more things that may go wrong with conventional manufacturing processes, whenever one takes into account human mistake and mechanical issues that could halt production. The molds are necessary for conventional methods of production like the injection molding process in order to produce parts. It may take 1-2 months to create these molds from scratch. Contrarily, the creation of a finished product using 3D printing is sped up starting with the conception or conceptualization phase to a working prototype and final product in just a matter of a couple of days. Here, it is obvious that the pace is exceptional and much quicker than conventional manufacturing methods. See Kinsley, K., Brooks, G. and Owens, T. (2014) International Legal and Ethical Challenges Related to the Use and

a horizontal cross-section manner in successive layers to create an actual 3-dimensional object based on a digitized blueprint.[27] A 3D printer bears a striking resemblance to inkjet or LaserJet printers—which is a standard 2D printer. However, rather than dispensing ink onto a paper, a 3D printer deposits substances such as metals, plastics, powders, glass and rubber-like substances onto a base, layer after layer, to create an object.[28] Succinctly, 3D printing in layman's terms is the technique of manufacturing a three-dimensional version of a digital file (CAD file) by using some sort of deposited material.[29] This technique differs from typical "subtractive" manufacturing, that involves cutting or machining raw materials to produce objects.[30] While there are many different types of 3D printers on the market nowadays, they all operate in the same way.

To start, a computer-aided design (CAD) file, which serves as a digitized blueprint for the intended product, is required.[31] A CAD file can be created by utilizing 3-D modeling software or by scanning[32] the outline, contours and features of the physical object.[33] The CAD files are prepared in a standardized format that may be altered and read using a variety of software programs. In preparation for printing, software programs are often used to segment the data into a sequence of layers.[34] To manufacture an object, a 3-D printer reads commands from a digital file—usually a CAD file—and executes the file's

Development of 3D Technology in the U.S. and China. *Journal of Knowledge Management Economics and Information Technology*, 4 (1), p. 2.

27 Nielson, H. (2015) Manufacturing Consumer Protection for 3-D Printed Products. *Arizona Law Review*, 57 (2), p. 610.

28 Wilbanks, K. (2013) The Challenges of 3D Printing to the Repair-Reconstruction Doctrine in Patent Law. *George Mason Law Review*, 20 (4), p. 1152.

29 Tran, J.L. (2015) The Law and 3D Printing. *UIC John Marshall Journal of Information Technology & Privacy Law*, 31 (4), p. 508.

30 Couch, J. (2016) Additively Manufacturing a Better Life: How 3D Printing Can Change the World Without Changing the Law. *Gonzaga Law Review*, 51 (3), pp. 519-520.

31 The data which the 3D printer requires to make the final product is included in an electronic file called a computer-aided design ("CAD") file, which guides the 3D printing process. See Sharpe, M. (2019) Products Liability in the Digital Age: Liability of Commercial Sellers of Cad Files for Injuries Committed With a 3D-Printed Gun. *American University Law Review*, 68 (6), pp. 2301-2302.

32 Activists Nora al-Badri and Jan Nikolai Nelles provide perhaps the greatest illustration of this. They strolled into Berlin's Neues Museum, where they have been scanning a 3,000-year-old bust of Egyptian Queen Nefertiti using mobile scanners concealed underneath their coats and scarves to produce a CAD file. They later utilized the scan to create a 3D-printed replica of the bust, which was gifted to American University in Cairo before making the CAD file available under a Creative Commons license. See Lewis, D. (2016) *Thanks to Sneaky Scanners, Anyone Can 3D Print a Copy of Nefertiti's Bust.* [online] Washington, D.C.: Smithsonian Magazine. Available from: `https://www.smithsonianmag.com/smart-news/thanks-sneaky-scanners-anyone-can-3d-print-copy-nefertitis-bust-180958213/` [Accessed 6 May 2022].

33 Nielson, H. (2015) *op. cit.*, p. 613.

34 Christopher, G. (2015) *op. cit.*, p.19.

computerized pattern.[35] After that, the 3-D printer interprets the CAD file and "prints" the product by releasing a selection of filaments, like plastic, ceramics, metal, or perhaps even food in small amounts onto a flat surface. The 3-D printer creates a product by layering filament horizontally on top of one another until product is completed.[36] Each subsequent layer will vary from the last in proportion to the object being created. [37] The layers are fused altogether and the object is further solidified once they have been set.[38] Despite claims to the contrary, a typical 3D printer cannot build an object with multiple parts—like a firearm. Rather, every component must be printed separately and then assembled afterward.[39]

Although this technology is still very much in infancy, others hope it may usher in a new market revolution in which people regain control of the means of production.[40] Despite all the hype, conventional manufacturing processes still outnumber 3D printing. In general, the size of what can be made with 3D printers is confined by the available motion and consequently the size of the 3D printer. Aside from size limitations, 3D printing is too slow for large-scale manufacturing and too pricey for many everyday users.[41] The everyday and ordinary users would still find using a 3-D printer challenging without training, hence aficionados now lead the sector.[42] Individuals obtain a hefty 3-D printer with the goal of creating intricate objects, however the only thing they manage to create is something simple and inexpensive that takes hours to finish—and would have cost a fraction of the price if bought conventionally. Accordingly, the ordinary user would find it difficult to manufacture anything other than ornamental things since objects take forever to print, use a lot of material, and need sophisticated assembly—which frequently requires non-3-D printed components.[43]

[35] Nielson, H. (2015) *op. cit.*, p. 613.
[36] *Ibid*.
[37] Wilbanks, K. (2013) *op. cit.*, p. 1152.
[38] *Ibid*.
[39] Sharpe, M. (2019) *op. cit.*, p. 2303.
[40] Jensen-Haxel, P. (2015) A New Framework for a Novel Lattice: 3D Printers, DNA Fabricators, and the Perils in Regulating the Raw Materials of the Next Era of Revolution, Renaissance, and Research. *Wake Forest Journal of Law & Policy*, 5 (2), p. 232.
[41] Couch, J. (2016) *op. cit.*, pp. 520-521.
[42] Nielson, H. (2015) *op. cit.*, p. 613.
[43] The few who grasp the technology, on the other hand, may print inventive, and practical things, such as to duplicate replacement parts for damaged appliance components in the household that are difficult to come by or are prohibitively expensive. See *Ibid*.

2.2. POTENTIAL SECURITY IMPLICATIONS WHEN GUNS ARE DEMOCRATIZED IN THE OPEN-SOURCE ERA: COMPUTER-AIDED DESTRUCTION AND THE UNTRACEABLE GUN CRISIS

Although 3D printing technology is innovative, it cannot be deemed completely novel in the legal sector.[44] It simply expands the range of opportunities and allows the creation of almost any shape possible. While the technology within that domain did not offer completely new stuff, the legal perspective is finding it very difficult to cope, rarely finding appropriate legal analogies.[45] Furthermore, regardless of the fact that we have been discussing this subject matter for several decades, there is a perpetual lack of decent literature on the subject.[46] Even though legal concepts extend to 3D printing in about the same way they do to other innovations, 3D printing seems to have a distinctive ability to disrupt the legal status quo.[47] The majority of the legal disruptions caused by 3D printing will most likely be inadvertent. People who 3D print objects may be unaware of their legal rights and duties. However, 3D printing without oversight may become so prevalent—and reproducing items with 3D printers may potentially become so ubiquitous.[48]

The possibility to construct difficult-to-detect, untraceable firearms is the biggest issue for criminal justice when it comes to 3D printing.[49] Since the 3D printing community is based on free open-source precepts, people may browse various file hosting websites to get CAD files. Each individual files on the open-source archives, on the other hand, are a major source of concern since they may be downloaded and modified by anybody.[50] This notion

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[44] For a brief overview of some relevant papers, as well as a discussion of the history of regulation and proposed solution, check e.g. Tran, J.L. (2015) *op. cit.*, p. 510.

[45] Loutocký, P. (2019) 3D Printing and Beyond: Intellectual Property and Regulation. Mendis, D.; Lemley, M.; Rimmer, M. (Eds.). *Masaryk University Journal of Law and Technology*, 13 (1), pp. 123-124.

[46] Yanisky-Ravid and Kwan suggest that the judicial system was and continues to be caught off guard by technological developments. This does not, in their perspective, imply that 3D printing should introduce novel notions; nonetheless, some legal frameworks must adapt to the changing environments. See Yanisky-Ravid, S. and Kwan, K. S. (2017) 3D Printing the Road Ahead: The Digitization of Products When Public Safety Meets Intellectual Property Rights—A New Model. *Cardozo Law Review*, 38 (3), p. 921.

[47] Actual models, prototypes, templates, machining components, and production parts may all be created with 3-D printing. It is used by design and production companies for consumers, industry, healthcare, and military product parts. All of these are achieved by democratizing and dismantling the existing supply chain network. See de Jong, J.P.J. and de Bruijn, E. (2013) Innovation Lessons From 3-D Printing. *MIT Sloan Management Review*, 54 (2), p. 44.

[48] Yanisky-Ravid, S. and Kwan, K. S. (2017) *op. cit.*, p. 927.

[49] Beyer, K. E (2014) Busting the Ghost Guns: A Technical, Statutory, and Practical Approach to the 3-D Printed Weapon Problem. *Kentucky Law Journal*, 103 (3), p. 446.

[50] An open-source is like a peer-to-peer file sharing platform that allows people to download and upload digital files to a social platform for other users to access and modify. Computer

spread swiftly in the fast-changing world of 3D printing, enabling people to improve the relevant technology at a faster pace.[51] Irrespective of their intentions, users can obtain and utilize CAD files and blueprints for firearms and explosive components. An innocuous object might be altered to serve nefarious purposes. The best thing is that downloading and editing these files is now mostly unrestricted thanks to "free" nature of open-source. The proliferation of "ghost guns"—firearms that are functionally undetectable, untraceable and frequently missing a serial number—threatens to jeopardize gun control and tracking attempts.[52] In 2013, two Daily Mail journalists used a £1,700 3D printer to build a plastic firearm and managed to transport it onboard a Paris-bound Eurostar train service from London at St. Pancras International Station. Despite its plastic construction, the firearm was capable of shooting a lethal 0.38-calibre projectile.[53] In July 2013, Israeli journalists obtained the CAD files for semiautomatic 3D-printed firearms and smuggled them to Prime Minister Benjamin Netanyahu's speech at the Knesset (Israeli Parliament). The metal firing pin was left inside the firearm, and it missed detection by security sensors. In fact, the journalists were able to get past Knesset security twice.[54] This has proven that security checks with metal detectors will be ineffective if potential criminals were to manufacture plastic weapons and smuggle them into secure public areas like airports or government buildings.[55] This understandably caused instant alarm on a global scale, with realistic concerns regarding the ease with which this new sort of weaponry may be easily concealed to facilitate an assassination

programmers are thought to have started the open-source trend by exchanging free knowledge with other computer users. These programmers were encouraged to provide this "free" knowledge alongside vast communities of other programmers, allowing many individuals to edit, enhance, and recreate various variants from the same source software. The word "free" relates not just to zero-cost transactions, but mostly to programmers' opportunity to modify their own programs. See Staed, K.C. (2017) Open Source Download Mishaps and Product Liability: Who Is to Blame and What Are the Remedies? *Saint Louis University Public Law Review*, 36 (1), p. 184.

[51] Lara, S.S. (2019) The iTunes of Downloadable Guns: Firearms as a First Amendment Right. *Catholic University Journal of Law and Technology*, 28 (1), p. 85.

[52] Eichner, A.W. (2020) Crime in the Age of Printable Guns: Methodologies and Obstacles to Prosecuting Federal Offenses Involving 3D-Printed Firearms. *Vermont Law Review*, 45 (2), p. 216.

[53] Murphy, S. (2013) *How Mail On Sunday "Printed" First Plastic Gun in UK Using a 3D Printer-and Then Took It on Board Eurostar without Being Stopped in Security Scandal.* [online] London: Dailymail. Available from: `https://www.dailymail.co.uk/news/article-2323158/How-Mail-On-Sunday-printed-plastic-gun-UK--took-board-Eurostar-stopped-security-scandal.html` [Accessed 10 May 2022].

[54] Captain, S. (2013) *Journalists Smuggle 3-D Printed Gun into Israeli Parliament.* [online] New York: NBC News. Available from: `https://www.nbcnews.com/technolog/journalists-smuggle-3-d-printed-gun-israeli-parliament-6c10570532` [Accessed 10 May 2022].

[55] Beyer, K.E. (2014) *op. cit.*, p. 446.

attempt or airplane hijacking.[56] The components for ghost guns can be acquired or constructed without going through a background check, making them appealing to restricted users and those who would otherwise fail these checks.[57] There seems to be a good chance that ghost guns will be employed in the future to support illegal acts. Lawmakers and academics fear that as 3D-printing technology progresses, the size and shape of printed guns will render detection unfeasible.[58] Furthermore, during times of emergency, the circulation of ghost guns is anticipated to escalate. Since the widespread of COVID-19, internet sales of untraceable and undetectable firearm parts and 3D printers have surged, according to the Giffords Law Center.[59]

The National Ballistic Intelligence Service (NABIS) of the United Kingdom stated that the 3D-printed firearm was indeed a workable lethal weapon, but only effective for three to four discharges (presuming one could find appropriate ammunition), as the polymer parts started to crack and distort with repetitive discharges, causing the "firearm" to blow up in the holder's hand.[60] However, now, the technology of 3D-printed guns has progressed. The capacity to manufacture polymer bullets compatible with 3D plastic firearms, for example, has increased the desire to oversee 3D printing of firearms.[61] Furthermore, a blueprint for a multi-use 3D-printed Glock is now openly available for download from the Internet.[62]

While illegal weapons are widely available, obtaining one requires contacting a third party. Manufacturing a 3D gun, on the other hand, may be done in full anonymity and secrecy. Furthermore, the firearm can be simply destroyed by remelting the plastic, leaving no sign of its existence. While authorities can track down firearms and, relying on projectile identification, perhaps correlate a firearm to a specific projectile and hence a crime scene, this opportunity is not available in the case of 3D gun-related crimes. When a 3D plastic firearm is destroyed, investigators could only look for 3D printers. It would be difficult to connect a suspect to a crime through firearm use

[56] Lewis, A. (2014) *op. cit.*, p. 309.
[57] Talbot, T. and Skaggs, A. (2020) Regulating 3D-Printed Guns Post-Heller: Why Two Steps are Better than One. *Journal of Law, Medicine and Ethics*, 48 (4), p. 99.
[58] Talbot, T. and Skaggs, A. (2020) *op. cit.*, p. 100.
[59] Pucino, D. (2020) *Ghost Guns: How Untraceable Firearms Threaten Public Safety*. [online] San Francisco, CA: Giffords Law Center. Available from: `https://giffords.org/lawcenter/report/ghost-guns-how-untraceable-firearms-threaten-public-safety/` [Accessed 12 June 2022].
[60] Daly, A. et al. (2021) *op. cit.*, p. 41.
[61] Leon, K.N. (2019) Beyond the Single-Use Plastic Gun: The Need to Make 3D-Printed Gun Laws Shatterproof. *Houston Law Review*, 57 (2), pp. 462-463.
[62] Hanrahan, J. (2019) *3D-Printed Guns Are Back, and This Time They Are Unstoppable*. [online] San Francisco, CA: WIRED. Available from: `https://www.wired.co.uk/article/3d-printed-guns-blueprints` [Accessed 6 May 2022].

and ownership if the perpetrator also destroyed any cache, buffer files on the printer and computer, and wiped all of his online presence during data download.[63]

From the aforementioned, the present regulations are inadequate to clearly control 3D-printed firearms due to ambiguities and lack of enforceability.[64] Simply requiring licensing and transfer registration of 3D-printed firearms does not address enforceability issues. Simply said, if 3D-printed firearms are to be distributed illicitly, certain gunsmiths and gun aficionados will just refuse to comply.[65] A complete ban on 3D-printed firearms is impractical, and even if it were to happen, such restrictions and rules would be hard to execute.[66] In addition, efforts to regulate online file sharing may also be futile.[67]

2.3. GUNSMITHING OPERATIONAL FIREARM FROM THE COMFORT OF YOUR HOME: HOW TECHNOLOGY DISRUPTS THE ARCHAIC LAW ENFORCEMENT FOCUSING ON TRADITIONAL SUPPLY CHAIN

Thus far, our laws have gradually evolved to address the issues that 3D printers provide, but the advancement of technology continues to surpass that of the law. The rise of 3D printing has implications–at least technically–for a variety of archaic legal frameworks that are affected by its operation and use. The regulation of guns is one of the most notable of these areas of legislation, owing to the manufacturing of firearm components created through the 3D printing technology.[68] Other regulations that pertain to 3D printing's uses and applications include intellectual property, product safety, medicinal regulation, and data protection. With the growing popularity of 3D printing among consumers and businesses, it is conceivable that new legal frameworks will be exposed to the innovation.[69] These regulations may appear to be rather distinguishable, having little in common other than their applicability to 3D printing. They do, nonetheless, embrace two aspects in this interaction with 3D printing: the structure of these

[63] Walther, G. (2015) Printing Insecurity? The Security Implications of 3D-Printing of Weapons. *Science and Engineering Ethics*, 21 (6), p. 1441.

[64] Leon, K.N. (2019) *op. cit.*, p. 446.

[65] Jacobs, J.B. and Haberman, A. (2017) *op. cit.*, p. 146.

[66] Osborn, L.S. (2013) Regulating Three-Dimensional Printing: The Converging Worlds of Bits and Atoms. *San Diego Law Review*, 51 (2), p. 579.

[67] Langvardt, K. (2016) The Doctrinal Toll of Information as Speech. *Loyola University Chicago Law Journal*, 47 (3), p. 794.

[68] Daly, A. (2016a) Don't Believe the Hype? Recent 3D Printing Developments for Law and Society. In: Dinusha Mendis, Mark Lemley and Matthew Rimmer (eds.) *3D Printing and Beyond*. Cheltenham: Edward Elgar Publishing, p. 350.

[69] *Ibid.*

legislation and their enforcement. Both of these challenges are fueled by 3D printing's democratization of manufacturing and the ability for people to make goods in their homes and workplaces, bypassing existing gatekeepers and control nodes.[70]

In contrast to the earlier kinds of centralized manufacturing in the Fordist period, 3D printing is a modern technology that is "democratizing" production.[71] Current gun control regulations were created for a Fordist period of mass production,[72] in which centralized companies produce goods that are subsequently sold in stores and purchased in their entirety by customers. Most of these goods were simply too complicated for the common person to create himself, and/or the expense of manufacturing machines was far too costly for these people. Law enforcement in the Fordist mindset is based on the idea that manufacturing takes place through centralized institutions and that goods are supplied through well-defined distribution networks, ending in a retail outlet where the customer makes the final sale. As a result, the law may be enforced at multiple locations throughout the distribution network against these identified parties.

This scheme is severely disrupted by consumer fabrication of goods via 3D printing, when these supply chains, with their control nodes, are bypassed.[73] The gap between post-Fordist decentralized manufacturing and current legal frameworks is highlighted by 3D printing. In general, current legal frameworks are based on the assumptions of centralized manufacturing and distribution of manufactured goods via a traceable distribution network to a passive end-consumer. In this case, law and its enforcement frequently lag behind the emerging technology.[74] However, bear in mind that although the "decentralization and democratization" which 3D printing (conceivably) involves is a departure from the status quo, there was

[70] Daly, A. (2016a) *op. cit.*, pp. 350-351.
[71] Daly, A. et al. (2021) *op. cit.*, p. 39.
[72] Fordism is a word coined to characterize the mass-production strategy spearheaded by the Ford Motor Company in the early twentieth century. In 1922, Henry Ford claimed that mass production had become the "new Messiah" as he marveled at his company's successful Highland Park facility. Although Henry Ford is not given credit with inventing the notion of mass manufacturing, he is recognized with revolutionizing the industrialized period by fragmenting operations and standardizing parts, allowing for the assembly line and mass manufacturing. See Richardson, M. (2016) Pre-Hacked: Open Design and the Democratisation of Product Development. *New Media and Society*, 18 (4), p. 657.
[73] Daly, A. (2016a) *op. cit.*, p. 351.
[74] Daly, A. et al. (2021) *op. cit.*, p. 40.

also a "reintermediation" trend including actors related to the process, like 3D printing filesharing providers.[75]

Another spectrum of law-disrupting 3D printing that is impacting the archaic law enforcement mechanisms in its sense that tends to rely heavily on the traditional supply chain can be seen from the intersection between 3D printing innovation and intellectual property protection. The challenges with intellectual property are now influencing the actual world. Although counterfeit products have traditionally been a source of concern, many of them remain dependent on huge production plants—particularly in less developed nations. [76] In theoretical terms, every design might be subject to a specific type of intellectual property protection, making any method of duplication potentially illegal. Since the 3D printing method is digitized in nature, it has become simpler nowadays to "steal" a product's design and subsequently produce it in small quantities. [77] Instead of buying the genuine product, consumers can now digitize genuine products and manufacture copies for themselves. They can subsequently upload the scanned file to the Internet—which means anybody can readily access it and manufacture as many copies of the product as they like. Additionally, regardless of whether individuals are inadvertently violating intellectual property rights, the readily accessible nature of the Internet and advancements in communications technology have made it possible for proprietors to take advantage out of the content for free. [78] To make matters worse, the materials that were downloaded may effortlessly be redesigned and reuploaded to the Internet, which makes intellectual property owners to have an exceptionally tough time tracing the root of the violation and making law enforcement extremely challenging. The simplest kind of intellectual property law infraction occurs when an individual creates, utilizes, distributes, proposes to sell, or exports the protected property without the appropriate permission. Anybody who manufactures a protected product using a 3D printer is immediately breaching the intellectual property rights given that the manufacture was done without permission. The owner

[75] Such actors may include 3D printing or CAD filesharing providers, print-on-demand service providers, and the producers of 3D themselves springing up as possible control nodes. See Daly, A. (2016a) *op. cit.*, p. 350.

[76] Kietzmann, J., Pitt, L. and Berthon, P. (2015) Disruptions, Decisions, and Destinations: Enter the Age of 3-D Printing and Additive Manufacturing. *New Media and Society*, 58 (2), p. 213.

[77] Chan, H.K. et al. (2018) The Impact of 3D Printing Technology on the Supply Chain: Manufacturing and Legal Perspectives. *International Journal of Production Economics*, 205, p. 158.

[78] Assuming it is being used for private or academic purposes, it might be permissible. The digitally produced material could nevertheless be released on the marketplace for monetary benefits. See *Ibid*.

of the intellectual property might theoretically bring a lawsuit against these individuals. But this approach might be pretty unworkable in practice. Firstly, it might be challenging for the owner of the intellectual property to pinpoint these violators due to how dispersed the 3D printers could potentially be. Secondly, irrespective of whether the legitimate owner of the intellectual property names the violators—who are likely to be internationally dispersed—the owner might nonetheless still need to bring individual lawsuits against each violator due to joinder rules[79] or specific jurisdictional requirements. At the end of the day, the owner of the intellectual property would also potentially file a lawsuit against a prospective customer—which is not good for business.[80] Looking at a policy standpoint, lawmakers, and policymakers face challenging difficulties as a result of the widespread expectation that entrepreneurial customers (prosumers) are going to create products of their own. If intellectual property infringements were left unscathed, intellectual property is going to turn less significant, [81] violation will continue to be a serious concern, and commercialization methods are going to shift drastically. Hence, the fight for the protection of traditional intellectual property rights for digital goods is going to become incredibly challenging. Another example would be the concern about standards, i.e., how will society manage them, or alternatively, what are the possible risks that the absence of standardization presents? as well as who checks, supervises, and guarantees the quality of the printed products?[82]

3. SCRUTINIZING THE LAWS OF 3D-PRINTED FIREARMS UNDER TODAY'S OUTLOOK: IS THE GENIE ALREADY OUT OF THE BOTTLE?

Technology helps our lives.[83] Even though 3D printers now has produced a diverse range of products, unforeseeable risks associated with this far-reaching innovation will surely provide issues. A number of these concerns will be complicated by the lack of an adequate legal framework to address them. Moreover, most of these concerns may fall within

[79] For a well-discussed elaboration on the joinder rules, see Taylor, D.O. (2013) Patent Misjoinder. *New York University Law Review*, 88 (2), p. 662.

[80] Holbrook, T.R. and Osborn, L.S. (2015) Digital Patent Infringement in an Era of 3D Printing. *The UC Davis Law Review*, 48 (4), p. 1333.

[81] Jiang, R., Kleer, R. and Piller, F.T. (2017) Predicting the Future of Additive Manufacturing: A Delphi Study on Economic and Societal Implications of 3D Printing for 2030. *Technological Forecasting & Social Change*, 117, p. 91.

[82] Kietzmann, J., Pitt, L. and Berthon, P. (2015) *op. cit.*, p. 213.

[83] Weinberger, V.P., Quiñinao, C. and Marquet, P.A. (2017) Innovation and the Growth of Human Population. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 372 (1735), pp. 1-2.

the scope of current legislation, notably in terms of gun control and information restriction. Technological improvements, on the other hand, will undoubtedly continue to raise new and difficult concerns. [84]

Every innovation brings with it a head-on collision with current legal systems around the world.[85] Instead of astonishment and enthusiasm, our legislative and regulatory reactions to technological innovations typically portray apprehension and irrationality.[86] Many people are fearful of technology. Some people even despise it—thus, the label 'luddite'.[87] People use the availability heuristic to create risk estimates while sifting through unknown or unfamiliar threats.[88] In this scenario, the human mind tends to construct a proxy estimate of the likelihood of an occurrence based on how easily preceding instances can be recalled from stored recollections.[89] The availability heuristics may be a useful tool to predict and traversing the hazards of everyday lives.[90] However, most of those heuristics and prejudices that contribute to systemic technological threat misconception were unconsciously institutionalized in clichés like "better safe than sorry," "the devil you know is better than the angel you don't," and "you can't teach an old dog new tricks."[91] Succinctly, how can we safeguard ourselves against ourselves? One thing is certain. Although the status quo may be pleasant, development is necessary to retain our global leading role and wellbeing.

According to data from the Small Arms Survey (SAS), a non-profit research initiative based at the Graduate Institute of International and Development Studies in Geneva, Switzerland, there is a positive correlation between wealth and firearm ownership. Firearms are more common in higher-income nations. While obtaining a 3D printer is still extremely costly, firearms would most probably be manufactured in wealthy nations, that

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[84] Cosans, J. (2014) Between Firearm Regulation and Information Censorship: Analyzing First Amendment Concerns Facing the World's First 3-D Printed Plastic Gun. *American University Journal of Gender Social Policy and Law*, 22 (4), p. 920.

[85] Ma, V.C.K. (2017) 3D Printing and the Law. *Intersect: The Stanford Journal of Science, Technology, and Society*, 11 (1), p. 1.

[86] Khasawneh, O.Y. (2018) Technophobia: Examining Its Hidden Factors and Defining It. *Technology in Society*, 54 (1), p. 94.

[87] There are countless instances of technology saving and enhancing lives, but there are also numerous cases of human mistrust of technology. Emerging technology is assumed to cause humans to continually and systemically misunderstand the risk it poses to humankind. See Calandrillo, S. and Anderson, N.K. (2022) Terrified by Technology: How Systemic Bias Distorts U.S. Legal and Regulatory Responses to Emerging Technology. *University of Illinois Law Review*, 2022 (2), p. 599.

[88] Khasawneh, O.Y. (2018) *op. cit.*, p. 94.

[89] Tversky, A. and Kahneman, D. (1973) Availability: A Heuristic for Judging Frequency and Probability. *Cognitive Psychology*, 5 (2), p. 208.

[90] *Ibid*.

[91] Calandrillo, S. and Anderson, N.K. (2022) *op. cit.*, p. 662.

already have more firearms than poorer nations. It is far too soon to say where 3D-printed firearms will emerge, but one assumption is that 3D firearms will be created by people who already have access to "regular" firearms and just want one for the curiosity instead of for practical reasons. This curiosity factor could have a serious complication of catching the attention of youngsters who want to manufacture one just to be 'cool.' If they are negligent, this could result in an upsurge of accidental discharges, especially since plastic firearms are far less reliable hence more deadly than regular firearms.[92]

A large portion of today's printing comes under the category of fun or handy trinkets rather than life-changing instruments.[93] The fourth industrial revolution is now underway. Since 3D printing is now at the center of this transformation, it is in a spot where it is being closely scrutinized. People appear to have little difficulty adapting to new ideas, but this is not the case with our legal systems. A fine example of a disruptive upstart is 3D printing. At the very least, 3D printing has the potential to render laws and legal safeguards obsolete. The 3D printing revolution is the intersection of technological possibilities and a passion to make the world a better place. Marvels may emerge from this combination, but notable change will only occur if the legal system permits it. Therefore, instead of being afraid of new technological advancements, why not regulate these innovations with a longer leash. Afterall, the protection and recognition of the law permits greater utilization and better certainty that would be beneficial to everyone.

Parallels, however, can be drawn from Web 2.0's experiences, where users partake in social creation knowingly, without much regard to regulatory framework. However, in this case users might expose themselves to repercussions beyond legal comprehension. In terms of uncertainty, it is best to let the market create (the *laissez-faire* stance).[94] Although it might seem alluring to engage in social creation without giving regulatory frameworks adequate consideration, it is crucial to be cognizant of the possible adverse legal ramifications and to abide by the laws and regulations established by

[92] Walther, G. (2015) *op. cit.*, pp. 1440-1441.

[93] Couch, J. (2016) *op. cit.*, pp. 521-522.

[94] In the example of Chinese peer-to-peer lending industry, the traditionally conservative Chinese monetary authorities, who chose a wait-and-see *(laissez-faire)* approach to promote such technological advances while minimizing onerous oversight, initially embraced and actually encouraged online peer-to-peer lending. Yet, the friendly regulatory approach gave rise to widespread Ponzi schemes or bogus financial innovations, which caused massive financial losses for many investors. To demonstrate a prompt and effective reaction, the Chinese government launched a four-year operation of tough Internet finance regulation (whack-a-mole approach), which has targeted and cracked down all P2P lending platforms in the country. See Xu, D., Taylor, C.J. and Ren, Y. (2022) Wait-and-See or Whack-a-Mole: What Is the Best Way to Regulate Fintech in China? *Asian Journal of Law and Society*, First View, pp. 9-15.

governmental bodies. Some would contend that unnecessarily stringent rules and regulations might impede creative and innovative thinking. For instance, a heavy regulatory load may cause some businesses to be reluctant to put money into new technology or commercial strategies.[95] It is crucial to remember that laws and regulations are set to safeguard both individuals and companies from harm and discourage anti-competitive behavior, despite the devil's advocate's claims to the contrary.

In relation to laws and technology, the interaction between the markets and social norms is frequently complicated and multifaceted. The introduction of cutting-edge technology and the creation of new rules and laws may both be influenced by social conventions. For instance, social standards about privacy and safeguarding data have influenced the creation of privacy safeguards like the General Data Protection Regulation (GDPR) in Europe—hence, when collecting and handling private information, businesses in Europe are required to adhere to stringent privacy rules, as compared to that of the United States that boasts a more liberal stance towards data protection.[96] Social standards may additionally have an impact on how people and businesses behave in the marketplace. For instance, the desire for environmentally friendly products and services has increased as a result of societal standards surrounding environmental responsibility. However, markets may additionally affect the creation of rules and regulations as well as social standards. Market pressures, for instance, can spur research and the creation of novel technology. Market conditions may additionally impact the creation of fresh rules and regulations by influencing political discourse and public sentiment. In a nutshell, there are many different ways that markets and social norms interface with laws and technology. Markets can impact social conventions and the creation of rules and regulations, whereas societal conventions and the acceptance of novel technologies can be influenced by cultural standards.

Predominantly, 3D printers produced the least dangerous of products.[97] Until now, the exorbitant cost of 3D printers and materials still curb its widespread use. Therefore, it is safe to say that the genie is not yet out of the bottle. However, the notable discharge of a 3D-printed firearm, on the other hand, demonstrates the increasing possibilities and hazards of this technological innovation. Given the apparent trend of decreasing

[95] Tu, K.V. and Meredith, M.W. (2015) Rethinking Virtual Currency Regulation in the Bitcoin Age. *Washington Law Review*, 90 (1), p. 307.

[96] Rustad, M.L. and Koenig, T.H. (2019) Towards a Global Data Privacy Standard. *Florida Law Review*, 71 (2), p. 372.

[97] Hearing aids and musical instruments are two examples of 3-D printed objects listed. See Jensen-Haxel, P. (2012) *op. cit.*, p. 450.

technological costs in the long run, it really is important to consider the implications of 3D printing today, before it becomes largely accessible.[98] This new innovation poses a substantial and imminent threat to public safety, indicating a justifiable reason for regulation and the urgent need to address this problem before technology outpaces the law. So, when we regulate, examining these threats and possible strategies to govern this modern-day innovation, while keeping in mind the huge economic and societal benefits is crucial in order to prevent stifling future beneficial advancements.[99]

4. PROPOSING EFFECTIVE REGULATION

4.1. WHY REGULATION?

There are at least four reasons why 3D printing regulation[100] is important to us. Firstly, as the technology progresses, it will undoubtedly have an influence on a broader spectrum of production processes, allowing for increased productivity and economic growth. Many heralded that 3D printing is the nearest approximation we have to a new industrial revolution.[101] Secondly, 3D printing makes for easier material utilization, allowing for enormous invention of objects that are only limited by human creativity. Some of these goods may be dangerous and present hazard for human use. Thirdly, 3D printing shows potential in a range of industries where applications and services were in the early stages of development. This technology has the potential to open doors to a variety of commercial sectors, which might have a significant and cyclical influence on other areas of the economy. Finally, 3D printing has applications in security and military, which may well have inadvertent security and safety ramifications.

As more powerful personal 3D printers become available, and as industrial clients understand they can create parts, components, and other goods in-house, production will become more democratized and less supervised. Many regulations will be jeopardized when anybody can 3D print devices with nearly any capability outside of government supervision. Since manufacturing becomes more democratized, current laws are expected to become more obsolete. Whenever anybody can 3D print products with nearly unlimited functionality, uncontrolled illicit activities

[98] Walther, G. (2015) *op. cit.*, p. 1443.
[99] Cosans, J. (2014) *op. cit.*, pp. 943-944.
[100] n this article, regulation refers to one of the four types of legislative instruments: delegated legislation. The procedure begins with Parliament enacting a broad statute (known as a parent or enabling Act) that delegated law-making authority to a government department or minister. The delegated legislation is referred to as a statutory instrument since it implements (helps to implement) the statute's provisions. See Huxley-Binns, R. and Martin, J. (2014) *Unlocking the English Legal System*. 4th ed. New York: Routledge, p. 12.
[101] Jensen-Haxel, P. (2012) *op. cit.*, p. 448.

will flourish (illicit/illegal activity). Such uncontrollable behavior will become progressively harder to identify (identification). Enforcing the law against such conduct will become more difficult or even impossible (impracticality or impossibility). These regulations may then become more ineffective—they will prevail and be enforced for 3D printing in supervised environments, but they will be mostly meaningless for 3D printing in unsupervised setting.

It is true that the judiciary develops more specific laws.[102] However, legislators are better at organizing bodies of law.[103] Stakeholders may seek for legal and regulatory reform if court action proves difficult.[104] Nevertheless, the concern with 3D-printed firearms is among ambiguity (uncertain) aversion, namely: how many innovations are we ready to endure if there really is a chance that those will be used to commit criminal acts? As a result, considering courts are unsuited to making such decisions,[105] it is ideal for ambiguous technology to be governed and regulated by authorized bodies (the executive and legislative).[106] The absence of guidance from the judiciary also paved the way to regulative commands. Therefore, supervising 3D-printed firearms is left to the legislative and executive branches for the time being.[107] Nonetheless, it is uncertain what kind of a danger or advantage 3D printing presents in our everyday lives. It is also feasible that technical advancements, notably the creation of more sophisticated

[102] Current laws and legal norms may already exist in the case of 3D printers, which can be utilized to handle societal concerns about future technologies. The best approach to understand the laws relating to specialized pursuits is to understand general rules, as Judge Frank H. Easterbrook highlighted in his 1996 essay, Cyberspace and the Law of the Horse. He maintained that the Internet was not exceptionally distinctive or special, necessitating either a reassessment of established legal principles or the creation of an altogether new set of regulations for the Internet. The very same logic may be used to 3D printing. Aside from existing legislation that may apply to new technology, several common law approaches exist to address issues that arise when things go south with emerging technologies. See Thierer, A.D. and Marcus, A. (2016) Guns, Limbs, and Toys: What Future for 3D Printing? *Minnesota Journal of Law, Science & Technology*, 17 (2), p. 827.

[103] Kołacz, M.K., Quintavalla, A. and Yalnazov, O. (2019) Who Should Regulate Disruptive Technology? *European Journal of Risk Regulation*, 10 (1), p. 13.

[104] Some scholars have even heralded to legal and regulatory reform as *sui generis* means of protection for disruptive technology to boost its acceptance. See Craig, S. (2017) Protection for Printing: An Analysis of Copyright Protection for 3D Printing. *University of Illinois Law Review*, 2017 (1), pp. 338-339.

[105] The courts are the best overseer of risky technology. This is because the best cost-effective technique of funnelling relevant data from litigants to legislators is through the court. In the case of ambiguous/uncertain technology, regulatory decisions must be made based on subjective preferences rather than factual (objective) facts. The legislature is preferable than the judiciary because it is created to aggregate societal values. Moreover, if sophisticated governance is placed in hands of the court, it typically becomes hierarchically unclear. See Kołacz, M.K., Quintavalla, A. and Yalnazov, O. (2019) *op. cit*., p. 21.

[106] Kołacz, M.K., Quintavalla, A. and Yalnazov, O. (2019) *op. cit*., p. 13.

[107] Leon, K.N. (2019) *op. cit*., p. 463.

and user-friendly 3D printers, will expand criminal opportunities.[108] The complicated combination of 3D printing, existing legislation, and current practice merits a one-of-a-kind regulatory response. Whatever happens in reality with 3D printing will be paramount in addressing the legal concerns around the technology. [109] Legislative action, on the other hand, is slow, and campaigning for reform in the legislature is complicated.[110] Furthermore, there is a risk that using stringent legislative tools may unintentionally stifle innovation.[111] As a result, regulating the fast-moving technological innovation by the executive branch is still preferable. Regulation is largely acknowledged as "a sort of governance instrument, affecting the manner in which stakeholders involved in the innovation process conceive, execute, and use technologies." Regulation serves as the foundation of governance for technological innovation movements in the emerging technologies sector, which has an element of uncertainty amongst different players. In innovation process, regulation thereby integrates the activity of the stakeholders and acts as "guidance" towards collective good.[112]

Looking at the market aspects of 3D printing regulation, it is indeed interesting to observe the response from various stakeholders in the arms markets to the broader utilization and regulation of 3D printing technology. Again, a parallel can be drawn by looking at the music industry in 1999 striking down advancing technologies and new trends of social creations to maintain their markets and supply chain, i.e., album sales (see, case of Napster).[113] However, considering that the market dynamics are fluid

[108] It is really easy to see how increasingly powerful machines becoming more widely available at a cheaper rate will result in more people 3D printing at home, and thus the potential danger to effective law enforcement.

[109] Daly, A. (2016b) *Socio-Legal Aspects of the 3D Printing Revolution*. London: Palgrave Macmillan, p. 97.

[110] Craig, S. (2017) *op. cit.*, p. 339.

[111] *Ibid*.

[112] Dagne, T.W. (2020) Governance of 3-D Printing Applications in Health: Between Regulated and Unregulated Innovation. *The Columbia Science and Technology Law Review*, 21 (2), p. 304-305.

[113] Napster originated as a peer-to-peer file-sharing platform which gave users the freedom to freely exchange audio recordings with one another. The Recording Industry Association of America (RIAA) won its case against Napster for violating intellectual property rights. This case was monumental given that it constitutes one of the earliest instances of the music industry tackling the problem of online copyright violations. The RIAA claimed that Napster was involved in or encouraging users to duplicate material that was protected by copyrights without compensation or the explicit permission of the intellectual property holders. Napster, according to the RIAA, would seriously hurt the music industry's sales. The Napster case set a legal precedent for file-sharing platforms and copyright law. The ruling was significant because it established that Napster could be held liable for contributory and vicarious infringement of copyright. A protracted legal dispute between Napster and the RIAA along with numerous musicians resulted in a brief shutdown of the service in 2001. Napster suspended operations in 2001 and filed for bankruptcy in June 2002 shortly after

in the sense that it is not always necessarily a binary notion towards polarization—like "whoever is not with us is against us,"[114] thus predicting the plausible reactions of the stakeholders may not be an easy task. Following on the Napster model, it is logical to think that the arms industry would attempt to intervene with the regulatory processes and imprint its agenda to maintain the existing supply chains (e.g., argue for the ban of 3D-printed firearms). Yet, arguing for the ban of 3D-printed firearms could outright spark momentum towards clawing back on the conventional firearms as well.

Furthermore, only time can tell how disruptive 3D printing is from a legal standpoint. Given the current political economics of 3D printing's emergence as a consumer-accessible technology, and also the participation of the nation-state, major companies, and people in its application,[115] it appears that it is never too early or too late to begin devising indirect regulatory action against 3D-printed firearms today. Admittedly, there would still be some lawlessness all around the fringes of regulation, with desperate users capable to secretly build their own 3D printers, and get 3D printing files and materials for other channels if they know where to seek. The lingering "ungovernable" (or hard to regulate) portions of the Internet at the fringes, as well as other "under the radar" activity in the darknet, reflect this. As a result, the regulations governing 3D printing *vis-à-vis* legal enforcement will not be able to be effectively applied.[116] As previously stated, this was the case before all these technical advancements. In a progressively decentralized society or market, it may be more difficult to enforce laws. But, with decentralization, also comes transparency. Therefore, regulation is still the most viable option to regulate disruptive technological innovations. What is left is just the matter of how and when to regulate.

4.2. THE CASE AGAINST REGULATING 3D-PRINTED FIREARMS

Prominent opponents of regulating 3D printing technology argued that market inefficiencies in the technology sector could not be pinpointed and that the sector itself lacked identifiable traits that would justify government intervention. Advising the government to concentrate on programs that will enhance economic growth rather than stifling innovation.[117] Passing the rules to regulate technological advancement poses a significant danger

losing a string of lawsuits. In the succeeding decades, the corporation saw a number of ownership changes.

[114] According to the Synoptic Gospels, Jesus said, "Whoever is not with Me is against Me, and whoever does not gather with Me scatters." (See Matthew 12:30; Luke 9:50; and Mark 9:40).

[115] Daly, A. (2016b) *op. cit.*, p. 99.

[116] Daly, A. (2016b) *op. cit.*, pp. 99-100.

[117] Traficonte, D. (2020) Collaboration in the Making: Innovation and the State in Advanced Manufacturing. *The Columbia Science and Technology Law Review*, 21 (2), p. 339.

in a system designed to stimulate innovation and protect the public.[118] Any limitation on technical innovation and development will hinder the technology's utilization and potential to inspire others.[119] Any regulation must weigh the advantages to innovation and people's safety against the threat of stifling a technology that has considerably more benefits than potential downsides.[120]

Some claim that the fear of 3D-printed firearms is overblown, unfounded, and serves as a diversion from the many advantages 3D printers provide to our society. Early in May of 2013, the warning sirens started to ring endlessly. That month, numerous articles appeared, warning people about the grim future we all faced as a result of the oncoming avalanche of 3D-printed firearms.[121] Other periodicals participated in the panic, building the hysteria. Most of these narratives have the same overarching theme: be terrified, be extremely fearful. Soon, the streets will be swarming with crooks equipped with many 3D-printed firearms that they can simply make at home. These 3D-printed gun-toting criminals would be capable of committing horrendous crimes that would be impossible to track.[122] For the following few years, the avalanche of articles died down. The news of 3D-printed firearms has started to trickle in since then. Yet, several years later, the actual reality is a far cry from what has been predicted. After nearly nine years, there has so far been little increase in 3D-printed gun-related incidents.

As a result, the concern of what transpired must be addressed—why did the worries of a slew of 3D-printed gun-wielding criminals materialize? The simplest answer to that complex question is that the alarms went off just a bit too soon. The fundamentals of making 3D-printed firearms have always been difficult to get right in terms of cost and functionality. The majority of the plastic 3D-printed firearms just were not sturdy enough, and they shattered when discharged.[123] Most 3D-printed firearm could only discharge one

[118] As a result, when it comes to the issue of regulation on emerging technology innovation, regulation is frequently seen as a determinant that escalates the time and expense of research and commercialization, hence reducing the motivation to innovate. See Stern, A.D. (2017) Innovation Under Regulatory Uncertainty: Evidence from Medical Technology. *Journal of Public Economics*, 145 (1), p. 181.

[119] Couch, J. (2016) *op. cit.*, p. 535.

[120] *Ibid*.

[121] Hassan, K. (2020) op. cit., p. 45.

[122] *Ibid*.

[123] Forensic scientist Olivier Delémont thinks that anybody who does have access to a traditional firearm would not be tempted by such a firearm, stating that "It would be more dangerous to be the shooter than to be the target." See Wilke, C. (2019) *3-D Printed "Ghost Guns" Pose New Challenges for Crime-Scene Investigators.* [online] Washington, D.C.: Science News. Available from: `https://www.sciencenews.org/article/3d-printed-guns-plastic-ballistics-crime` [Accessed 29 April 2022].

round before the barrel will need to be replaced. A blade, on the other hand, may be more deadly because it can be used multiple times. For instance, if a terrorist was forced to discharge the firearm during an airline hijacking, his leverage over the other passengers would be lost.[124] Optionally, 3D printing a metal firearm would produce a more potent weapon than a 3D-printed plastic firearm. Unfortunately, the costs would be exorbitant because an industrial-grade printer is required to do such task.

Furthermore, in Adam Thierer's book entitled: Permissionless Innovation: The Continuing Case for Comprehensive Technological Freedom, he defines permissionless innovation as "refer[ring] to the notion that experimentation with new technologies and business models should generally be permitted by default."[125] Will innovators be compelled to gain validation from government officials before developing and deploying new devices and services, or should they be liberated to innovate with new technology and business models? If the former, "the precautionary principle," prevails over the latter, "permissionless innovation," Adam Thierer claims, the outcome will be fewer services, lower-quality products, increased cost, sluggish economic growth, and a generally lower living standard.[126] The key idea is that governments should "allow" unfettered experimentation and risk-taking with new technology until and unless there is a strong reason to do otherwise. That is, policymakers must only act if there is a genuine harm or issue, or if it can be demonstrated that unfettered innovation will cause substantial damage to society.[127] Governments must be able to demonstrate that the advantages of intervention outweigh the downsides of continuing to experiment. Permissionless invention should be given the "benefit of the doubt" unless they can prove otherwise. The position's principal justification is based on economics. This notion suggests that defaulting to permissionless innovation will "advance long-term economic progress."[128]

The aforementioned argument however, was not meant to be the "overarching" and "one-size-fits-all" panacea, simply because it fails to

[124] Walther, G. (2015) *op. cit.*, p. 1441.

[125] Thierer, A.D. (2014) *Permissionless Innovation: The Continuing Case for Comprehensive Technological Freedom.* 1st ed. Arlington, Virginia: Mercatus Center at George Mason University, p. 1.

[126] Whenever "precautionary principle" rationale is used to mould government policy, it poses a major threat to technological innovation, socioeconomic entrepreneurialism, and long-term development. "Permissionless innovation," on the other hand, has recently driven the boom of the Internet along with much of the current tech sector, and it is poised to drive the next industrial revolution—if we allow it. See Thierer, A.D. (2014) *op. cit.*, p. 2.

[127] Pantella IV, J.J. (2017) Ready, Print, Fire! Regulating the 3D-Printing Revolution. *Journal of Law, Technology & the Internet*, 8 (1), pp. 3-4.

[128] Thierer, A.D. (2014) *op. cit.*, p. 128-129.

take into account the Coasean approach.[129] Coase's paper criticized the conventional notion of externalities. In his paper, it was claimed that in an environment without transaction costs, bargaining over contracts would remove externalities and would force the market to an effective outcome without the need for interference from the government. Such involvement is only necessary when transaction costs are not zero.[130] In that case, regulation may accomplish a number of objectives—and from a Coasean standpoint, laws and regulations are put in place to lower transaction costs and improve market efficiency.[131] The online-based 3D printing platform paradigm offers a previously unthinkable prospect of moving closer to Coase's portrayed equilibrium. At the same time, issues surrounding platform regulation remain complicated and will primarily hinge on the socioeconomic policies and objectives at hand—like those of Thierer's. The 3D printing industry may be suitable for private ordering in certain contexts, for instance developing safety feature by means of firmware programmed to identify unprintable objects, as technical and trade-related mechanisms grow in breadth and depth—in this case, let the market innovate and private ordering structures the markets in unregulated industries. However, the outcomes of private ordering might not be optimal. Therefore, for other contexts, like guaranteeing basic public safety requirements by means of oversight, deviants may disrupt and circumvent the safety features of private ordering. Thus, regulators must intervene to offer an auxiliary framework that adds another layer of protective mechanisms.

4.3. PROPOSED REGULATORY RESPONSE: A THREE-PRONGED APPROACH

3D printing is a two-edged sword:[132] although it has numerous prospective benefits to the public, it also has certain potentially serious repercussions

[129] In law and economy, the Coase theory is a property rights economic and legal theory put out by economist Ronald H. Coase. According to the Coase Theorem, when parties have competing property rights, negotiations between them will result in an effective outcome regardless of who ends up receiving the rights to the property in the end, provided that the transaction costs resulting from the negotiations are negligible. See Coase, R.H. (2013) The Problem of Social Cost. *The Journal of Law & Economics*, 56 (4), p. 838.

[130] Elkin-Koren, N. and Salzberger, E.M. (1999) Law and Economics in Cyberspace. *International Review of Law and Economics*, 19 (4), p. 567.

[131] Dempsey, P.S. (1989) Market Failure and Regulatory Failure as Catalysts for Political Change: The Choice Between Imperfect Regulation and Imperfect Competition. *Washington and Lee Law Review*, 46 (1), p. 20.

[132] "When you have a general-purpose technology, it will be [utilized] for things you [do not] want people to use it for," Michael Weinberg as remarked by Anne Lewis in his commentary. See Lewis, A. (2014) *op. cit.*, p. 310.

which should not be overlooked.[133] It would be impossible to oversee once household and industrial 3D printers are capable of large-scale manufacturing. Instead of dismissing the reality that the 3D printing revolution ushers in new eras of growth, prosperity, and alternatives, we must contend not only with the ambiguity that comes with the 3D printing period, but also with the grave risks, hazards, perils, and dangers that follow it. Regulators must be cognizant of the whole range of risks and problems in order to prepare society before catastrophic events emerge.[134]

Beyond the realm of intellectual property, 3D printing has become a hot topic in the criminal justice system. Currently, 3D printers have demonstrated that they are capable of creating real, working firearms— hence compromising current gun restrictions.[135] This has prompted authorities throughout the world to assess the risks of 3D printing technology and, in some cases, introduce laws prohibiting such usage.[136] Although these actions are admirable, they are still in their early phases, and they only attempt to utilize retaliatory sanctions to prohibit particular applications of the technology—they do little to eliminate its unlawful usage in the first place.[137]

A movement for regulatory change in the context of 3D printers and their capabilities has been proposed by some scholars. Obviously, each scholarship contributes a unique viewpoint to the discussion.[138] Most scholars write in the hopes of informing or alerting 3D printer aficionados for the need to obtain license to manufacture, or to be aware of regulations

[133] Gilpin, L. (2014) *The Dark Side of 3D Printing: 10 Things to Watch.* [online] San Francisco, CA: TechRepublic. Available from: `https://www.techrepublic.com/article/the-dark-side-of-3d-printing-10-things-to-watch/` [Accessed 8 May 2022].

[134] Yanisky-Ravid, S. and Kwan, K. S. (2017) *op. cit.*, p. 927.

[135] *Ibid*.

[136] The City Council of Philadelphia declared in November 2013, no individual shall utilize a 3D printer to build any weapon, or any portion or part thereof, unless such individual possesses a permit to fabricate weapons under Federal law, 18 U.S.C. § 923(a). See Lewis, A. (2014) *op. cit.*, p. 308; New South Wales, an Australian state, has outlawed the ownership of files for 3D printing guns. See Butler, J. (2015) *NSW Tightens 3D Printed Gun Legislation As Expert Warns They're Getting Cheaper, More Effective.* [online] New York City: HuffPost. Available from: `https://www.huffpost.com/archive/au/entry/3d-printed-gun-laws-nsw_n_8595818` [Accessed 8 May 2022]; The United Kingdom's Firearms Licensing Law was modified to include a paragraph specifically prohibiting 3D-printed firearms. The prohibitions in section 57(1) of the Firearms Act 1968 cover the manufacturing, procurement, transfer, and ownership of 3D-printed firearms, ammunition, or spare parts in the United Kingdom. See Home Office (2021) *Guide on Firearms Licensing Law (Accessible Version).* [online] London: Gov.UK. Available from: `https://www.gov.uk/government/publications/firearms-law-guidance-to-the-police-2012/guide-on-firearms-licensing-law-accessible-version#chapter-23-proof-of-firearms` [Accessed 8 May 2022].

[137] Yanisky-Ravid, S. and Kwan, K.S. (2017) *op. cit.*, pp. 930-931.

[138] Kinsley, K., Brooks, G. and Owens, T. (2014) *op. cit.*, p. 13.

that require them to declare the firearms printed.[139] Another viewpoint is that 3D printer laws ought not be enacted too soon.[140] Nevertheless, the aforementioned regulatory measures fail to take into account the concerns of personal liberty, the technological development, and the interest of public safety as a whole. Prevailing scholarships also proposed ambitious regulation to require licensing for 3D printers and 3D-printed firearms. But this initiative lacks enforceability.[141] Simply requiring licensing and transfer registration of 3D-printed firearms does not address the issues of illicit 3D-printed firearms. 3D-printed gun-toting criminals will just refuse to comply.[142] Another initiative is to impose complete ban on 3D-printed firearms, which would be highly impractical—and even if it were to happen, such restrictions and rules would be hard to enforce.[143] In addition, efforts to regulate online file sharing may also be futile.[144] Another strategy is to make the processes of manufacturing a firearm and owning it more complex and expensive, thus delaying the technology's adoption.[145] However, it would be too desperate and counterproductive to the purpose of developing technological development and reaping the advantages it delivers to society. Efforts have also been made to enhance the capacity of 3D printer software to reject producing components that are analogous to firearms. However, improving the software's security may be meaningless since the software itself might be jailbroken.[146]

Ultimately, the suggested regulation appears to address several major concerns: gun manufacturing and possession by inappropriate individuals such as felons or minors, the fabrication of ghost guns, and ghost guns still passing through security screening. Bans, including on 3D-printed plastic firearms, does not entirely answer any of these problems since it does not prevent the manufacture of the firearms; rather, it penalizes those who manufacture illegal firearms. Likewise, the serial numbers with registration

[139] Lewis, A. (2014) *op. cit.*, p. 307.
[140] Finocchiaro thinks that given the small possibility for 3-D printing technology to inflict economic harm and the fact that neither politicians nor the courts can predict its future potential, it would be smart to minimize legislative incursions into the industry. See Finocchiaro, C. (2013) Personal Factory or Catalyst for Piracy? The Hype, Hysteria, and Hard Realities of Consumer 3-D Printing. *Cardozo Arts & Entertainment Law Journal*, 31 (2), pp. 507-508.
[141] Leon, K.N. (2019) *op. cit.*, p. 446.
[142] Jacobs, J.B. and Haberman, A. (2017) *op. cit.*, p. 146.
[143] Osborn, L.S. (2013) *op. cit.*, p. 579.
[144] Langvardt, K. (2016) *op. cit.*, p. 794.
[145] Leon, K.N. (2019) *op. cit.*, p. 464.
[146] Leon, K.N. (2019) *op. cit.*, p. 465.

technique tries to solve the broader issues,[147] but it mainly fails owing to its dependence on human compliance with merely the threat of modest penalty.[148] While some kinds of 3D-printed items are supervised, there is presently no overall government regulatory scheme in place for 3D printers. While establishing the foundation for such a mechanism would be tricky at first, diverting the regulatory attention away from 3D-printed weapons and toward the 3D-printers themselves might prove to be a more successful way of adopting and executing firearms-tracing rules.[149] In addition, a meaningful approach will resolve these problems at their source and therefore will necessitate a multifaceted approach.

Additionally, since there is currently no empirical evidence as to how effective (or not) these various measures criminalizing and seeking to constrain the production and distribution of 3D-printed firearms, and considering the paucity of reliable and systematic evidence on the incidence of 3D-printed firearms (or firearm components) being found by police,[150] there really is no guarantee that the existing approaches proposed by the prevailing scholarships may be effective in regulating and supervising 3D-printed firearms. The open-source era provides myriad of unique obstacles to law enforcement, but this issue does not have to be unsolvable.[151]

The previous sections have brought up to surface that in this open-source era, ghost guns do possess potential security implications that necessitate governmental intervention. In relation to laws over technological innovations, this complexity is oftentimes exacerbated by the dynamics of the markets and societal standards which tends to be complex and multifaceted. There are cases against regulating technological innovation, but there are some merits for regulatory actions as an effective tool for managing technological innovations. To come up with regulatory responses

[147] 3D printers are designed to be identical, but little differences in their hardware result in distinct, immutable features. This feature might be used in place of a serial number. The researchers used this information to design a test in which they manufactured "five door keys apiece" using 14 different widely accessible 3D printers. They were able to identify the key to its printer 99.8% of the time using the algorithm and cross-referencing data about the keys. The test was replicated ten months later to see if the ability to match things to their original 3D-printer was impaired by increased usage of the printers, but the findings remained the same. This study implies that identifying the origin of a 3D-printed weapon without using a serial number system is a viable possibility. A regulatory framework focusing on 3D printers may be easier to implement than one attempting to govern the guns they create. See Eichner, A.W. (2020) *op.cit.*, pp. 223-224.

[148] Beyer, K.E. (2014) *op. cit.*, pp. 446-447.

[149] Eichner, A.W. (2020) *op. cit.*, p. 222.

[150] Daly, A. et al. (2021) *op. cit.*, p. 45.

[151] Tremble, C. (2018) Don't Bring a CAD File to a Gun Fight: A Technological Solution to the Legal and Practical Challenges of Enforcing ITAR on the Internet. *Fordham Law Review*, 87 (1), p. 139.

that are balanced enough to ensure public safety without stifling the positive advancements of 3D printing technology, this paper approaches this issue using solution-oriented approach by taking a more problem-solving strategy by beginning with a real-world issue followed by examining which theories may be used to address it.[152]

The synthetization in this paper argues based on the solution-oriented approach argues that producers of at-home 3D printers will tolerate government regulation and are willing to collaborate with governmental intervention to a certain degree—known as the producers' "threshold" based on the threshold models of collective behavior by Granovetter.[153] This model is deemed straightforward but tenable to explain individual or collective willingness under the pressure of social influence.[154] In this case, the practical problems and dilemmas as mentioned above are the social influences or "shocks." Since threshold models and game-theoretic models depend on the premise that players act rationally in the face of ample information, and consequently, both contend that logic (occasionally deliberate) frequently influences behavior as a whole.[155] This model is predicated on the notion that human beings are more inclined to be shaped by the actions of others, and that whenever they are subjected to circumstances that include "shocks" caused by societal influence, they will behave in accordance with the standards and expectations of those around them. Additionally, it implies that despite being confronted with complex situations, individuals will frequently make reasonable decisions based on the information at hand.

Game-theoretic models such as the prisoner's dilemma is a wonderful example of how self-serving actions by both players (producers and government) will lead to a conclusion that is unfavorable for neither the producers nor the government. This game-theoretic approach enables each player to comprehend the potential risks and benefits of their choices and take action to maximize the outcomes they achieve. They can come up with a solution that maximizes the collective benefit whilst minimizes the individual cost. Unregulated market will also result in a tragedy of the commons, where the lack of regulation could lead to a race to the bottom in terms of quality, safety, and environmental standards.[156] The aforementioned findings shows that cooperation amongst participants is necessary to develop a more just

[152] Watts, D. (2017) Should social science be more solution-oriented? *Nature Human Behaviour*, 1, p. 1.
[153] Granovetter, M. (1978) Threshold Models of Collective Behavior. *American Journal of Sociology*, 83 (6), p. 1422.
[154] Watts, D. et al. (2017) *op. cit.*, p. 1.
[155] Granovetter, M. et al. (1978) *op. cit.*, p. 1433.
[156] This is not only detrimental to customers, but it is also detrimental to businesses, who will be forced to compete on pricing as opposed to the quality of their goods or services. This could

and equitable framework that benefits everyone in the long run. This article also believes that the applicable regulatory actions that can be implemented may be in the form of law and designing-out crime (infrastructure). The definition of law is rather self-explanatory: it is an authoritative instrument that establishes the legal foundation for the imposition of penalties for criminal behavior. On the contrary, designing-out crime entails altering the physical environment in order to lessen the chances of wrongdoing.[157]

Instead of attempting to prematurely pigeonhole new technological invention into prevailing regulatory categorization, governments might allow the sector to be "born free" rather than "regulated in captivity." As a result, the sector prospered from a policy of benign neglect in this regard.[158] Regulators should not seek an outright ban. They may instead, regulate the fringes of this innovative technology, in hope to control such developments so not to harm public interests, but careful enough not to stifle its growth. For both the Internet and digital technology, permissionless innovation would seem to be the standard practice, giving entrepreneurs an "unequivocal free pass" to just let their imaginations run freely and experimenting with a limitless array of intriguing new products and services. 3D printing can be governed by the same strategy and regulatory approach.[159] Governments may explain and advocate a vision of permissionless innovation for 3D printing, sending a clear message to people that commercial and non-commercial entrepreneurial activities will be permissible.

This suggests that, in the case of 3D printing, governments would make it absolutely clear in their statements that creators in this field will be granted wide leeway in their creative pursuits, and that governance will not be founded on hypothetical concerns or handled via ex ante regulatory limitations. People will be free to experiment with 3D printing technology in general, and any difficulties that arise will be dealt ex post.[160] This article also contends that the first step in regulating this field should not be to restrict the sharing of "technical information" generated by people. Therefore, this article proposes a three-pronged regulatory approach along the fringes of 3D printers as a preventive measure that incorporates protection for public security in the face of the dangers posed by 3D-printed firearms, but still taking into account technological development aspects of this innovation and

result in unsustainable rivalry that spirals out of control, driving down prices and lowering overall product and service quality.

[157] Nelken, D. (2018) The Legitimacy of Global Social Indicators: Reconfiguring Authority, Accountability and Accuracy. *Les Cahiers de Droit*, 59 (1), p. 44.

[158] Thierer, A.D. and Marcus, A. (2016) *op. cit.*, p. 823.

[159] Thierer, A.D. and Marcus, A. (2016) *op. cit.*, pp. 824-825.

[160] Thierer, A.D. and Marcus, A. (2016) *op. cit.*, p. 826.

the personal liberty of its users. The true objective of this approach would be to discourage people from making 3-D printed firearms at home and reduce the likelihood of increased gun violence.

4.3.1 Turn to Technology

Rather than controlling and penalizing the sharing or possession of CAD files, this article suggested that the government collaborate with producers of at-home 3D printers to develop firmware that can identify whether a file is capable towards becoming an undetected weaponry or a component of firearm. The approach would start with the development of firmware that stops 3D printers from creating gun-making components. The printer might be programmed to reject creation of undetectable firearms that are constructed by the user from printed components.[161] This can be seen as a form of private ordering structures that fill in the gaps in the market that is currently unregulated, known as technological protection for exclusion measures. It is also a way of designing-out crime[162] since by programming 3D printers to not be able to print firearm components, it prevents criminals from being able to easily create ghost guns. This is a way of deterring criminals from attempting to commit this type of crime in the first place.

This firmware mimics current printers' inability to duplicate currencies. Many copiers nowadays are unable to scan or copy banknotes as a result of this firmware. These setups can definitely be applied to 3D printers as well. In addition, 3D printers would need to be kept updated on which newer designs they are not permitted to manufacture.[163] However, such firmware can definitely be compromised, but it would be a lot more difficult task than obtaining a weapon CAD file freely online. The creation of exclusionary mechanisms frequently inspires users to create counter-mechanisms for code-cracking and hacking programs. Hence, the effectiveness of security measures in technology hinges on its resistance to attempted hacking and the absence of cheap ways to get around it. To function effectively, the exclusion measures must be resilient to hacking. Once broken into, authorities then have historically reacted to circumvention by passing anti-circumvention legislation that renders circumvention of safety precautions illegal.[164]

The anti-circumvention legislation by the authorities will act as an auxiliary. Elkin-Koren and Salzberger contends that there are two

[161] Tremble, C. (2018) *op. cit.*, pp. 139-140.
[162] See Nelken, D. (2018) *op. cit.*, p. 44.
[163] Walther, G. (2015) *op. cit.*, p. 1443.
[164] Elkin-Koren, N. and Salzberger, E.M. (2013) *The Law and Economics of Intellectual Property in the Digital Age: The Limits of Analysis*. New York: Routledge, pp. 192-193.

economic rationales to justify the anti-circumvention regime: the necessity to discourage circumvention and the dire need to prevent what others see as an unnecessary technological race.[165] The former simply means that the anti-circumvention regime is there to discourage circumvention tools by making it not cost-effective, while the latter bears a deeper understanding—the urgency to end the technological arms race between anti-exclusion tools and their counterparts.[166] The government may also work with 3D printer manufacturers to use the blockchain technology to keep records on every printed items.

Blockchain[167] was at the heart of some of the next-generation firearms startups' product ideas. [168] This initiative intends to integrate blockchain into a 3D printer so that it logs every time the device 3D prints an item, as well as its exact location, and the blockchain data are totally safe and reliable.

4.3.2 Cooperate with Industries

Measures might be targeted at 3D printer manufacturers to develop firmware that demands personal identity to be submitted first in order to operate the device. [169] This approach is fashioned after the regulatory framework that oversees the sale of controlled drugs to verify that they have not acquired above a certain amount of the medication. The 3D printer manufacturers would be in charge of keeping the records, which would be accessible to law enforcement through appropriate channels.[170]

Manufacturers may be obliged to ensure that 3D printers marketed to the general public may only produce specific materials. A license would

[165] Elkin-Koren, N. and Salzberger, E.M. (2013) *op. cit.*, pp. 197-198.

[166] A number of economists have argued that the creation of circumvention tools is an unnecessary use of economic resources. They contend that such a competition can waste resources which might be better spent to make more worthwhile investments. Furthermore, the constantly changing dynamics of this rivalry in technology is not recognized by the present-day economic system. The interactions between emerging technology versus counter-technology could feed into the technological arms race, which may eventually give rise to more advancements in exclusion tools as well as various other technologies. In this regard, the competition amongst technological instruments for technological exclusion and technological circumvention could contribute to advancements in technology in other areas, thereby benefitting overall innovation, advancement, and societal welfare. See *Ibid*.

[167] Blockchain is a more advanced sort of digital ledger technology ("DLT") that is best recognized for its correlation to cryptocurrencies like Bitcoin. Blockchain is a sort of computerized archiving that is decentralized and verifiable. Encrypted and numerous independent backups of data are frequently used in blockchain to actually make information more resistant to malicious tampering, loss of data, and unwanted access. Blockchain can be used to keep track of specific occasions or incidents in an unalterable, automatically documented ledger.

[168] Stevenson, D. (2020) Smart Guns, the Law, and the Second Amendment. *Penn State Law Review*, 124 (3), p. 734.

[169] Tremble, C. (2018) *op. cit.*, p. 140.

[170] *Ibid*.

be necessary for members of the public who wish to print things requiring regulated materials. The license may impose a cap on the amount of controlled material they can acquire, along with a requirement that the licensed user reports on the final product created with this material.[171] In addition to reporting on materials manufactured by 3D printers, the proposed regulation may also compel licensees to inform on any unused materials.[172] This would make licensees responsible for any unused materials, making it more difficult for them to resell or even use them unlawfully.

4.3.3 Strengthening the Regulation on Propellant and Projectile

Since it is constructed of plastic, a 3D-printed plastic firearm poses a number of drawbacks, such as the printing of actual projectiles and propellant out of 3D printers is still unachievable.[173] Simply restricting a gun's frame will no longer be appropriate since 3D-printed firearms may be created at home and thus avoid all of those restrictions. To prevent the abuse of 3D-printed firearms, policymakers must go far beyond the frame and focus on alternative gun-control alternatives. For the time being, and for the near future, 3D printers are unable to produce every single component required to simply print, aim, and fire.[174] Printing gunpowder is now not possible thanks to a required chemical reaction, and will most certainly be incredibly complicated to achieve.[175] Since modern ammunition contains gunpowder, those who print firearms have two alternatives for ammunition: buy cartridges from nearby sports equipment retailers or buy propellant to use in printed ammo. As a result, regulating propellant is the most realistic approach to govern 3D-printed guns.

Since many bullets[176] is pre-loaded with propellant, it is important to broaden the regulation to every transaction of munitions containing propellant or a gunpowder substitute in order to govern it successfully.[177] This strategy would achieve a common ground between discouraging

[171] Reddy, P. (2014) The Legal Dimension of 3D Printing: Analyzing Secondary Liability in Additive Layer Manufacturing. *The Columbia Science and Technology Law Review*, 16 (1), p. 246.
[172] *Ibid.*
[173] Walther, G. (2015) *op. cit.*, p. 1441.
[174] Berkowitz, J. (2018) *op. cit.*, p. 81.
[175] Little, R. (2014) *op. cit.*, p. 1508.
[176] In common parlance, "bullet" usually refers to a cartridge, which really is a three-part vehicle with the actual bullet installed on the very end. The primer, propellant, and projectile itself are the three basic components of a cartridge. The chemical reaction is started by the primer. The propellant contains the chemical explosive's energy. Its job is to propel the bullet out of the firearm and into the target down range. The front segment of the cartridge is the actual projectile, the part that actually travels to hit the target.
[177] Berkowitz, J. (2018) *op. cit.*, p. 81.

the manufacture of illegal 3D-printed firearms while not hamstringing individuals who use 3-D printing for non-firearm applications. As a result of some sort of government oversight in place to regulate the presence and distribution of 3D-printed firearms, the possibility of increasing gun violence against society would be reduced.[178]

In addition to the three-pronged regulatory approach as mentioned above, regulators must also think about how teaching the public and business on how to use new technology properly might help achieve policy goals in a less expensive and much more efficient way. The purpose of such literacy instruction and "digital citizenship" activities is to develop rational thinking standards to enable the assimilation of new technology into society while also encouraging ethical conduct, politeness and responsible utilization new technologies.[179] For 3D printing, this might include lectures on the risks of developing instruments that could have negative societal consequences, such as guns, unsafe medical gadgets, or counterfeit items.

The 3D printing community may also want to exercise caution and refrain from publishing CAD files for firearm or its component. This would not preclude a motivated individual from constructing a firearm using their own CAD program, but it would be more difficult than merely downloading a file and printing it off. However, in the absence of regulatory solutions, engaging the 3D printing community in a meaningful discussion about the potential repercussions of their action may be beneficial. Communities could also adopt a code of conduct. A similar collaboration could help to alleviate 3D printing security problems.[180]

Considering 3D technology is being more widely used across the world, moral and legal difficulties may vary from country to country,[181] but most will be comparable enough to exhibit the traits addressed in this article. Regretfully, the approach offered in this paper is neither conclusive nor exhaustive. Building on lessons learnt from previous scholarships, it is believed that this suggested regulatory framework—schematic as it is for now—represents a tiny step forward in the appreciation of the complexities of regulating technological disruptors *vis-à-vis* 3D printing.

Governments would also be wise to wait and watch how social norms and society attitudes change, even if no rules or regulations exist. New technologies can be regulated in ways that go beyond the law. Since norms generally discourage many actions that are accessible but undesirable,

[178] Johnson, J.J. (2013) Print, Lock, and Load: 3-D Printers, Creation of Guns, and the Potential Threat to Fourth Amendment Rights. *Journal of Law, Technology and Policy*, 2013 (2), p. 358.
[179] Thierer, A.D. and Marcus, A. (2016) *op. cit.*, p. 829.
[180] Walther, G. (2015) *op. cit.*, p. 1443.
[181] Kinsley, K., Brooks, G. and Owens, T. (2014) *op. cit.*, p. 17.

social pressure and personal norms often operate as a "regulator" of new technology applications (and misappropriations).[182] To put it another way, many of today's fears surrounding 3D printer abuse might not always materialize in a significant way, or the public may grow to regard those behaviors more positively in the future. When all else fails, lawmakers can enact tailored legislation to address the most pressing matters, such as those involving the possibility for obvious, cataclysmic, imminent, and irreversible harm. Lastly, a shifting market is really not a terrible thing. At the very least, the oncoming shift has already been nice enough to announce itself publicly; we need to recognize what it is and how to reap the benefits of it.

5. CONCLUSION

3D printers and their printed firearms are not apocalyptic machines, given the risks they pose to public safety. We are on the precipice of the next industrial revolution, and opposing this directly will only result in penalizing the unforeseen and uncertain, while enraging a huge society that innovates or benefited from the technological advancements brought about by 3D printing. Lessons learned from the 2013 3D-printed firearms hysteria has proven that in the long term, no exhaustive prohibition on 3D-printed firearms can preserve public safety; instead, it would leave the law enforcement scurrying to catch up. The genie is also not yet out of the bottle, and current regulatory framework, on the other hand, can and will safeguard public safety from egregious infringers, such as those who try to 3D print a firearm for criminal activities by extending current regulations to tangentially target 3D-printed firearms manufacturing processes.

The solution to this potential problem is to ignore the regulations requiring strict controls on 3D printers and instead embrace 3D printing technology to assist people that are in need creating a better life. The authorities should take into account the many advantages of 3D printing as a technology when creating new regulations. The authorities may try to design narrower regulations to circumvent a stringent public scrutiny while providing timely oversight of 3D-printed firearms. The three-pronged approach relies on 3D printer producers as a control point for untraceable firearm creation and illicit firearm manufacturing surveillance. This strategy avoids contentious questions of public liberty while allowing gun restriction to the degree that the legislature has already reached an agreement. Ultimately, cognizance should be made of other possible illegal uses of 3D printing beyond just firearms fabrication.

[182] Thierer, A.D. and Marcus, A. (2016) *op. cit.*, pp. 829-830.

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