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3D Printing: A Paradigm Shift in Political Economy

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Abstract

3D printing is expected to do for manufacturing what the Internet did for information: It will decentralise and democratise it. The technology seems to be at its really early phases, however studies have already started to emerge on possible implycations of the technology in certain social spheres, especially in what pertains to national security, through the proliferation of 3D printed guns. Increasing focus has also been put on how to properly regulate the technology. However, implications can also be significant in the international political economy sphere. Most scholars believe that if 3D printing will allow for the creation of not only prototypes but mass production, then the economies of scale advantage of manufacturing platforms like China or other states with a similar production profile will perhaps stand a lot to lose. However, even a maximal deployment of 3D printing will not completely make the Current Account imbalances recede. To the contrary, it will place the focus more on input materials, but also on intellectual property. This paper, after advancing a primer of the technology, attempts to offer a "first-cut" analysis of the impact of 3D printing from a political economy and geopolitical perspective.

Keywords

3D Printing; Additive Manufacturing; Architecture; Creative Destruction; Design; Paradigm Shift; Regulation; Safety; Security; Social Transformation.

1. The Third Industrial Revolution?

“The third industrial revolution”. This is how the Economist magazine has dubbed 3D Printing, or, additive manufacturing technologies more broadly. Of course, any technology, prior to its deployment, has implications that we are unable to foresee. One could very easily make the case that it would have been impossible for the original creators of the internet to envision its current state and the manner in which it has affected almost all aspects of our lives, let alone its economic impact. 3D printing, a technology which was previously used for modeling and prototyping, is increasingly considered as a “physical analog” of the Internet, in the sense that has the potential to disrupt traditional production as the internet disrupted content creation and modern communications.

3D printing is a truly revolutionary emerging technology that could up-end the last two centuries of approaches to design and manufacturing, with profound implications in the geopolitical, economic, social, demographic and security spheres (Campbell et al. 2011, Pierrakakis et al 2014). Many claim that 3D printing makes it equally cheap to develop single items as it is to create thousands, and thus manages to undermine economies of scale, causing dramatic changes in social and economic evolution. It may, thus, have as profound an impact on the world as the coming of the factory. The development of 3D printing has the potential to change business models, shift production locations, shrink supply chains and alter the global economic order, potentially degrading the importance of the Asian manufacturing platform. At the same time, it might hold the key to revitalizing the innovation engine of western economies, and, most notably, of the United States.

Of course, competing claims exist, often included in the very same studies. Susson (2013), for instance, while initially forecasting a new industrial revolution because of additive manufacturing, then goes on to claim that "3D printing is not likely to replace traditional manufacturing methods for most applications - it simply takes too long to print individual objects to make it cost effective on a sufficiently large scale". This might initially seem problematic, however it is quite normal to witness such discrepancies for a technology in its initial stages. How initial, of course, remains to be seen. A 2010 Ganter report identified 3D printing as a "transformational technology" in the Technology Trigger phase of the Hype Cycle, i.e., only 5-10 years from mass adoption. Thus, 3D printing is indeed *ante portas*. However, only a limited number of studies have focused on its potential implications from a political, regulatory, and social standpoint.

2. A Primer on Additive Manufacturing

Traditional manufacturing was the driving force behind the industrial revolution, while, as Ashford et al (2011) note, the industrial revolution was the historical turning point in sustained increases of GDP per capita, which up until that point fluctuated instead of increasing. Of course, manufacturing has in itself progressed significantly in the previous decades, significantly "detaching" it from its French etymology, which literally means "made by hands". Today's manufacturing increasingly involves the use of machinery, robots, computers etc. What is essential to understand is that these technologies are "subtractive" techniques, which means that objects are created through the subtraction of material from a work-piece (Campbell et al. 2011). Thus, final products are dependent on the capabilities of the tools used in the subtractive manufacturing processes (see Table 1).

Additive manufacturing is a group of emerging technologies that make objects from the "bottom-up", by adding layers of material in cross-sections, a process similar to creating objects by blocks of Legos (albeit, smaller). The process starts by having a 3D model of the object that will subsequently be printed, typically through the use of computer-aided design (CAD) software. Thus, 3D printing, in simple terms, is a technology that allows one to transform a digital file to a physical object. Thus, we can now print real objects in three dimensions, depending of course on the capabilities of the printer.

So far, several additive manufacturing processes have been advanced, differentiated by the manner in which they create each layer. Campell et al. (2011) include a series of such techniques. "Fused Filament Fabrication", for instance, involves extruding thermoplastic or wax material through heated nozzles to develop a part's cross-sections (Campbell et al. 2011).

3D printed shoe by Z Corporation

3D print context models by AEC

3D printer designed by E. Dini, capable of creating buildings from stone

Monumental Architecture with 3D printing by N. Ervinck

3D prosthetic limbs by S. Summit and K. Trauner

Red rock guitar prototype by D. Manson

3D printed headphones by B. Garret

3D printed models of dental parts by Glidewell Labs

Full size 3D printed polymer motorcycle

Le Mans race engine built by Aston Martin using 3D printing technology

3D printed bicycle by EAD

Table 1: Indicative samples of 3D printing

Other technologies range from jetting a binder into a polymeric powder (3D printing), using a UV (ultraviolet) laser to harden a photosensitive polymer (Stereolithography), to using a laser to selectively melt metal or polymeric powder (Laser Sintering) (Campbell et al. 2011). The key lies in the capabilities of the printer to make use of certain materials, and in what level of craftsmanship. Recent developments in the synthesis of end-use products indeed allow for increasing numbers of materials to be used simultaneously. One could think of a normal printer with several different cartridges, printing simultaneously, but instead of ink making use of materials, such as metals, plastics, etc. in each cartridge.

Additive manufacturing processes, of which 3D printing is a subset, offer significant advantages. First, they entail reduced waste, when compared to subtractive manufacturing. Second, additive manufacturing makes it possible to create functional parts in a decentralized fashion, without the need for assembly, thus offering distinct advantages in time and cost. Finally, additive manufacturing processes have the capacity to create advanced geometries that are not feasible by any other means, thus offering significant geometrical freedom in engineering design (Campbell et al. 2011).

While initially additive manufacturing and 3D printing were considered emerging technologies mainly used in prototyping, i.e. the fabrication of conceptual models of new products for form and fit evaluation, such as 3D models of buildings by architects, processes appear to have already drastically improved, and 3D printing is increasingly being used for the creation of parts for functional testing but also even end-use parts. Furthermore, 3D printing is used for the development of automobile and aircraft components but also in custom orthodontics and in the creation of custom hearing aids. Generally, most of us have already encountered 3D printed objects, even if we do not yet quite know it (Susson 2013).

The medical implications of 3D printing technology appear to be astounding. Susson (2013) notes that in February 2012, the Belgian firm LayerWise announced that doctors successfully implanted an entire replacement titanium jaw it had produced for an elderly woman who suffered from progressive osteomyelitis. In March 2013, American medical doctors surgically replaced seventy-five per cent of a patient’s skull with a custom-made 3D printed implant (Susson 2013). At the same time, certain companies use additive manufacturing techniques in order to create custom braces for hundreds of thousands of patients across the globe. Specifically, osteolithography is used to fabricate molds from 3D scan date of each patient’s dental impressions (Campbell et al. 2011). Finally, other companies make use of laser sintering in order to quickly fabricate custom hearing aids, based on 3D scans of impressions of the ear canal.

Susson (2013) also notes that researchers at MIT are working on 3D printers that allow users to print food. The idea is that such a technology will employ certain input materials and will then be able to replicate the most elaborate recipe of the most famous chef. As the technology progresses and has the capability to include an increasing amount of input materials, produced recipes will become more sophisticated, thus potentially disrupting not only domestic food preparation but also, perhaps, the restaurant business more broadly.

A basic 3D printer is currently less expensive than what a laser printer was in the 80’s. Currently, one can purchase a desktop 3D printer for less than $1000 (Susson 2013). Because of this low price, interest in 3D printing has escalated as an increasing number of hobbyists are able to interact with the technology. In essence, this process is democratizing manufacturing in a way similar to how information was democratized in the Internet.

3. Impact Area I: Production and Manufacturing

Even though additive processes have been available in the market for decades, we are seeing their widespread adoption only recently. With the capability to efficiently manufacture customized goods through 3D printers, one might envision that local manufacturing could start making a return to developed countries. Indeed, 3D printing has the capacity to dramatically reduce costs related to production, packaging, distribution and overseas transportation (Campbell et al. 2011, Pierrakakis et al 2014).

One primary effect of the technology is that is fosters the trend towards increasing product design freedom. In traditional methods of manufacturing, product designs are constrained by the limitations of the machines that produce them, while additive processes allow designers to place material in a selective fashion, only where it is needed (Garrett 2014). Along similar lines, 3D printing is also characterized by a non-linear relationship between costs and complexity. Typically, the more complicated a product, the more expensive it is to produce it. 3D printing is a "single-tool" process, in the sense that the production process is not a function of the complexity of the product geometry. Thus, a single 3D printing manufacturing facility is capable of printing a huge range of types of products without any need for retooling. As a consequence, each printing run can be customized without any additional cost and products can be printed on demand without the need to build-up inventories (Garrett 2014).

This "on-demand" production of batches of one can truly revolutionize manufacturing in many aspects. The increasing adoption of 3D printing should be expected to lead to less unnecessary products, as most products will increasingly be printed on demand. This will significantly resemble the «Just-In-Time» management philosophy of making only «what is needed, when it is needed and in the amount needed». Rendering inventories unnecessary will lead to having fewer of a final product printed, with important monetary and environmental benefits. Printing will, thus, be on demand, in a fashion similar to the transition from traditional books to e-books (Campbell et al. 2011). The process itself, however, has the capacity to drive a change in tastes, namely a transition from mass production to mass customization, in which each item produced is customized for the end user at little or no additional production cost. This is an expected outcome of the technology, as printing one-of-a-kind products increasingly becomes equally costly to the mass production of the same object, thus enabling the efficient manufacture of purely personalized products.

The pace in which the technology is expected to develop is, of course, uncertain, and it will probably vary widely for different types of products (Campbell et al. 2011). This means that many consumer products may still be cheaper to mass produce through traditional methods and shipped to points of consumption for a long time, despite the introduction of 3D printing. However, 3D printing was initially perceived and even referred to as "rapid prototyping", and was primarily used in order to quickly fabricate conceptual models of new products for form and fit evaluation (Garrett 2014). 3D printing technologies are increasingly being used for fabricating parts for functional testing, for creating tooling for injection molding and sand casting and, finally, for directly producing end-use parts. The technology is, thus, evolving from making prototypes to manufacturing finished products. The speed of this evolutionary path, of course, remains a question. More specifically, the key question here is at which point will a product as complex as a laptop or an engine will be printed in a single process? Campbell et al. (2011) note that for such products, the shift will be in spurts, as certain parts are increasingly being printed and then assembled in a traditional fashion, but with a declining number of individual parts to be assembled. This process will gradually lead to a decline in the costs of production, and, thus, supply chains will increasingly be simplified and shortened. The expected future outcome is for a final product like a car to be produced by 3D printing in one single process. This end-goal will lead to the full elimination of supply chains and assembly lines for a whole series of products. As we increasingly speak about printing large items, such as a house, the key question will lie in the size of the printer. There are already companies working on printing small residential buildings, while Airbus is developing 3D printing to print entire wings of airplanes (Campbell et al. 2011).

Furthermore, the rise of 3D printing will quite likely lead to the re-invention of many old or traditional products, as well as to extraordinary new innovations. When 3D printing processes will have fully matured, virtually anything that can be designed in a computer will have the capacity to be printed. This will thus eliminate the limitations posed by machine tools, stamping and molding, and engineers and designers will no longer be limited by their designs because of the very limitations of traditional manufacturing technologies. New hybrid materials, such as nanocomposites via 3D printing, are being research to take design and material properties manipulation even further (Garrett 2014).

3D printing is also expected to reduce waste in the manufacturing process by the very nature of additive versus subtractive manufacturing, as the latter has lower resource productivity by definition. In fact, the printing process has almost zero waste. At the same time, the waste of excess or unsold production will also be eliminated, as well as the cost of storage of inventory (Campbell et al. 2011). 3D printing is, thus, likely to play a significant role in dramatically increasing the efficiency of resource use and in lowering overall carbon emissions, from the process of manufacturing itself, to the delivery of products to the end-user. Finally, 3D printing processes can reduce or eliminate the use of toxic chemicals often used in conventional manufacturing processes (Garrett 2014).

4. Impact Area II: Work

With regards to the economic aspects of 3D printing, the first consequence of the analysis above entails the transformation of tradable goods into commodities. For example, there would be no need for someone who owns a 3D printer to buy plates, bottles or other everyday objects, unless if there is a specific property about a certain commodity that justifies it, such as its sentimental value, branding issues etc. Thus, several areas of traditional manufacturing and trade will struggle to survive, causing a snowball effect on international political economy and the society more broadly.

3D printing is expected to create new industries and professions. First of all, the production of printers of all different types and sophistication is gradually becoming a rapidly expanding industry, with a growing customer base from industrial printers, to printers for home use, manufacturing centers, printers in local stores and government agencies. The shift in global manufacturing to 3D printing processes has the potential to become by itself a trillion dollar business for the coming decades, including the value of products produced, the printers themselves and professional services, including product engineering and product design (Garrett 2014). Producing and distributing printer cartridges of all sizes and materials will also become an especially profitable industry, as has been the case in the 2D printing world for Compaq, Hewlett-Packard etc. Legal services will also have a significant share of the financial pie of the emerging industry, as protection of 3D printed intellectual property will likely pose significant legal challenges, as designs for products can quite possible be widely disseminated without the consent of their creators, as is the case today with typical .cad files or any other type of software affected by internet piracy.

More broadly, "Creative Destruction" is a well-known term, coined by Joseph Schumpeter, in order to describe how innovative products and processes displace old ones in the context of a dynamic market economy. In reality, Schumpeter considered the forces of technological competition and innovation to be the locomotives of capitalism, contrary to the traditional model of price competition and equilibrium, advanced by traditional economics (Ashford et al. 2011). As Ashford and Hall note, in the classical literature one meets two types of innovation, i.e., product and process innovation. A product innovation occurs when a new product is developed and launched in the market or an old product is changed in a radical way. A process innovation involves an improvement in a product without significantly changing its final characteristics.

This distinction between product and process innovation is very significant vis-à-vis their impact to employment. Namely, in the context of the impact of creative destruction with regards to employment, product innovations destroy jobs but also create new jobs, as new products are advanced that require new talented workers. To the contrary, process innovations typically destroy jobs, even though they can have positive microeconomic effects, possibly through more competitive prices. Nonetheless, the effect of process innovation on employment can be very significant.

In this context, is additive manufacturing, and more specifically 3D printing a product or a process innovation? While a 3D printer does indeed constitute a new product, the function that 3D printing can serve in the future can fully displace a series of employments in the manufacturing sectors, thus destroying a significant amount of jobs. The limited literature on this seems to concur. Garrett (2014) along with Campbell et al (2011) claim that the reduced need for labor in manufacturing could be politically destabilizing in economies that rely on traditional manufacturing for a large percentage of their labor force. Developing countries without large factories employing large numbers of workers, however, may benefit from encouraging entrepreneurs to set up 3D printing facilities for design and manufacture for local consumption. This would have the potential to expand these countries' skilled labor forces and manufacturing sectors to produce goods appropriate for local consumers, while reducing reliance on expensive imports and reaping the profits from this production. Thus, it seems that 3D printing might have a similar effect to the one that computers did with regards to displacing labor.

Similarly, countries with ageing societies, typical of the western world, would benefit from the ability to produce more goods with fewer people while reducing reliance on imports. This could have a positive effect in the productivity statistics of these societies, which would otherwise fall as a pure outcome of problematic demographics, as the ratio of employed to retired would gradually shift towards fewer workers to support the growing proportion of the population that is elderly and retired. And, as also mentioned above, 3D printed medical equipment and bioprinted organs, not to mention eventually targeted nanotherapies, could also significantly lower the cost of healthcare, with, along with the cost of pension systems, is expected to become an increasingly problematic factor for economic growth in the coming decades.

Since 3D printing technologies create physical products directly from a standardized physical file, these computer-controlled processes require a low level of operator expertise and reduce the amount of human interaction needed in order to create an object. Thus, it can be expected that 3D printing will boost the direct relationship between the designer and the product, a relationship that was strained after the industrial revolution, and will render it similar to the relationship between software developers and their products. As a result, this might spur interest in engineering and industrial design, in a similar fashion to what happened in the field of computer science over the past decades. Simultaneously, 3D printing is expected to create new industries and professions, such as the production of printers itself, from the production of individual home printers to the creation of manufacturing centers, printers in local stores and relevant government agencies (Campbell et al. 2011).

The exact nature of social transformations that 3D printing will entail will most certainly be extremely interesting to watch and even more difficult to predict. Furthermore, several questions arise, such as the evolution of the working environment after a collapse of the traditional labor paradigm. Society may face the further emergence of new classes, like the *precariat* (Standing 2011). This could be closely linked to the issue of the availability of 3D printing, raw materials and designs.

5. Impact Area III: National Security

Potential security threats inherent to 3D printing are already evident in initial successes in printing guns and high-capacity magazines for assault weapons. Indeed, most of the headlines that 3D printing has produced thus far lie in areas relevant to homeland security. The reader must have already pondered on the capability of an individual to print potentially hazardous material. The simplest case would lie in printing a simple firearm, a case which appears to have already taken place in more than one occasions around the world, as several individuals have already printed and assembled firearm components (Susson 2013). Susson notes that a Texas resident and his nonprofit organization, Defense Distributed, 3D printed the lower receiver portion of an AR-15 rifle and successfully fired off over 600 rounds, while, within days, the man acknowledged that already more than 10,000 people had downloaded the CAD file with the blueprint for the AR-15 lower. So far, US Federal Law does not prevent an individual from manufacturing her own firearm for personal use.

The discussion on 3D printed firearms raises the question of what different weapons could be developed through the use of 3D printers. How easy would it be to develop a traditional bomb, for instance? What about chemical or even nuclear weapons? The capacity to develop such capabilities would depend on the availability of relevant designs, along with that of material inputs. However, the very notion that such technologies could become increasingly more accessible through 3D printers raises significant concerns about the proper monitoring and regulation of the technology. This might be also seen in connection and relation with the emerging threats raised by the wide use of social media (Kandias et al 2013). Pierrakakis et al (2014) have mapped some original regulatory possibilities for this emerging technology, taking into account both ideological factors but also the way in which each approach might impact the deployment of the technology.

Thus far, it seems that there is little that governments can or should do in order to stop the development of additive manufacturing techniques, and 3D printing more specifically. Governments will have to hedge against possible as well as actual threats posed by this technology, which, fortunately so far, do not appear to include making new types of lethal equipment, but only enhancing the ability to elude controls and detection in production of already existing types of weapons. In the long run, however, one could predict new classes of weapons developed with 3D printing techniques.

The geo-economic impact of 3D printing has the potential to affect the mission of the US military (Garrett 2014). A decline in the mass production of products on assembly lines at the end of long and complex supply chains can lead to a gradual decline of global shipping of finished goods. On a primary approach, this could reduce the magnitude of the challenge of protecting sea lanes with naval forces. Raw materials will continue to move around the planet by ship but one can expect that the quantity of shipping would likely be sharply reduced. Increased resource productivity through 3D printing also has the capacity to lower quantitative demand for natural resources and thus reduce the likelihood of resource conflict.

3D printing will not only affect the national security environment for the military but also the way in which it operates. The US military is already benefiting from 3D printing medical advances from printing skin and prosthetics and is likely to help spur further development of the technology that could enhance the survival and rehabilitation of wounded or injured military personnel. 3D printing will also play an increasingly important role manufacturing spare parts, especially on ships and at forward bases, reducing repair time and cost. The military could benefit substantially in the future from requiring defense contractors to provide the Defense Department the intellectual property and the computer files for most if not all parts of every weapons systems so the military has the resources and rights to produce spare parts, which would not only speed up repairs but provide huge savings in maintenance costs over the lifetime of weapons systems. Many of these capabilities that benefit the military will be critically important for NASA for human exploration of space. NASA has already commissioned the development of 3D printing for the International Space Station, especially for printing spare parts. Made in Space, a Silicon Valley startup, has built printers that passed all NASA tests for relevant certifications.

6. Impact Area IV: International Political Economy

Since it is extremely difficult to foresee the micro-implications of 3D printing beforehand, one could claim that such an approach would be even harder for the macro-implications in economics and geopolitics. Nonetheless, some initial thoughts have started to emerge. The first major shift taking place by this emerging technology is the fact that it will be designs and not products that will move around the world, digital files that have the capacity to be printed by any printer that can meet the design parameters. This is quite similar to the effect that the internet had for information, as it first eliminated distance as a factor in moving information instantly across space. The representation of physical artifacts with a digital file thus enables rapid global distribution of products, thus potentially transforming product distribution much in the say way the MP3 did for music.

Campbell et al. (2011) and Pierrakakis et al (2014) note that through the extensive use of 3D printing, manufacturing could be pulled away from today's traditional manufacturing states, such as China, and be brought back to the countries where the products are consumed. According to this line of thinking, such a development would play a significant role in reducing the economic imbalances (current account surpluses and deficits), because export countries surpluses would be reduced and importing countries' reliance to imports would shrink as well (Campbell et al. 2011). This would lead to a new form of "import substitution" taking hold.

This shift will reduce the movement of finished goods around the world. The decentralization of manufacturing to potentially vast numbers of sites all over the globe also will reduce the needed quantitative output of any one facility and thus render less important the speed of manufacturing each item. Mass production of hundreds of thousands of a given product may be done by producing thousands of the same product on hundreds of printers that are near the source of demand around the world rather than hundreds of thousands of the same item all at one factory. This would also serve to bring supply and demand into near perfect alignment, as the products will only be printed where and when there is specific demand.

However, while such a displacement could potentially be envisioned, in reality it would depend on two factors. The first one lies in the true potential of the technology with regards to its capability to sustain economies of scale. In the context of the same study, Susson (2013) makes two competing claims: While originally stating that “3D printing now makes it as cheap to create single items as it is to produce thousands, which may have as profound an impact on the world as the coming of the factory did”, he then goes on to say that “3D printing is not likely to replace traditional manufacturing methods for most applications – is simply takes too long to print individual objects to make it cost effective on a sufficiently large scale”. So, which is it? Is 3D printing a proper means for prototyping only or could it really displace the factory and have significant macro-effects in the economy? One could make the case that the former claim describes the contemporary reality, however as the technology advances it could be expected that 3D printing becomes increasingly cost-effective.

The second factor involves the availability of material inputs for production. If we attempt to envision a future where 3D printing becomes the norm and production is brought back from the East to the West, for the current account imbalances to fully recede one would need to guarantee the availability of material resources domestically. Currently, commercial 3D printers can utilize only certain materials: plastics, resins and metals, and print with the precision of approximately a tenth of the millimeter (Susson 2013). However, many scholars increasingly make the case that in the future there are going to be 3D printers that will allow one to create 3D structures out of living cells, building rather complex structures, such as blood vessels, skin tissue or even heart valves and organs, while researchers from MIT are working on printers that allow users to print food. It thus becomes clear that for 3D printing to fully roll-back current account imbalances, the availability of material resources that will be used in additive manufacturing will be critical, and might create its own new set of imbalances as needs shift.

3D printing might significantly help with regards to meeting environmental and resource preservation goals. First of all, as production is shifted to the places where consumption is occurring, it is expected that the transportation and manufacturing carbon footprint of many products can be reduced, as designs, rather than products, will now be shipped internationally (namely, digitally rather than physically). The carbon footprint will be further reduced by the diminishment of complex supply chains of parts produced by a significant amount of suppliers scattered around the globe, while the total energy required for the production of any final product may also be reduced, depending on the previous complexity of its manufacturing process (Campbell et al. 2011).

7. Conclusion

This work first performs a literature review, examining the contours of 3D printing and additive manufacturing, along with its impact in the selected areas of production, employment, national security and international political economy. We have quoted a series of parameters that are able to render 3D printing a hegemonic technology globally. To this extent, this technological achievement may produce a ripple effect on innovation, research, daily life and thus to society, the economy and politics.

As Bohr observed, "prediction is difficult, especially about the future". 3D printing is expected to have ground-breaking implications, impossible to foresee at the moment. However, it does appear that the technology will have a disruptive power similar to that of the Internet, or perhaps even greater.

For future work we intend to focus upon regulatory issues along with the political transformations and the contextual background of 3D printing. Another interesting issue is the diversification of social gratification models, under the prism of additive manufacturing.

Finally, we also plan to focus on relevant security and ethical issues that appear to eventually arise (Gritzalis 2002, Mylonas 2013, Pipyros 2014, Virvilis 2013).

References

[1]. Ashford, N., Hall, R., "The Importance of Technological Innovation", in Ashford, N., Hall. R., *Technology, Globalization and Sustainable Development*, Yale University Press, USA, 2011.

[2]. Ashford, N., Hall, R., Pierrakakis, K., "Economic Development and Prosperity: Current Theory and Debate", in Ashford, N., Hall. R., *Technology, Globalization and Sustainable Development*, Yale University Press, USA, 2011.

[3]. Campbell, T., Williams, C., Ivanova, O., Garrett, B., *Could 3D Printing Change the World? Technologies, Potential and Implications of Additive Manufacturing*, Strategic Foresight Report, Atlantic Council, 2011.

[4]. *The Economic Impacts of 3D Printing*, http://madameeureka.wordpress.com/the-economic-impacts-of-3d-printing/

[5]. Garret, B., "3D Printing: New Economic Paradigms and Strategic Shifts", *Global Policy*, Vol. 5, No. 1, 2014

[6]. Gritzalis D., "Principles and requirements for a secure e-voting system", *Computers & Security*, Vol. 21, No. 6, pp. 539-556, 2002.

[7]. Kandias, M., Stavrou, V., Bozovic, N., Mitrou, L., Gritzalis, D., "Can we trust this user? Predicting insider's attitude via YouTube usage profiling", *Proc. of 10th IEEE International Conference on Autonomic and Trusted Computing*, pp. 347-354, IEEE Press, Italy, 2013.

[8]. Kandias, M., Stavrou, V., Bosovic, N., Gritzalis, D., "Proactive insider threat detection through social media: The YouTube case", *Proc. of the 12th Workshop on Privacy in the Electronic Society*, pp. 261-266, ACM, Berlin, 2013.

[9]. Kandias, M., Mitrou, L., Stavrou, V., Gritzalis, D., "Which side are you on? A new Panopticon vs. privacy", *Proc. of the 10th International Conference on Security and Cryptography*, pp. 98-110, Iceland, 2013.

[10]. Kandias, M., Galbogini, K., Mitrou, L., Gritzalis, D., "Insiders trapped in the mirror reveal themselves in social media", *Proc. of the 7th International Conference on Network and System Security*, pp. 220-235, Springer, Spain, 2013.

[11]. Mylonas A., Tsalis N., Gritzalis D., "Evaluating the manageability of web browsers controls", in *Proc. of the 9th International Workshop on Security and Trust Management*, pp. 82-98, Springer, LNCS 8203, UK, 2013.

[12]. Pierrakakis K., Kandias M., Gkritzali C.D., Gritzalis D., "3D Printing and its regulation dynamics: The world in front of a paradigm shift", in *Proc. of the 6th International Conference on Information Law and Ethics*, Law Library Publications, Greece, 2014.

[13]. Pipyros K., Mitrou L., Gritzalis D., Apostolopoulos T., "A cyber attack evaluation methodology", in *Proc. of the 13th European Conference on Cyber Warfare and Security*, pp. 264-270, ACPI, Greece, 2014.

[14]. Susson, M., *Watch the World "Burn": Copyright, Micropatent and the Emergence of 3D Printing*, Social Science Research Network, 2013.

[15]. Virvilis N., Gritzalis D., "The Big Four - What we did wrong in Advanced Persistent Threat detection?", in *Proc. of the 8th International Conference on Availability, Reliability & Security*, pp. 248-254, IEEE, Germany, 2013.