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Workshop

The Collaborative Economy: Impact and Potential of Collaborative Internet and Additive Manufacturing

IN-DEPTH ANALYSIS

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STOA Workshop
The impact and potential of collaborative Internet and additive manufacturing technologies

Will Crowd-sourcing, Big/Open data, Crypto-money and 3D printing revolutionize the industrial society?

In-depth analysis

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1. Introduction

In recent years a trend has been identified where distributed collaborative approaches have been adopted in many areas of endeavor, just as fast as technology has been deployed that could support it. This has taken place in conjunction with the digitization of many manufacturing processes as well as the virtualization of currency: we observe that these areas are now being brought together. Consequently, we are now faced with questions about how this entirely new type of manufacturing sector would, or could, function within an existing economy and how it would affect society.

This briefing paper provides an overview of four technologies that are the subject of a workshop to be held on 27 Jan 2015 in building PHS, room 7C050. The workshop is designed to provide input to a subsequent paper, which will ultimately make policy recommendations based on foresight around subject areas raised there. Herein, we take each of the contractually pre-selected areas in turn and after a brief subject introduction we reflect upon current and emerging practice, we then consider headline socioeconomic factors and attempt to predict evolution trajectory. This structure is followed explicitly or implicitly, depending on the scope and nature of the area being discussed.

2. Analysis of Individual technologies

2.1 Collaboration on the Internet

In recent years, the Internet has come into much more widespread use, and Skype and other e-meeting tools have enabled people to work together more or less independently of their location. Facebook and other social media are helping people discover shared interests and form new groups for collaboration. New collaboration modes are emerging - crowd sourcing and crowd funding capitalise upon the power of individuals joining forces to promote shared interests, and companies are exploring ways of letting their customers co-create innovations with and for them. Free resources are increasingly becoming available, as open design, open source and as a result of commons-based peer production.

2.1.1 Definitions

The definitions of the new modes of collaboration on the Internet are intertwined, and their definitions are sometimes contentious. Below some abbreviated definitions are given, bearing in mind that these terms are sometimes used in a broader sense.

- **Crowd Sourcing** is the practice of obtaining needed services, ideas, or content by soliciting contributions from a large group of people and especially from the online community rather than from traditional employees or suppliers (Merriam-Webster).
- **Crowd Funding** is the practice of funding a project or venture by raising many small amounts of money from a large number of people, typically via the Internet (Oxford Dictionary).
- **Co-creation** is a means for companies to enlarge their base of information about needs, applications and solution technologies (Piller and Ihl 2013) by engaging and involving their customers in design and innovation processes.

- **Open Design** is the development of physical products, machines and systems through use of publicly shared design information (Wikipedia).
- **Open Source Software** is computer software with its source code made available with a license in which the copyright holder provides the rights to study, change and distribute the software to anyone and for any purpose (Wikipedia).
- **Commons-based peer production** describes a new model of socio-economic production in which the labour of large numbers of people is coordinated (usually with the aid of the Internet) mostly without traditional hierarchical organization. The term is often used interchangeably with the term **social production** (Wikipedia).

2.1.2 State-of-Practice and Emerging Trends

The new modes of collaboration on the Internet described above are heavily intertwined, and often used in combination. Crowdsourcing principles are used for diverse purposes, for example for facilitating tasks that are only actionable by a human (Amazon Mechanical Turk), for competition-driven design of graphics, web, print and corporate identity (DesignCrowd), and by technological stakeholders for extracting valuable data from the sensors in smartphones owned by individuals (eg. Google extracting anonymised information about signal strengths of mobile and WiFi networks, for positioning purposes). The European Commission funds a research and innovation challenge "Collective Awareness Platforms for Sustainability and Social Innovation", within the Horrizon 2020 programme. Interestingly, individuals are often willing to participate in crowd-sourced efforts with low or no financial incentives.

The crowdfunding business is dominated by Kickstarter, that by the end of 2014 will have raised about 1.5 billion USD for about 76 000 projects. The main runner-up Indiegogo is about one-sixth their size. 40per cent of the Kickstarter projects succeed in reaching their set funding goal, while 60per cent do not and therefore do not receive any funding at all. 30per cent of the Kickstarter backers have backed more than one project. The usual fee of crowdfunding sites is about 5per cent of the raised capital. Indiegogo allows flexible campaigns where partial funding can be received for a steeper 9per cent charge. We see new entrants trying to establish themselves as alternatives, with mixed success. Meanwhile, Kickstarter is quickly expanding into new countries in Europe and world-wide. The success of crowdfunding has also attracted dishonest stakeholders, and a number of fraudulent projects have been cancelled on Kickstarter, while Indiegogo applies less strict controls.

Co-creation, open design, open source software and commons-based peer production have many similarities, and some prefer to let the term co-creation encompass all of these collaboration modes. While customers have long since been engaged in either predefined and narrow tasks like discussion forums or creative and open tasks like idea contests, there is an emerging trend towards peer production modes, that combine intense collaboration with high degrees of freedom (Leading Open Innovation, MIT Press 2013). One example is *threadless.com*, a manufacturer of garments with designed graphics that leverages their customers both for idea generation and for selecting the best ideas to go into production. Open designs for 3D-printing are strongly increasing, facilitated by **www.thingiverse.com** (reaching 100 000 downloadable models in June 2013) and an array of new entrants. Open Source software is firmly established as a viable alternative to proprietary software, and its use is steadily increasing. Companies are slowly becoming more aware of the limitations and opportunities associated with the various open source licensing models, making informed decisions about what parts of their business eco-systems will be more beneficial to offer as open source, whilst avoiding breaking the rules of open-source software used in their products. The suite of Creative Commons licenses are emerging as a good way to contribute digital materials for the benefit of humanity

2.1.3 Potential Socio-Economic Impact

The continued success of many crowdsourcing and crowdfunding initiatives indicates that they will play an important role in the future collaborative economy. Individuals are learning that they can contribute together with their peers to make new their new ideas for products and services come true. This approach, however, has a darker sides too - fraud and potential privacy invasion. If too many fraudulent crowdfunded projects manage to receive funding, or if crowdsourced data from people's smartphones are not properly anonymised, then the price may be perceived to be too high. This is likely to lead to more wide-spread use of reputation services for vetting projects and services asking for participation by individuals. Overall, crowdsourcing and crowdfunding will create and strengthen communities of people with similar interests, mostly unhindered by national borders. This will contribute to the accelerating process of the world becoming more homogeneous across the different countries, while instead being more fragmented across cultural and social group categories. This presents policy makers with a huge challenge - how can the power of the "wisdom of people" be harnessed while avoiding the emergence of conflicting factions across Europe?

Co-creation (including commons-based peer-production, open designs and open source software) will increasingly be a necessary element for successful business. The previous patterns of new services being quickly used by early adopters and then more slowly penetrating their markets will tend to be replaced by "super companies" that try out their services on a select initial group of users, and then quickly expand into global offerings. Recent examples of such rapidly rising global companies are *Uber* disrupting the taxi business, *AirBnB* disrupting the travel accommodation business, and indeed *Kickstarter* disrupting the previous value chains for funding companies in their earliest stages.

Social media must also be mentioned here - Facebook and other social platforms engage an increasing portion of the population - it is becoming part of the main social fabric, and even people who are not very keen on adopting new technologies are joining social networks. The availability of immediate translation between languages can already be seen to bind together people that would previously have struggled to communicate.

2.1.4 Envisaged Long-Term Evolution

The Internet has repeatedly surprised us in generating new modes of collaboration, and disrupting previous models for business and governance. It is likely to continue to make the world more homogeneous, while enabling niche communities to exist across the entire world. As the availability of Internet continues to increase, we will see more people engaging in crowdsourcing and crowdfunding activities. The Digital Agenda goal of 50per cent of the population subscribing to broadband above 100 Mbps by 2020 means that people will collaborate using video, completely unimpeded by other net-based activities - in fact much less than 100 Mbps is needed for that. Commons-based peer production is a mode of co-creation that enables extensive reuse of digital resources for co-creation, because no specific licenses need to be obtained. The body of material published under Creative Commons licenses can be expected to keep growing, potentially to a point where it becomes pointless to provide proprietary collections of photos, music, videos and other creative products. If this happens, then it will require a fundamental shift in how creative products are funded and managed, extending so far as the discussion about copyright.

2.2 BigData and OpenData

BigData and OpenData represent two major technological trends that are already shaping the next era of ICT technologies, while at the same time empowering better ways of doing business and boosting a more transparent and democratic society.

2.2.1 BigData

BigData refers to large and complex datasets, which comprise multiple data streams of varying speeds, structures and formats. As a result of these characteristics, BigData tend to exceed the capabilities of traditional data processing systems, although this can be quite subjective and technology dependent given the continual improvements in data storage and analysis technologies. Overall, BigData are characterized by 3Vs, namely: (a) Volume referring to the size of data (i.e. how big it is), (b) Velocity referring to the rate based on which data is being generated, and (c) Variety referring to great diversity and variations in terms of sources, formats and structures.

The power of BigData nowadays lays in the employment of data analysis techniques towards improving decision making, discovering new opportunities in reduced time, anticipating customer needs and more. The most common uses of BigData concern the following problems: (a) risk analysis, (b) provision of recommendations, (c) analysis of churn rates in customer processes, (d) analyzing threat, (e) identifying system failure points and states, (e) analyzing point of sale transactions, (f) displaying targeted advertisements, (g) predicting systems' failures, (h) searching information in the right context and more. Such applications are already used in a variety of sectors including:

- **Financial services**, where BigData techniques are used for algorithmic trading, risk analysis, portfolio analysis and fraud detection.
- **Retail services**, where BigData offers supply chain optimization, fraud detection, fraud prevention, and CRM functionalities through customer scoping.
- **Advertisement and Public Relations**, where BigData is used for sentiment analysis, targeted advertisements and the implementation of customer acquisition strategies.
- **Media and Telecommunications**, with particular emphasis on fraud prevention, network optimization and reduction of subscribers' churn rates.
- **Manufacturing**, with a focus on product research, engineering analytics and optimization of distribution at the supply chain of products.
- **Energy**, in areas such as smart grid and energy optimization applications.
- **Healthcare and life sciences**, and more specifically in clinical research, bioinformatics, pharmaceuticals research and pharmacogenomics.
- **Government**, in applications like market regulation, health economics, econometrics and anti-terrorism activities.

While application instances are found in all the above areas, BigData deployments are considered to be in their initial stage. In the coming 2-3 years the industry is expecting[1] to see more tangible business value through the blending of analytics in business processes as means of achieving productivity improvements and boosting managerial decision making. This is also in-line with market trends, which demonstrate that BigData is among the fastest growing segment of IT industry. According to a recent market report by IDC, the BigData technology and services market (including infrastructure, software and services) will grow at a Compound Annual Growth Rate (CAGR) of 50per cent between 2013 and2017 (towards a total value of $32.4 billion). This growth rate is almost six times higher than that overall growth rate of the ICT (Information and Communication Technologies) market.

The anticipate growth of BigData solutions is propelled by a range of other trends in relevant applications areas and technological disciplines. One of these trends is the explosion of internet connectivity, which enables people and devices to provide/contribute data streams to BigData sets, thereby increasing the volume of data available and the scope of potential applications. Another trend relates to the proliferation of internet-connected objects, as part of the emerging Internet-of-Things (IoT) computing paradigm. The IoT is gradually generating myriads of data streams, including sensor streams, social media streams, streams from signal processing algorithms and more. Furthermore, several of these streams include high-velocities and a wide range of structures and formats, thereby rendering BigData technologies indispensible for their analysis and use. A final trend that reinforces the importance of BigData in the years to come relates to the on-going digitization of large volumes of physically stored information (e.g. government archives). This digitization will beget new datasets and opportunities for deriving value from their analysis.

Overall, businesses and governments are expected to exploit BigData in order to benefit from the explosive growth of data streams, which come to organizations from different areas and in myriad formats. For several years the economy has been highly influenced by data analytics and business intelligence processes. In the scope of the collaborative economy these processes will be revised/reengineered in the light of BigData sets stemming from corporate repositories, users/citizens, the IoT, social media, digitized archives and a variety of other data sources.

2.2.2 Open Data

OpenData refers to datasets that can be freely used, re-used and redistributed, without any restriction associated with legal, technological or even social issues. Open data is expected to be relatively easy to use, while being available free of charge or at least at a minimal cost. People, enterprises and organizations can take advantage of open data sets for: creating new ventures, identifying socioeconomic trends, creating knowledge (open knowledge), analyzing trends and improving their decision making. While BigData is characterized by the three Vs, open data is characterized by its availability and use. However, OpenData are related to BigData technologies, since the latter can be applied to the processing of open data sets in order to make BigData sets even more useful, more democratic, more transparent and less threatening to the society.

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[1] According to the International Institute of Analytics (IIA) (iianalytics.com)

At present governments are increasingly publishing and using open data sets (e.g., UK government open data (data.gov.uk), US government open data (**www.data.gov**)). The latter are nowadays used for a variety of purposes, including: (a) Transparency and accountability (e.g., about government budgets and decisions); (b) Delivering services on behalf of the government (e.g., providing information on public transport and/or public health services); (c) Improving commercial services and products (e.g., through enabling them to use additional government-owned information that significantly improves service delivery and user friendliness); (d) Enhancing the efficiency of public services e.g., in the area of urban mobility.

Based on the above use cases, open data can have a significant and proven economic impact, while at the same time boosting transparency, efficiency and participatory/connected governance. Nevertheless, there are still set-backs to realizing the potential of Open Data, such as the great diversity and heterogeneity of publishers, data formats and licensing schemes. Some of these challenges can be confronted based on BigData techniques. However, the proper exploitation of open data requires the highest possible automation in their processing (i.e. with minimal intervention from an analyst), as well as the linking of diverse datasets (e.g., from different publishers) in the scope of a given application. In order to alleviate these concerns, the wave of LinkedData has also emerged, which links related (open) data sets. Apart from technical aspects, successful open data infrastructures are characterized by their breadth and granularity, their timeliness and the overall ease of re-using the data. Furthermore, strong political leadership is required on the basis of supportive government initiatives. Also, open data infrastructures should feature usability, which should be reflected in user interfaces, search functionalities and an active engagement of end-users communities.

In the coming years we expect a proliferation of open data sets and their linking as part of the LinkedData cloud (**http://lod-cloud.net**), an infrastructure that already links numerous open data sets. More open data sets will enable improvement and more transparent government, better research (thanks to the sharing of open data journals), as well as a wealth of opportunities for the development of innovative applications and services that will consume the data sets.

2.3 Crypto-Money

2.3.1 Overview

Crypto-currencies represent a type of digital or virtual currency that employs cryptography for transaction security. Since their first iteration, early forms of virtual currencies could not be characterized as a currency – a medium of exchange - but more as an advanced payment system, as these systems primarily served to transfer fiat currencies between parties while offering some form of anonymity. Their objective was the ability to digitally transfer large amounts of money between parties at fast speeds while, as mentioned, offering some level of anonymity.

However more recent innovations in virtual currency have taken the next step into creating what may be characterized as digital money, serving as both a peer-to-peer payment system as well as a store of value, with BitCoin (in 2009) serving as one of the first examples. BitCoin is a decentralized electronic cash system and as such there is no central point of trust and has a completely distributed architecture, without any single trusted entity and thus revolutionizes commerce on the Internet that has come to rely almost exclusively on financial institutions serving as trusted third parties to process electronic payments.

2.3.2 State-of-Practice and Emerging Trends

In order to understand crypto currencies we showcase the example of BitCoin. Bitcoin is based on a peer-to-peer network layer that broadcasts data to all nodes on the network. There are two types of object that are broadcast: transactions and blocks. Transactions are bundled into blocks, which are linked into chains. Through a process called mining, these transactions are verified through cryptographic proof in the peer-to-peer network. The computer that successfully solves the cryptographic puzzle is rewarded with new bitcoins for the service of preventing fraudulent activity and verifying that Bitcoin's accounts are balanced. Blocks are a sequence of data that produce a particular pattern when the Bitcoin "hash" algorithm is applied to the data record and with their uses the transactions are vetted as valid.

Transactions are the operations whereby money is combined divided, and remitted. Transactions are verified, and double-spending is prevented, through the clever use of public-key cryptography. Public-key cryptography requires that each user be assigned two "keys," one private key that is kept secret and one public key that can be shared with the world. Because Bitcoin is a peer-to-peer network, there is no central authority charged with either creating currency units or verifying transactions. This network depends on users who provide their computing power to do the logging and reconciling of transactions. These users are called "miners" because they are rewarded for their work with newly created bitcoins.

The protocol was designed so that each miner contributes a computer's processing power toward maintaining the infrastructure needed to support and authenticate the currency network. Miners are awarded newly created bitcoins for contributing their processing power toward maintaining the network and verifying transactions in the block chain. And as more processing power is dedicated to mining, the protocol will increase the difficulty of the math problem, ensuring that bitcoins are always mined at a predictable and limited rate. Bitcoin was designed to mimic the extraction of gold or other precious metals from the earth—only a limited, known number of bitcoins can ever be mined. The arbitrary number chosen to be the cap is 21 million bitcoins. Miners are projected to painstakingly harvest the last "satoshi," or 0.00000001 of a bitcoin, in the year 2140.

Crypto-currency transactions are (usually) anonymous, untraceable and might have created a niche for illegal transactions (e.g. money laundering and tax evasion). Because the currency has no central repository, law enforcement and payment processors have no jurisdiction over accounts. For crypto-currency supporters, this anonymity is a primary strength of this technology, despite the potential for illegal abuse, as it enables a shift in power from institutions to individuals.

2.3.3 Potential Socioeconomic Impact

In order to examine the impact and potential of the development and adoption of crypto-currencies one has to look for economic implications as well as on the scientific aspects of the supporting technology. Being a digital, virtual currency, its very nature is tied to IT capabilities, either for its algorithmic generation, for its peer to peer transaction and for it being essentially not tied to a physical repository thus a user's digital crypto-currency balance can be wiped out by a computer crash if a back-up copy of holdings does not exist.

On the economic side, one has to look at e-commerce issues but also examine the European financial regulation landscape, which has its own idiosyncrasies, due to the pursuit of the single market agenda that has produced a complex regulatory and institutional system. Perhaps because of speculators getting involved with crypto-currencies, such as Bitcoin, as an investment rather than practical currency, the value of Bitcoin has been extremely volatile over its short history. This, combined with security exploits, has tarnished the image of Bitcoin within the general public. The world's largest Bitcoin exchange—Mt. Gox, based in Tokyo—filed for bankruptcy protection in the United States in early March 2014 after halting transactions for a month in response to an alleged bug in the Bitcoin software.

While the double-spending problem is theoretically solved in the p2p architecture of BitCoin, in practice it is the lack of ACID compliance (transactional atomicity, consistency, isolation, and durability) within some transactional systems that continues to beleaguer many transactions and exchanges. Furthermore, Some crypto monies may suffer runaway inflation where others may not, depending upon the model underlying their implementations. The distributed BitCoin model, for example, is based on a hybrid fiat/representative commodity approach and its proponents claim that, despite the lack of central control, inflation is impossible because of the finite number of coins available. Economists and supporters of other money systems disagree. Whether this is true or not, it does not prevent unpredictable and wild fluctuations in BitCoin value.

The anonymity afforded by Bitcoin has made it popular as a medium for exchanges involving illicit goods. Websites such as the Silk Road—an online market primarily organized around narcotics—facilitated the exchange of illegal goods around the world. Although taken down by U.S. authorities in 2013, the Silk Road 2.0 launched soon after. One analysis estimated that approximately 4.5per cent - 9per cent of the Bitcoin economy moved through the original Silk Road website. Aside from the potential criminal elements entering the Bitcoin community, virtual currencies present a broader set of problems for the status quo of state oversight over currency transactions.

2.3.4 Envisaged Long-Term Evolution

It is impossible to predict where crypto-money will head in the longer term because it is so highly technology-based and its user communities are vigorously against any kind of official involvement or central control. All we can say is that it is here and will not go away without a fight. In the shorter term we can already see new approaches, which do not rely on mining (e.g. Rimbit), which claim to have devised a way to remove the wild value fluctuations of their competitor currencies. Furthermore, some governments have looked, or are already looking, into ways of adopting and regulating them. This implies a normalization of some, maybe even a fracturing of the community into users of regulated and unregulated crypto-monies.

2.4 Multi-material 3D printing, Contour Crafting and similar technologies

Additive Manufacturing (AM) or 3D printing is transforming the creation of physical 3D objects just as printing once transformed the creation and reproduction of 2D images. The cost and challenge of printing a 2D image from a digital source file is nowadays more or less the same whatever the complexity or level of detail of the image. This is extraordinary progress by contrast with the middle-ages, when documents were written by trained scribes and copied by hand. Although variation exists in the cost of image reproduction, these come down to the size and quality of the "paper" and the cost of the "ink". Complexity is no longer an issue and the great burden of effort resides in the conception or design of the image and no longer with the one who renders it. This the kind of transformation that is now happening in manufacturing thanks to the emergence of powerful new technologies for a phenomenon that goes by a variety of names including "3D printing", "additive manufacturing" and "desktop manufacturing". These trends go way beyond the desktop world of hobbyists and small entrepreneurs. They play an increasingly important role in mainstream manufacturing industries. They are driving progress in surprising new areas of construction, healthcare and pharmaceutical development.

2.4.1 State-of-Practice and Emerging Trends

Recent years have seen rapid growth in a form of 3D printing known as "desk-top manufacturing." This is a reference to the fact that a wide range of 3D printers, capable of printing complex 3D physical objects, even complex multipart objects that are impossible to construct using traditional manufacturing techniques, are intended for use by people working at small home offices and workspaces. The practical implication of this being that "making" things no longer requires a long series of steps whereby primitive pieces are cut, drilled and polished into component parts, to be later assembled by gluing, welding or bolting. The designer no longer has to spend so much time figuring out how a system will be made up of parts, how these parts will fit together and how the whole thing will be assembled. In many cases the maker only has to print the final object. This has given new energy the maker movement, a modern version of DIY, where people borrow or exchange designs for the things they want to build and improve them using their own insight as consumers or users, very much in the same spirit of the open-source movement.

Already two thirds of industrial manufacturers in the EU and the US use 3D printing techniques. Industrial giants such as Volkswagen, Ford and General Electric as well as Airbus and the European Space Agency are all using additive manufacturing in one way or another. Initially this was confined to the area of design and rapid-prototyping but it is increasingly applied to other areas such as mold-making and the manufacturing of final parts. Today motor vehicles and consumer products correspond to about 50per cent of all 3D manufacturing projects. At least one company, US based **Local Motors**, has developed a fully functioning 3D printed car. Its vision is for cars to be adapted to local needs using a co-design approach. It foresees production being done locally, based on a global network of "micro-factories." So far people from over 130 countries have contributed to the design of their cars and it intends to offer the first models for sale some time in 2015. It is interesting to note that whereas a traditional car can have up to 25,000 component parts, their design requires only 50 parts for assembly. This is a radical simplification of the production process and it will be interesting to see how the car fares, in terms of road worthiness and user satisfaction. Whatever the outcome for local Motors, it is surely not the last new automobile venture using this kind of a radical AM enabled approach to design and manufacture. A Japanese designer called Nori Kurihara founded the **Car Design Academy** in 2013. He is now offering online master classes on all aspects of car-design at a very reasonable price. Combining this possibility with access to finance via crowd-funding suggests that the barriers to entry into this market may be quickly coming down as the ability to design, manufacture and finance something as complex as a car or other vehicle for transport, is well within reach of almost anyone with the vision, ambition and energy to follow-through on a new personal or professional mobility concept.

Earlier this year Adidas opened a pop-up store in London to celebrate the 50th anniversary of its bestselling trainer shoe (the "Stan Smith"). The store sells limited edition shoes and includes an interactive store section that allows fans to design and (3D) print their own personalized lace locks for real time incorporation into the shoes they buy. Both Adidas and Nike have been using AM to speed up the shoe design process. It used to take 12 technicians 4 to 6 weeks to make shoe prototypes by hand. Now it requires no more than 2 technicians, and as little as 1 to 2 days to develop the prototype. Nike has also been following this trend. The savings in time and resources needed for prototyping mean that it was possible to cycle through many more design, build and test loops than is normally feasible, to develop a highly superior product. Of course these are not the only players in the game. A company called **Continuum Fashion** has developed a fashionable line of ready-to-wear shoes called **Myth**, it has also produced what it claims to be the world's first fully 3d-printed beach wear entitled **N12**, a little-black dress called **D.dress** for special occasions and a range of clothing products and accessories called **CONSTRVCT** based on a crowd-sourced design paradigm. Some industry observers consider that the large scale adoption of 3D printing in areas such as this will be driven by sports brands like Adidas and Nike.

Additive manufacturing is also being applied to construction. One such technology, developed by Prof. Behrokh Khoshnevis at the University of Southern California is based on (and called) **contour crafting**. It is a large-scale 3D printing or additive manufacturing technology that can be used to "print" objects such as panels, spars, stairs, doorways and window-frames, out of quick setting cement for use in construction. According to his claims it can be used to print entire two story buildings and colonies. The University of Loughborough already has a long history of carrying out research in this domain. Their technology which is very similar to contour crafting is called **freeform**. They see it as a generally applicable technology that enables innovative architects to build structures that would have been impossible to construct in the past. However they see limitations to the kind of structures that can be built in this way. Instead they prefer to see it as a catalyst for the introduction of automation in buildings on a much larger scale than used today, with ultimate benefits in terms of difficult or costly tasks such as retrofitting old buildings and transforming old buildings into more energy efficient and user friendly forms at affordable cost. Others see great potential in the use of AM to transfer the effort and cost of building more towards design or co-design with building users. Alastair Parvin of London based design firm 00 is one of the driving forces in Europe behind the Wikihouse project to globally co-develop open-sourced building designs and see AM as a way to make these designs realizable at lower cost. An important proof of concept project in Amsterdam is **called the "**3D Print Canal House project" led by Dutch architect **Tosja Backer.**

2.4.2 Envisaged Long-Term Evolution

There are over 30 different 3D printing technologies. It is possible to print with plastics, metals, glass and ceramics even wood and stone. It is also possible to print with food ingredients such as sugar and chocolate. One of the hottest areas of development right now is 3D bio-printing. That is the printing of biological artifacts using soft-tissue and living cells. The ultimate goal is to be able to "print" replacement organs such as muscles, kidneys, livers and human hearts. Extraordinary progress has already been made in this direction and a race is already on between teams across the world for example in the EU, the US and China to see who will be the first to "print" a healthy, transplantable fully functioning complex organ such as a kidney. Some teams claim they will do this within the next few years. Others estimate that it will take 30 years to achieve this. One of the biggest challenges is that any healthy organ must have a supply of blood, which means that the printing process must lay down blood vessels in sufficient density to irrigate all of the cells of the organ so that they get the oxygen and other nutrients they need to stay alive.

In summary a combination of powerful new design tools, easily accessible, low cost and increasingly capable 3D printing technologies and services, as well as powerful collaboration technologies based on principles such as co-creation and open-source hardware are challenging how and what is made in one industry after another. These trends are not limited to traditional manufacturing. They are challenging other industries such as fashion and clothing, shoes and accessories, the food industry, as well as construction, healthcare and medicine. It has simplified the task of manufacturing to the extent that the largest effort for many manufacturing tasks is now found in design and not in production. This has created a new and emerging generation of "makers" whose main asset is their imagination, and who no longer need to master complex manufacturing skills to make even complex objects, and which are looking at old industries in new ways as the basis for entrepreneurial ventures.

3. Combined Impact of New Internet and manufacturing technologies

3.1 Considering all four topics together

Considering the highest level of unification does not really help the discussion. The ability to foster online collaborative communities that are funded through cyber currencies and take big data inputs to create real world (3D printed) outputs at any connected location is so broad that it becomes meaningless. Good things and bad things can be done, just as in the real world. The problem becomes one of policing but that question is outside the context of this discussion except to note that it is an important part of any policy discussion in this area. However, it is worth noting that in developing nations, which currently lack the necessary conventional industrial infrastructure to support typical economic development, this model of collaborative funding and manufacturing may be very attractive. It is similar to the telecoms revolution which saw some nations bypassing copper and going straight to fibre, whilst others went further still and went straight to a 3G mobile infrastructure, especially in rural regions.

3.2 Combinations of fewer topics with collaboration as the common factor

3.2.1 The online collaboration perspective

Online collaboration has been with us for some time now. It started with the Open Source software development and Social Networking communities. Once these networked communities were established, people looked for new ways of benefiting from them, or more importantly, how others might benefit from them. Many examples exist where people have been brought together on FaceBook to scour aerial images for survivors after the Haiti Earthquake, where people have rapidly contributed to increasing the resolution of OpenStreetmap in disaster areas, to help emergency services gain access, and where software developers have collaboratively refactored code so that it could be very swiftly integrated into the platforms and unify the systems operated by aid agencies in emergency situations. Unfortunately, there are other examples of people collaborating to do bad things.

There is already evidence of online collaboration resulting in direct change to the material world, notably in the case of (3D printed) car design and manufacture. Although US based, Local Motors (**www.localmotors.com**) employs micro factories run by a global community, members of which collaborate to create large-scale products such as cars and motorcycles. Cars are already traded through online collaborative peered communities such as Beepi (**www.beepi.com**). Importantly, these are trusted communities; the owners work very hard to maintain this trust and use it in their advertising to increase membership. There are recent examples of people buying cars with crypto currency and this facility has just reached the mass market, also at Beepi.

3.2.2 Big/Open Data in the context of Collaboration

There is already visible evidence linking collaborative crowdsourcing as an input to Big/Open Data and its consumption there. Crowdsourcing already features among the most prominent of means of assembling/generating BigData sets for areas of high societal and economic impact. A good example is to be found in the healthcare sector where healthcare data collection is carried out through eHealth and mHealth devices and sensors. There are even social networks of patients (e.g., PatientsLikeMe) and collaborative mobile crowd-sensed preventative measures (e.g., air pollution monitoring etc.) In future, this approach could be enhanced and developed to embrace a wide range of Big/Open Data applications (e.g., broader environmental monitoring and ecological sustainability). The collective intelligence that relies on the wisdom of crowds may also play a part in the processing and analysis of this data as well as in its collection.

The creation of Big/Open Data sets may also serve as an incentive for businesses to work in strategically important areas. In other words, Big/Open Data could be seen as, and used as, a means of attracting / incentivizing contributors to the crowd funding processes, in the same way that businesses are attracted to regions that are well served with effective, relevant and affordable infrastructure. Once they are situated there, the businesses return considerably more, over time, to the region than the infrastructure cost to deploy.

The conventional manufacturing, as well as additive manufacturing, industries can use Big/Open Data for the creation of items which better match social needs and desire. It can also help the industry itself to radically improve maintenance efficiency and production efficiency through applying intelligent algorithms to analyse data collected across multiple plants. This is not such a large step, this kind of intelligence is already used in autonomous production processing and order handling, under the heading of Holonics.

3.2.3 3D Printing in the context of Collaboration

Collaboration in the context of software has been with us for some time. The advent of additive manufacturing heralds a new industrial eco-system where hardware can also be created collaboratively by highly distributed teams of people working towards common goals. In the same way that Big/Open Data can be seen as a means of attracting investors to the crowd-funding arena, additive manufacturing can be seen as a means of attracting people to Big/Open Data through the Open Source Hardware they create in support of (e.g.) IoT applications and related business models. For example the "Pi Top" maker-made laptop, featuring the Raspberry Pi motherboard, comes packaged with the 3D printing software and access to a data repository containing all of the (Big) data files necessary to manufacture its own case.

Bespoke clothing is seen as the killer app for 3D printing and is anticipated to drive the techniques into the general consumer market. Moreover, some brands are employing open source collaborations to design clothing lines, which can then be manufactured on the spot by anyone with a 3D printer and access to the data files. A less frivolous side to this capability is the reduction in the testing cycles of manufactured goods, the efficiency of which is dramatically enhanced.

3D printers are also starting to make their way into the food industry where they are planned for use creating socially responsible foodstuffs. Education has failed to stop people eating too much fat, sugar and salt; socially responsible collaborative 3D printing techniques are now being trialed in the context of gaining control over nutrition. The approach sees beneficial additives (e.g. minerals and vitamins) being added to the structure of popular foods such as ice cream and chocolate. With an ability to potentially change appearance, taste and texture, this type of additive manufacturing has the potential to fundamentally change society.

All types of artifact can now be printed, from belt buckles, through houses to aeroplanes and, of course, guns. The point is not now "what can be printed?" but "where can it be printed?" We could dwell on the security or terrorist threats posed by the ability to print a gun wherever it might be used but we will concentrate on the positive aspects. Exploration is a collaboration, especially space exploration. A driver for this collaboration in the past has been the need to find economies to reduce the financial burden on any one nation of launching heavy materials into space. It is not impossible now to imagine the manufacture of these materials being exported off planet to some extra-terrestrial location where local minerals can be consumed to manufacture all manner of artifacts on site. A more prosaic example of this exporting the manufacture of a good rather than the good itself is in housing where 3D printing is set to accelerate the construction process through delivering improvements in quality and quantity. If conventional construction practices can be thought of as a series of collaborations between various trades, then in this case 3D printing delivers a form of de-collaboration; however, other forms of collaboration ride on this function. New forms of construction collaboration lie in the area of design/redesign, maintenance and service delivery focusing on the relationships between (e.g.) landlord and tenant, or local authority and householder, or even parent and child.

At the lowest level every one of us is a collaboration between the cells in our bodies. There are predictions that organs and body parts can be manufactured through 3D bio-printing techniques within the foreseeable future. Of course such items will have to be constructed to exactly match the receiving body and the most reliable way to achieve this is (if possible) to use parts of the recipient as a source of donor material. In such a system, we would become self-collaborating entities: collaborating with (expert) others helping us to collaborate with ourselves: taking our own cells to manufacture replacements for our own malfunctioning organs, etc. Further new forms of collaboration may emerge based on the donation of personal stem cells and the provision of access to personal genetic data, which could be used to design and manufacture individually tailored and bespoke medical treatments. The data collected here will be in itself a source of Big Data and it could contribute to larger community-level Big Data. Whether this Big Data can also be Open Data as well depends very much on the ability of policy makers to remain aware of the benefits and costs associated with these technologies and that they are able to properly balance individual benefit with community benefit.

3.2.4 Crypto-Money in the context of Collaboration

Crypto currencies, like all modern currencies, are (to some extent) pseudo-fiat currencies and as such fundamentally depend upon collaboration and trust: collaboration and trust are the touchstones of any fiat currency. For any currency to function there must be widespread collaboration in the chosen exchange mechanism and trust in its utility. Trusted collaboration in a fiat currency is usually underwritten by a central bank of some kind, although there are still some surviving examples of older currencies (or more precisely: payment systems) which embody decentralised trust models. Crypto currency presents just another currency collaboration context, one that is not yet regulated by central authorities. So, other forms of trust mechanism must be discovered and deployed before widespread uptake can be anticipated. Trust has two main dimensions when considered in respect of crypto currencies. Externally, the public must trust the stability and durability of the currency, or they will not use it in sufficient numbers that will result in critical mass being achieved. Internally, the "bankers" must trust their own systems and technologies to perform in a predictable manner and deliver anticipated results in a uniform manner.

In the current cyber currency context there are examples of both of these areas failing and in these early days there remain many trust-based pitfalls to catch out the unwary, even amongst those who are directly involved in these initiatives. Not least of these is the ease with which the criminal leader of the Silk Road Dark Web marketplace had nearly his entire personal bit-coin account drained because of the poor ACID compliance of the payment system employed there, eventually leading to his arrest by the autorities. Members of the public will (rightly) not sign up to a payment system when this is still possible. It was because of his need to replace this loss, before moving on, that reduced his anonymity shielding and which directly resulted in his detection and detention by US authorities.

Although trust is the key to widespread uptake, there seems to be sufficient belief in trusted transactions for current early adopters to be already pioneering new online economic models. It is not inconceivable that means can be found to deliver the trust levels required for cyber currencies to start gaining traction in the general public.

Fiat currencies also create, or enable, the phenomenon of seignorage. Seignorage describes the effect of generating income from the production of currency which is worth less than its face value. Governments generate income through seignorage. How large will a government allow a decentralised virtual competitor to grow before it is has to act to protect one of its own revenue generation mechanisms? Moreover, how might taxes be raised on virtual goods or services paid for with a cyber currency? How might fraud and tax avoidance be detected and enforced?

Of course, cyber currencies might make it more difficult to detect and track terrorists, or to detect unwanted activities where outputs are virtual rather then real but they also open the door to the possibility of novel, innovative and potentially disruptive financial services.

3.2.5 Overall

The collaborative economy and the technologies supporting it enable few really new capabilities. Instead they offer new and exciting means of doing things in different ways. The environment that encapsulates these capabilities is no more benign than the real world. The online collaborative world is a new frontier and care must be taken when exploring it. Individually, we need to learn new ways of being safe, and for us collectively to feel that there is some form of control[2], or access to redress. The historical imperative shows us that frontiers are always pushed forward by pioneers, many of whom are not motivated through entirely wholesome ideals, and that these frontiers are often dangerous places. When society follows in the wake of the pioneers, social norms are developed and encoded in policies and laws. Is this a model for the future of the online collaborative environment?

In general, we assume that in joining these domains together we will experience multiplicative benefits and that these will increase the impact of efforts made in this larger space. However a joining together of capability domains necessarily entails a requirement for joint/combined policy formulation and community engagement. In areas where a strategic common good is recognized, some form of bootstrapping maybe required (possibly through public-private partnerships) enabling the creation of (parts of) this new industrial model. Such an approach is being taken by the EC in the context of the Big Data SRIA, which has been launched as a cPPP (**www.bigdatavalue.eu).** This initiative is taking on the role of creating a roadmap to define the process required for advancement from small pilots to large deployments in the Big Data area. Other such initiatives may also be required in the other three topic areas, if coherence between them is recognised as a good thing.

We must also consider the wider social and health issues associated with this acceleration in the way technology shapes the lives of citizens. To do this we will consider the bleakest of scenarios. Outside of the context of this briefing paper and workshop, synthetic meat has already been created. If now we add in the capability previously discussed to print biological samples, it is easy to imagine a time when it will be possible to print a meal on demand. Might that food be printed from recycled organic waste? If we no longer need to go out

[2] The alternative view is hard to argue against, where it is this lack of (centralised) control that allows (oppressed) minorities to come together in order to affect social change.

shopping or even cook our own food, we move further away than we already have from the "caveman' lifestyle our bodies were designed for. What will be the associated social and health implications? Will we be able to crowdsource a distributed remote medical intervention to graft in new personalized bio-printed organs and sculpted bio-printed body parts to replace those that have deteriorated though lack of use or abuse? If we no longer need to leave home, what will the cost be to society, at all levels, of everyone interacting and collaborating through virtual means instead of meeting for a chat in the street? If everything about life moves into the digital domain what will it mean to be human? And, what will happen to that humanity if some energy disruption causes a shortage or interruption in the electricity supply that the compute infrastructure supporting our virtualized lives will still depend upon? Will we see new Luddite-like movements resisting this change? Will they be led by farmers made redundant by synthetic printed food causing the closure of their farms, or by central and investment bankers made redundant by decentralized crypto currencies? With large chunks of a major source of secondary economic activity and a tertiary, yet primary, (capitalist) means of financial growth undermined, what will replace them in European economies?

4. Conclusions

This paper has been designed to set a context and to provoke thoughts leading to questions. We do not presume to draw conclusions just yet. We defer this activity until after the workshop, when we will have gathered the thoughts and opinions of a wide range of participants. The conclusions we then draw will be used to develop scenarios for the cultivation and refinement of policy recommendations, which we will subsequently present in a more detailed paper.

5. The Collaborative Economy Social Media

THE COLLABORATIVE ECONOMY

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