Editorial

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3D printing (also known as 'additive manufacturing' has attracted a lot of media attention recently, especially, after US President Barack Obama, in his 2013 second term State of the Union address, emphasised the possible critical role of 3D printing in strengthening manufacturing, scientific, defence and energy sectors. The strong potential of 3D printing was earlier noted by Karlgraad (2011), publisher of *Forbes* magazine. In particular, Karlgraad conjectured that 3D printing would become the "transformative technology of the 2015–2025 period". Likewise, Anderson (2012), Wired Editor, speculated that the "desktop manufacturing revolution […] will change the world as much as the personal computer did".

Recent works on 3D printing and digital manufacturing have indeed highlighted the transformative effects of these technologies. In particular, Ford and Despeisse (2016) find that 3D printing has the potential to enable sustainable manufacturing, hereby promoting

the shift towards a circular economy (Despeisse et al., 2017) and reaching global sustainability (Gebler et al., 2014). Petrick and Simpson (2013) emphasise that the 'economies of one' enabled by 3D printing and additive manufacturing created new rules of competition. West and Kuk (2016) show that the advent of 3D printing has provided a fertile ground for open communities that can be incorporated in innovation strategies. Finally, 3D printing and additive manufacturing have the potential to reconfigure business models (Rayna and Striukova, 2016), supply chains (Bogers et al., 2016), and promote open and user innovation (Rayna et al., 2015). Yet, while we now have a clearer idea of the potential impact of these technologies, much remains to do. As noted in Ford et al. (2016), the impact of 3D printing technologies is extremely broad.

While there are great expectations that 3D printing will lead to extensive changes in our economies, and numerous businesses across a wide range of industries have begun to look into the benefits the use of 3D printing could provide them, our understanding of the actual changes brought about by these new digital manufacturing technologies is still limited. The main objective of this special issue is therefore to bring together a variety of articles that shed a greater light on the transformational effects of 3D printing.

Understanding the future evolution of 3D printing also requires understanding its past. While the public awareness of 3D printing technologies has sharply grown over the past five years, 'modern' 3D printers have been around since the early 1990s. Yet, despite 3D printing being close to 30 years old, it is only rather recently that these technologies have started to have a sizeable impact, and even that tends currently to be restricted to niche markets (e.g., prosthetics, aerospace) or particular usages (e.g. prototyping and tooling). Considering the critical advantages these technologies provide, it could be argued that they have had, so far, a relatively slow adoption. To explain this apparent paradox, Roth adopts a long retrospective outlook. Arguing that 3D printing has, in fact, existed in different forms since at least the beginning of the 19th century, Roth proposes that the relatively slow adoption of the technology may be due to a confusion between form and medium and advises that to unleash the full potential of 3D printing, suppliers of 3D printers should focus on selling the process of 3D printing instead of the machines. For Roth, 'The cash is in the medium, not in the machine', which means that business models must be reconsidered to achieve a 'golden moment'.

3D printing is often associated with the rise of the 'maker' movement. The comparatively low cost of 3D printing – in comparison to other manufacturing technologies – enables virtually anyone to benefit from this technology. Of course, not everyone owns a 3D printer (far from it, in fact), but spaces, such as makerspaces and Fab Labs have emerged to bridge this gap and provide a wider access to the technology. Because 3D printing enables to prototype products at a relatively low cost, as well as to manufacture small runs of production without incurring the high-tooling costs associated with mass manufacturing, it is expected to have a transformative impact on entrepreneurship. This is this question that is explored by Mortara and Parisot. In particular, they investigate how Fab Labs and similar spaces enable entrepreneurship by transforming 'makers' into entrepreneurs. Using a grounded approach, Mortara and Parisot find that, indeed, such spaces foster entrepreneurship by reducing both the fear

of failure and the performance threshold. This is because 3D printing and the other technologies available in such spaces allow would-be entrepreneurs to "learn the skills and establish a correct set of routines to grow and survive". Moreover, Mortara and Parisot emphasise that Fab spaces enable 'high learning speed', which plays a critical role both at the beginning of the venture process (to understand the key features of the products and how to manufacture them) and at a later stage (to test the market and decide whether to scale-up their operations).

Because the effects of 3D printing are potentially so broad, one would expect differences to appear across regions. For this reason, the two last papers in this special issue investigate the impact of 3D printing and its adoption in different regions. Beltrametti and Gasparre investigate industrial 3D printing in Italy. Based on 48 in-depth interviews of a combination of stakeholders (e.g., entrepreneurs, managers of technology supplier companies, early adopters in the manufacturing sector, service-provider companies specialised in additive manufacturing, 'makers'), they find that the most prevalent usage of 3D printing in Italy is still rapid prototyping, with a few sectors, such as aerospace and biomedical, where end-use parts directly manufactured with 3D printers are becoming increasingly common. In addition to that, developments are currently undergone in a variety of sectors, such as the automotive industry, the dental industry, and the jewellery sector. Aside from these sectors, however, Beltrametti and Gasparre note that there is still no sign of a 'manufacturing revolution' in the consumer good industry, mainly because of the lack of competitiveness of 3D printing technologies in comparison to other manufacturing technologies. They emphasise that such 'revolution' in the consumer goods market may well never happen, unless a 'technological quantum leap' occurs.

Finally, Roth et al. investigate 3D printing in Finland and Europe using a foresight approach. Based on a study of 100 emerging technological cases in Finland, they find that while by 2015 many 'new technological breakthroughs relevant for 3D printing and industrial revolution' will have happened, many bottlenecks – related to skill gaps, uncertainties of existing efficiency potential, feasibility of 3D technologies, transition management models and associated path, legal constraints, and risk and threats associated with 3D printing systems and technologies – remain. Furthermore, uncertainties related to the availability of materials, and their sustainable use, the adoption and diffusion rate of new 3D printed products, and IPR issues make it very difficult to build a roadmap of market development through 3D printing. Finally, in regard to innovation policy, Roth et al. assess four different long-term scenarios ('global economy', 'local standard', 'sustainable times', 'focus Europe') and identify the 'local standard' scenario – which entails a decrease in globalisation, low integration of EU policies – the most favourable development from a 3D printing adoption perspective.

As a conclusion, the articles in this special issue show that despite its unique and highly beneficial features, 3D printing still has significant hurdles to overcome before it can achieve its full transformative potential. Thus, the much anticipated 'third industrial revolution' may well have to wait significantly longer than expected.

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