Technological Forecasting & Social Change xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

3D printing and the third mission: The university in the materialization of intellectual capital

Thomas Birtchnell [a,*], Tillmann Böhme [b], Robert Gorkin [c]

[a] School of Geography and Sustainable Communities, Faculty of Social Sciences, University of Wollongong, Australia
[b] School of Management, Operations and Marketing, Faculty of Business, University of Wollongong, Australia
[c] ARC Centre of Excellence for Electromaterials Science, Intelligent Polymer Research Institute (IPRI), University of Wollongong, Australia

ARTICLE INFO

Article history:
Received 30 September 2015
Received in revised form 21 January 2016
Accepted 18 March 2016
Available online xxxx

Keywords:
Triple helix
Additive manufacturing
Multilevel perspective (MLP)
Innovation systems
Prototyping

ABSTRACT

The production, diffusion and preservation of knowledge are the main goals of universities, which are critical nodes for mediating intellectual capital. In recent years, 3D printing (additive manufacturing) technologies are emerging as a possible disruptive or transformative force in the knowledge economy and by extension the material economy as consumers are given the affordance of materializing information into real-world objects. To understand the role universities will play in this potential convergence of the material and knowledge economies, this paper surveys current levels of involvement of tertiary institutions in 3D printing. The paper projects how the materialization of data will affect a range of social dynamics for creators-cum-consumers at different scales: community, region and nation-state and applies case studies to the multilevel perspective (MLP) framework. Studies are considered in three empirical cases: Berlin in Germany, Lancashire in the United Kingdom, and the United States. The research indicates that the National Additive Manufacturing Innovation Institute (NAMII) 'America Makes' Program is a top-down knowledge dissemination program for 3D printing. In contrast, the UK Lancaster University Product Development Unit (LPDU) is a 3D-printing value-network, which has developed organically over a decade of operation. Fablab Berlin is a local initiative loosely coupled with industry and tertiary education providers. The paper proposes a future-oriented conceptual framework to capture a variety of present-day university engagements with additive manufacturing in terms of intellectual capital.

1. Introduction

> Already, we've been able to get 80 cities to commit to working in a public–private partnership to generate more manufacturing efforts in their respective cities. We've created four high-tech advanced manufacturing hubs, and we have budgeted to create a whole lot more around the country. And some of it has to do with advanced materials, some of it has to do with 3D printing. The idea is, we start building an ecosystem, a network of companies, universities, researchers, and entrepreneurs, all of whom start really focusing and becoming experts on a particular facet of industries of the future.
>
> (Hudson, 2014: no pagination)

In this article we consider the materialization of intellectual capital. As academics reading this article will most likely know from their own institutional experiences, universities in the twenty-first century understand themselves to be driven by a 'third mission'. In short, the mission is for a university to operate in a similar fashion to a business. Akin to businesses, universities—that is, once the mission is met—will have clients, assets, shareholders and wealth creation. Highly ranked universities already produce a lion's share of the world's intellectual capital. The problem for many of them is how to capitalize on this knowledge in order to yield a profit. Although research that produces intellectual capital is a form of knowledge production universities must operate more entrepreneurially in order to secure value from their efforts, or so the mission statement goes. In harvesting and reaping information universities are lead participants then in the 'knowledge economy'.

As the quotation from US President Barack Obama at the beginning of this section shows, governments—also under pressure to operate more like businesses in this neoliberal era—are advocates of this mission too and channel resources into public universities in order to realize the goal of wealth creation. Universities make profit as businesses primarily through 'spin-off' companies from patents and marketable ideas. But benefactors and beneficiaries alike are now realizing that if universities truly seek to invoke wealth creation, as their driving modus operandi, they will also need to participate in the material economy too. Their activities will need to stretch beyond simply providing graduate training and research patents for companies to nurture and bring to fruition.

The concept of a third mission is also known as the triple helix: a triumvirate combining university, industry and government (Leydesdorff,

* Corresponding author.
E-mail addresses: thomas_birtchnell@uow.edu.au (T. Birtchnell), tillmann_bohme@uow.edu.au (T. Böhme), robert_gorkin@uow.edu.au (R. Gorkin).

http://dx.doi.org/10.1016/j.techfore.2016.03.014
0040-1625/

1996). Academic studies of this helix emphasize that communication between the distinct entities is vital for the equitable transfer of innovation going forward (Leydesdorff and Etzkowitz, 1998). According to Stanford University's Triple Helix Research Group, the thesis behind the concept is 'that the potential for innovation and economic development in a Knowledge Society lies in a more prominent role for the university and in the hybridization of elements from university, industry and government to generate new institutional and social formats for the production, transfer and application of knowledge' (Triple Helix Research Group, 2014: no pagination). So it is not just universities needing to undergo change—it is the entire triumvirate. No less than a systemic 'socio-technical' transition.

In this article we consider the theme of this special issue from the perspective of the future of mass-production, -distribution and -consumption—that is, the 'material economy'—and its possible future convergence with the 'knowledge economy' in light of the dramatic social change foreseen in the materialization of data due to the mass adoption of 3D printers (Ratto and Ree, 2012). 3D printers are already an interface between these two economies in materializing intellectual capital in the pre-production 'rapid prototyping' phase. Industrial designers make use of these technologies for prototyping single instances of test models quickly and cheaply before their designs are sent to factories for bulk volume manufacturing. Increasingly 'rapid manufacturing' is becoming the norm as custom parts in limited instances of finished products: automobiles, aeroplanes and other products made in minimal batches (Hopkinson et al., 2006).

The notion that the knowledge economy could converge with the material economy was intimated by a special section of this journal guest edited by Fred Phillips and Manabu Eto titled 'Revitalizing University Research and its Contribution to Society' in the 1990s. A key finding from that special issue was that in the future 'other new kinds of institutions will be needed to foster transfer of university research to society' (Phillips, 1998: 260). One particular phenomenon the special issue's guest editors flagged as demanding future inquiry was the 'hollowing out of industry' (Phillips and Eto, 1998: 207).

In the spirit of this special issue we argue that in light of 3D printing the material economy represents an area of engagement for universities, particularly in post-industrial states that have 'lost' capacity in manufacturing despite efforts towards 'leanness' and flexibility. Instead these states have become overtly services-focused catering to consumers of products mostly made in offshored manufacturing clusters and transported long distances by global logistics industries to be stored in bulk inventories. With the emergence of new technologies that do not necessarily interface closely with the current production–distribution–consumption triad, such as 3D printing, there are opportunities for universities in post-industrial states to fill the gaps left by past waves of offshoring and 'servicization' (Foresight, 2010; Urry, 2014).

Much previous research in this journal shows that many innovative technologies reach the market through collaborations of industry, government and university across differing scales and degrees. In the nanobiopharmaceutical sector university–industry patent collaboration is proving fruitful (Guan and Zhao, 2013). In the innovation of nano materials there is evidence the global corporation Samsung collaborates extensively with Korea's major universities (Ozcan and Islam, 2014). We suggest that, in the same fashion as these examples, 3D printers will become ubiquitous due to a convergence of the material and knowledge economies within the collaborative relationships of the triple helix.

A range of commercial and custom printing instrumentation is now available that can print a variety of printed objects from polymers, resins, metals and even biomaterials (so called bio-printing). There is also an expanding ecosystem where the technologies are used in a distributed manner: in small businesses and in the home for the personal production of mostly plastic prototypes (Amis and Silk, 2010). The commonality in the spectrum of 3D printing is the ability to take a digitally created object, and using a given layer-by-layer building technique, recreate that object in a physical form. It is critical to note that this process typically involves not only access and understanding of infrastructure, materials supply and specialized software, but also requires significant knowledge in design (to model the engineering of the final structure, scaffolding and the printability correctly and effectively) and further finishing (as objects typically need post treatments or cleaning).

In order to examine the future of the university in a world where 3D printing is ubiquitous, we first summarize in the next section the existing presence of 3D printing in the university system. In section two, we provide detail to our hypothesis that there is a convergence of the material and knowledge economies with 3D printing. In section three, we outline the methods for the case studies in this paper and the conceptual framework of the multilevel perspective (MLP). In section four, we provide three examples from the present in order to 'prototype' different futures for the university in light of 3D printing using abstract models and the MLP. Finally, we discuss the impacts of these different models on the social dynamics of intellectual capital as materialized knowledge.

3D printing is most advantageous in market environments characterized by demand for customization, flexibility, design complexity, and high transportation costs for the delivery of end products (Weller et al., 2015: 45). How does 3D printing fits into the so-called 'third mission' (Laredo, 2007) of universities—that is, in engagement with society beyond research and teaching? To answer this research question we consider the convergence of the material and knowledge economies through this new technological innovation that materializes digital data in a 'world-transforming' way (D'Aveni, 2013). Since the mid-twentieth century tertiary institutions underwent a transformation from being opaque, privileged 'ivory towers' to becoming transparent, open-for-business 'skyscrapers', both symbolically and in some cases literally (Etzkowitz et al., 2000). There are vocal critics of this push for a third mission and new 'social contract' between universities and their outreach targets, whether it is industry or government or both (Vavakova, 1998). In line with this special issue's mandate, we ask: how do universities make use of knowledge exchange with other parties to shape society?

2. Universities as 3D printing hotbeds

At first glance, the materialization of intellectual capital would seem to be the polar opposite of the focus of this special issue, namely, the knowledge economy and universities. Not so, in fact universities—as producers, diffusers and preservers of new knowledge—are inching ever closer to the material economy due to the emergence in recent years of 3D printing within research centres, design schools, laboratories and even academic libraries. Indeed, university libraries are the forerunners in the convergence between material and informational intellectual capital (Scalfani and Sahib, 2013). Invariably this innovation is in response to demand from engineering and design students for rapid prototyping tools. However, many institutions are taking this on board in a similar fashion to the provision of centralized paper printing services by purchasing and making available 3D printers to all students, staff and researchers (Pryor, 2014). Others, such as Dalhousie University, are innovating across the 3D printing ecosystem by establishing online repositories of intellectual capital in the form of 3D model file collections (Groenendyk and Gallant, 2013).

3D printing, known more formally as additive manufacturing, has had a renaissance in the last decade due to the commercialization of consumer level, mostly thermo-plastic extrusion, technologies and the consolidation of metal sintering in industry settings for end-user parts and products (D'Aveni, 2015). In part, 3D printers have become mainstream due to the introduction of open-source technologies to the consumer market; the recent demise of patents for metal 3D printing suggests further innovation, marketization and systematization of the technology for a broader range of products (Intellectual Property Office, 2013). A spate of start-up companies now offer consumer-level

Please cite this article as: Birtchnell, T., et al., 3D printing and the third mission: The university in the materialization of intellectual capital, Technol. Forecast. Soc. Change (2016), http://dx.doi.org/10.1016/j.techfore.2016.03.014