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Technology, innovation, employment and power: Does robotics and artificial intelligence really mean social transformation?

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Abstract
How far do recent innovations in robotics and artificial intelligence herald an unprecedented economic and social transformation? This article provides a critical evaluation of this question, challenging the relentless technological determinism of much debate, and reframing the issues involved within a political-economic and sociological approach. This focuses on the economic, political and historical dynamics of technological innovation, and its consequences for employment and economic restructuring, mediated through sovereign and discursive power. A range of epistemological and empirical problems with the transformationist position are identified, and an alternative perspective proposed emphasizing complexity and uncertainty around contemporary and future trends.

Keywords
artificial intelligence, employment, robotics, social transformation, sociology, technological innovation

Introductory comments

Concern with the social dynamics and consequences of new technologies based on robotics and artificial intelligence (AI) has become a major theme in academic, professional,

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public policy and business discourses. Within social theory, much effort has been directed to broad questions regarding the changing interface between humans and robots (Suchman, 2007). This includes a general blurring of biological–mechanical/human–machine boundaries (Arthur, 2009), the emergence of the 'post-human' (Braidotti, 2013; Hayles, 2008) and 'cyborg' (Haraway, 1985; Smith, 2007), the distinctiveness of human embodiment (Alac, 2009), and new understandings of the brain as 'social' (Restivo et al., 2014). Other studies have analysed new forms of sociality arising from increasing interactions with robotic companions (Turkle, 2012), normative models of 'the human' that inform the design of anthropomorphic robots (Suchman, 2011) and the way intelligent machine systems evolve as dynamic technological-cultural constructions (Dourish and Bell, 2011; Šabanović 2014). Within social studies of science, such questions have been integrated within more general studies of the assemblages and practices within which technologies and human activities are articulated, embodied and performed (Latour, 2005; Pickering, 2010).

A systematic sociological analysis of robotics and AI, drawing on wide-ranging theoretical resources available within the sociology of technology is currently lacking. Our aim here is not to attempt such an ambitious analysis. The more restricted objective is to provide a critical assessment of business and policy-orientated debates, which assume that robotics and AI will lead to an unprecedented social transformation in employment, arising from processes of technological innovation.

When the Council for Economic Development in Australia (CEDA) published its report on *Australia's Future Workforce* in the middle of 2015, its projections of high levels of job vulnerability under the impact of robotics (CEDA, 2015) mirrored similar findings overseas (Brynjolfsson and McAfee, 2014; Frey and Osborne, 2013; Graetz and Michaels, 2015; World Economic Forum, 2016). Extensions to the scope of robotics and AI are widely portrayed as destructive of future jobs, both for unskilled and skilled workers/professionals. The scale of employment vulnerability in countries like the USA, UK, Japan and Australia is measured at around 35–50% overall. How far employment destruction of this kind would be accompanied by new positive opportunities, and how far the effects would be thoroughly negative, remains open to debate.

Faced with such scenarios, some commentators make doomsday predictions of a dystopian future of robotic substitution for human labour and mass unemployment (Ford, 2015). This would not only destroy opportunities for paid employment but also transform structures of power. Others regard 'smart machines' as contributors to the dehumanization of work (Head, 2014) or as creating a cyberproletariat (Huws, 2014). In one way or another, control of information technology, robotics and AI, so it is supposed, will mean domination over society. These concerns clearly echo recurrent anxieties over the last two centuries about the domination of society by machines (Carr, 2014).

Radical changes of this kind are certainly of great contemporary concern for organized labour and social movements aiming to reverse the declining share of national income going to labour (Haldane, 2015), and enhance democratic inroads into corporate power. They also raise difficult questions about the ethical and legal implications of robot use in interpersonal settings. Such concerns are particularly acute in the use of interactive social robots within areas of human service delivery such as aged care (de Graaf, 2016).

In much business discourse, by contrast, intense technological change is subsumed under the norm of 'creative disruption'. This notion has broadened out from its origins in marketing (Dru, 1996) to become more closely involved with technological and organizational innovation. Within contemporary business rhetoric 'disruption' is regarded positively as the midwife of innovation, in contrast to Schumpeter's more double-edged concept of 'creative destruction' (Schumpeter, 1950: ch. 7). Business rhetoric about disruption should not be taken at face value. As outlined below, there is every reason to be sceptical about such claims because many innovations don't work or have a very limited impact that contrasts with the relentless optimistic hype surrounding them.

Another way of framing optimistic scenarios for economic change is through the idea of a Fourth Industrial Revolution centred on robotics and AI. This approach moves beyond notions of a Third Industrial Revolution, developed in the 1990s on the basis of computer technology (Rifkin, 1995). The more recent claim is that spectacular increases in data storage capacity, computation power and wireless digital communications, along with greater capacity to combine technological innovations, means that we are now fast approaching a transformational take-off point where robotics and AI will become a general-purpose platform. For Klaus Schwab, founder of the World Economic Forum, this Fourth Industrial Revolution mirrors three previous transformations associated with steam power, electricity and digitalization (Schwab, 2016). However, rather than subsuming creative disruption into an excited technological utopianism, Schwab relies on the historically grounded Schumpeterian observation that phases of intense technological change are episodic and discontinuous.

Much of the optimistic rhetoric surrounding discourses of technological transformation focuses, by contrast, on the argument that 'this time is different'. Arguments here propose that a radical change in relations between humans and machines means unprecedented challenges for human adaptation. Such arguments may be found in a discussion paper on 'robust and beneficial artificial intelligence' (Russell et al., 2015) circulated by the Future of Life Institute, a body made up of world-leading scientists, engineers, mathematicians, technology entrepreneurs, philosophers, economists and science communicators, committed to ensuring that emerging technologies work for the benefit of humanity. Yet the document itself conveys a sense of inevitability about the emergence of advanced AI systems, capable of delivering 'guaranteed benefits' (Russell et al., 2015: 2). It also uses a technocentric approach to technology-induced social problems, framing these in ways that render them amenable to further technological interventions. In all this the social sciences and humanities occupy a marginal and reactive position. The tasks assigned to social enquiry centre on enhancing social adjustment to technological change, notably maximizing 'social flourishing' in a post-employment world.

The technological determinism of this document is as striking as its atheoretical and ahistorical approach to relations between technology and society. The argument simply bypasses social theoretical issues to do with the 'hidden social conditions of existence' of new technologies and the complex discourses and situated practices within which 'technology', 'machines', 'human actors' and 'intelligence' are constructed, embodied and enacted (Latour, 2005; Suchman, 2007). Rather, engineering is the dominant frame, whereby autonomous technological solutions to problems should and will be adopted.

Whether this is inevitably so is not, however, a question that can be resolved by engineering discourse. This question requires analysis of the social and political context and consequences for technological diffusion. One key element of this broader social approach is the importance of power relations for the 'form, content, and outcomes' of technological change, an insight first elaborated by Marx (Spencer, 2016: 4). Spencer's political-economic approach is valuable, but there is equally a need for a discursive focus, especially in understanding the social construction of AI embodied robots and their interaction with human actors.

Our argument is, first, that the various transformative impacts claimed for robotics and AI cannot be assumed as inevitable, necessary or historically unprecedented. This analytical stand is one of scepticism rather than outright opposition towards the clamour of voices predicting a transformative technological revolution. It is also multidisciplinary, drawing on insights from economic history and economics as well as sociology, anthropology and political economy. Second, our position is one of normative openness as to whether radical technological change will have a positive or negative effect on economic life and social cohesion. The underlying theme here is one of complexity and uncertainty rather than technological utopianism or doomsday prediction.

What is new? What is different?

Attempts to understand processes of technological innovation and social change have two interrelated dimensions. Analytical questions focus on the nature of change and the reasons for it. Normative questions scrutinize how far changes have positive and negative characteristics judged according to a variety of yardsticks.

Two main analytical positions may be identified in contemporary debates. The first is that robotics and AI are simply the latest in a series of technological changes that are significant but not transformative. They may create serious technological unemployment but they represent no major new watershed in economic organization and no novel normative challenge to social life. The second is that robotics and AI represent unparalleled transformational change.

No real change

The 'no-real-change' position has recently been forcefully put by economists Gordon (2014) and Cowen (2011). They argue that the IT revolution has already occurred and has not yielded sufficient productivity gains to counter current economic headwinds such as an ageing population, falling standards of education, rising inequality and high levels of consumer and government debt. They conclude that new technologies are having nowhere near as profound an impact on economic productivity as steam, electricity or the internal combustion engine. This revival of an older line of thinking about stagnation trends in western economies (Hansen, 1938) poses a serious underlying challenge to transformationist arguments. On the one side is the historic experience of diminishing returns from the application of any kind of innovation; on the other, assumptions of constant growth at the heart of information technology, symbolized in Moore's Law predicting a doubling of computing power every two years.

One way of evaluating the 'no-real-change' argument is to consider longitudinal evidence on new technologies, including robotics, to establish trends over time. Graetz and Michaels (2015), the first major study to examine claims about the impact of robotics on productivity and employment, used the large historical datasets produced by the International Federation of Robotics (IFR). This research demonstrates that the increased use of robotics between the mid-1990s and mid-2000s depended in large measure on significant cost reductions for robots. Robot densification increased at a rapid rate in sectors such as transportation, chemicals and metal-working. This led to increased productivity, though by the end of the decade studied diminishing returns set in to further investment in robots. The pace of robotic diffusion of this kind appeared to slacken, though there are uncertainties regarding controlling for variations in the service life of robots influencing depreciation and re-supply. Adverse effects on employment were nonetheless found, especially at the low-skill end of the labour market.

Any such support for the no-real-sustained-change argument must be heavily discounted, however, given the data analysed focusing on first-generation industrial robots, not the later generations of physical robots, soft bots, social robots and the host of robotic technologies that collect, interpret and learn from Big Data. Annual IFR data for 2014–15 show a significant increase in domestic and professional service robot sales (IFR, 2015: 1). While more longitudinal evidence is required to make sense of such trends, it is possible that longer life cycles for certain kinds of robots – especially those that can adapt to and learn from their environment, thereby lessening any need for extensive retooling to take on new functions – complicate any smooth upward trend line. The productivity benefits of social robots are nonetheless unclear given their very recent and uneven introduction.

Comparisons with steam or electricity also need to be treated with care given that these technologies had a revolutionary impact only once they became general-purpose platforms (Nye, 2007: 43–5). How far then, can robotics/AI be considered such a new platform?

Taken at face value, the massive expansion of 'smart machines', as Sachs and Kotlikoff (2012) point out, has a striking impact on 'our' lives (or at least the lives of wealthier western populations). They 'collect our highway tolls … take our blood pressure … give us directions, transmit our messages, rock our babies, fly our planes, teach our children, kill our enemies …' (2012: 2). This is a list that could be radically extended to include items like 'drive our cars', 'participate in our surgery' and 'manage our power storage', as well as performing functions beyond the world of private consumption, such as 'monitoring our movement through city streets' or 'tracking our mobile phones and our phone traffic'. This list, it might be noted is culture-blind, avoiding any engagement with who the 'we' is at the heart of 'our' experience of change, as well as blind to inequalities in the development and reproduction of smart machine technology. It bypasses the anthropological insight (MacKenzie, 1998: 6) that technologies have a different meaning and significance for different social groups.

Underlying this seemingly growing list, nonetheless, is the crucial question of how far AI can extend the scope of its operations into areas once thought to be the sole preserve of human intelligence? Is there anything smart machines cannot do? For those who claim we are indeed undergoing a profound transformation around robotics and AI, the answer is far less than was once supposed.

Very real transformation

The 'no-real-change' position is very much a minority standpoint in the face of a second analytical position, namely that technology and society are in the process of radical transformation. Those who think this way take contrasting normative positions – optimistic (Brynjolfsson and McAfee, 2014; Susskind and Susskind, 2015) or pessimistic (Ford, 2015; Huws, 2014; Spencer, 2016) – on whether such changes will improve or undermine economic welfare and social cohesion. Yet they share the belief that radical technological change is very real, and novel in its challenges and reverberations.

Research into the impact of robotics/AI on employment, cited at the outset of this article, has done far more than demonstrate transformational job loss in unskilled work. Earlier work on the impact of computer technology (see Powell and Snellman, 2004) showed labour market polarization, with diminishing demand for unskilled work in wealthier economies and increasing returns to educated labour. More sophisticated research by Autor et al. (2003) placed more emphasis on the distinction between routine and non-routine employment, with routine work – both manual and white-collar – facing the greatest threat.

More recent research, however, indicates that some non-routine cognitive tasks are now being performed robotically, and that the service sector, source of most recent employment expansion, is under considerable threat (Brynjolfsson and McAfee, 2014; Frey and Osborne, 2013). One of the most provocative versions of this argument is the claim that technology will transform the work of experts, dismantling the existing professions (Susskind and Susskind, 2015). The combination of robotic advantages in manual dexterity and precision is already influencing surgery and architecture, while robotic sensing and companionate robots also affect professional employment in health and community services (2015: 166–75). More complex possibilities, including complementarities between professionals and robotics, are noted but not explored further. The Susskinds' tone is very much that of the relentless and 'irreversible' (2015: 1) onward march of robots. This, combined with popular internet access to information and pressures to democratize professional monopolies, generates a bleak future for levels of high-end service employment based on past professional norms and privileges (2015: 264).

This scenario, however, is presented without any concern for limits or uncertainties. Rates of smart machine diffusion are not a matter for close scrutiny, with technological innovation alone considered a sufficient basis for this scenario, without any concern for issues of diffusion, cost or social acceptability.

While there is plenty of evidence of changes in service employment across the range of skills involved, there is no clear evidence of a general threat. Haldane (2015), for example, using UK data analysed by the Bank of England, notes that accountancy positions have a 95% vulnerability to extinction due to robotics and AI, whereas for hairdressers the figure is 33% and for economists only 10% (2015: 13). So, while certain kinds of service positions, including some non-routine and professional occupations, are very vulnerable, the imminent collapse of service employment or radical decline in professional work seems exaggerated. Transformation is real, but only goes so far. How then to understand this complexity?

A good deal depends on what are taken to be the drivers of employment transformation. For technological determinists like Ford (2015: 61), the question of whether smart machines will displace human labour ‘will be answered by the nature of the technology that arrives in the future’. There are, however, contrasting perspectives on the future of work. One argument drawn from economic history is that while technological transformations typically erode or destroy some occupations, new occupations are also created through the transformation process (Mokyr et al., 2015). This happened in the epochs of steam power and the factory system, electricity and digitalization, and will too, so the argument goes, in robotics.

The mechanisms involved in new activities and forms of employment include the cheapening effect of technological change in one sector on other parts of the economy. Cheaper power, steel or information technology, for example, create opportunities to develop new processes and services. These emerge even when the benefits of productivity increase accrue more to capital than labour or to those with greater skill and status. Even if those displaced are not direct beneficiaries of these changes, aggregate demand for labour in the expanding economy typically increases insofar as productivity and real incomes increase (Autor, 2015)

In the mid- to late 19th century, losses in agriculture and some craft areas were offset by increasing industrial employment and the expansion of business and retail services. Examples of unpredicted areas of employment expansion in recent times include cyber security work, exercise trainers and personal beauty consultants (Mokyr et al., 2015: 36). It is difficult to predict future areas of occupational expansion with automation and social robotics. But plausible examples might include robotic maintenance and repair work, or concierge services on driverless vehicles.

Economic history and political economy also draw attention to the corporate strategies behind decisions to adopt or reject technological innovation. These take account of the costs as well as benefits of technological change, including the risks as well as opportunities promised by innovation. Concern about the costs of new technological innovation may delay or postpone its introduction, especially where financialization creates pressures to short-term profit maximization (Spencer, 2016: 6). In a globalized environment, decisions are clearly taken without any commitment to protect employment in a particular locality or nation, or to opt for capital-intensive rather than labour-intensive or cheap labour options. The spatial location and skill mix of employment opportunity is far too complex to be read off from ‘the nature of the technology’.

Spencer’s (2016) critique of Brynjolfsson and McAfee, makes the point that technological change is typically treated as a neutral background force rather than processes linked with the politics of production and the structure of power. For Spencer, following Marx, most technology arises in situations of inequality and contributes to its reproduction (4-6). Technological diffusion is dependent, in part, on political structures that are capital-supportive and capable of neutralizing dissent. The key question concerns who controls digital technology, robotics and AI-based intellectual property, and why political regulation of these areas is typically weak. For Krugman (2012), any aggregate increase in real incomes per head could well be accompanied by a situation where wealth-gains simply ‘accrue to whoever owns the robots’. Missing from the research so far is a systematic study of who owns the robots, including the intellectual property embodied in them.

Further complexities arise when cultural preferences associated with human as opposed to machine delivery of personal services are considered. Do citizens and consumers find social robots acceptable or is there resistance to their presence in service delivery? There is some research into cultural attitudes to robots and whether these vary by age, national culture and so forth (Li et al., 2010). But there is currently insufficient evidence to resolve questions of acceptability. For Haldane (2015: 14), a good deal depends on whether consumer and citizens continue to want their hair cut, their children taught and elderly care delivered by human beings. To the extent they do, many services are safe from transformational loss of employment.

Our arguments here share much in common with those historians and sociologists of science and technology who point up the crucial role of social, cultural, economic and political factors when seeking to account for the development, deployment and dissemination of technologies and technological systems (Nye, 2007). To highlight the ‘non-technological’ is not, however, to deny to technological objects any social shaping powers altogether. In this regard, Winner’s (1980) discussion on the political properties of artefacts is instructive. Here two broad categories of cases in which technologies/systems might be said to exercise power are suggested. The first entails instances where technologies are supportive of, deepen or extend existing arrangements of social relations that systematically privilege some social groups at the expense of others. Contemporary examples involving robotics/AI might include Irani’s (2015) discussion of the ways the Amazon Mechanical Turk enables the offshoring of data processing tasks, or the implications of domestic robots for everyday gendered relations (Fortunati et al., 2015).

The second concerns the inherently political nature of technologies/systems. Here Winner distinguishes between stronger and weaker variants. In the former, a given technological system requires, as its operating environment, the creation and maintenance of a particular set of social conditions. Carr (2014: 211–32) approaches something like this when he discusses the anaesthetizing effects of automation: the diminishing skill demands made upon workers or the ever-increasing technological interventions in people’s perceptual and material dealings with the world, leading to forms of disengagement not experienced with earlier generations of tools. The impression gained is one of robotics/AI initiating a sort of zero-sum transfer of agency from humans to technologies with the only real options being passive acquiescence or resistance.

The weaker variant offers a far more nuanced prospect wherein a given technology ‘lends itself’ to, or is compatible with particular social arrangements – in keeping with the notion of ‘affordances’. Here technologies can offer hitherto unthought of possibilities for acting and thinking, resist or frustrate our plans prompting modification and learning, or startle us with the “slight surprise” of realizing that our plans have been overtaken by the actions they initiated (Latour, 1999: 26692). In other words, agency is better seen as distributed among, as a function of the relationships between, humans and technologies (among other things) rather than something that can be zero-summed.

This view of humans and intelligent machines caught up in a dynamic and creative embrace is consistent with evidence from small-scale production where robotics/AI have served as catalysts for reskilling, including the development of new forms of craft expertise along with the revivification and repurposing of older craft knowledge (Gibson and Warren, 2016), and the joint engineering–arts experiments with human–robot interaction carried out by the Creative Robotics Lab, University of Sydney (Velonaki and Rye, 2010). It also accords with Arthur's (2009) complex-systems theoretical model of economy-technology co-evolution, in which a constant generative interplay of technological possibilities, problems and economic needs calls forth social arrangements, these creating further possibilities, problems, responses 'and yet further arrangements' (2009: 201). The dramatic proliferation of combinatorial possibilities that digitalization enables serves to take the 'messy vitalism' and global reach of complex socio-technical systems to unprecedented levels (2009: 206–11). What remains muted in Arthur's account is the way further increases in complexity emerge through the intervention of social and cultural factors – often driven by a desperately felt urge to reduce complexity (Nowotny, 2005). Here normative questions become a part of the empirical material that analytic questions work over.

Returning to the argument that 'real change' has occurred, the strongest counter-argument against the 'no-real-change' position is that an interconnected bundle of technological changes is approaching a transformational take-off point, from which will emerge a general-purpose platform – the recently observed slowing of Moore's Law notwithstanding (Cross, 2016). This bundle includes spectacular increases in data storage capacity, computation power and wireless digital communications, together with greater capabilities for combining technological innovations, robotics and expanded forms of AI. Interactive or 'social' robots are now expanding beyond factories into hospitals, care facilities, educational settings and households (Siciliano and Khatib, 2008: 1–2). Many depend on AI developments moving through areas of cognition such as visual perception and speech recognition into 'deep learning' (Pratt, 2015). Innovations such as cloud robotics generating Big Data seem likely, in this view, to permit memory-based deep learning in robots, thereby extending their functionality, especially where they can learn from human agents through interaction.

The AI/robotics platform is possibly the most powerful way of understanding what is new. A crucial element here is the interrelated extension of robotics and AI into sectors of the economy such as services, and into aspects of social life such as consumption, transportation and even the creative arts, previously thought to be resistant to robotics and AI (Autor et al., 2003). Examples include driverless cars, and specialist search programs for legal cases. Meanwhile, within professional discourses around health and caring, as well as education there is evidence that robotics/AI has already begun to open up new advances in practice (Bemelmans et al., 2012; Compagni et al., 2015; Mubin et al., 2013).

The list of robotic/AI-enhanced extensions into broader aspects of social life is impressive. Yet much of the literature cited reveals the experimental character of a great deal of the work conducted, and methodological difficulties in measuring how far specific robotic applications actually work. Nor is there any precise way of determining the employment consequences of such initiatives should they be introduced. Clearly service work will persist, including many aspects of the interpretive work of professional practice as well as very cheap labour in areas like cleaning and domestic service. As with robots used in manufacturing, there is no compelling sense that robotics is applicable to all sectors of activity, or that craft-based or human-interpretive forms of employment will necessarily be eroded.

Another way of understanding the key transformational platform involved in technological change is through idea of 'an internet of things' (Greengard, 2015). This has been defined in terms of the internetworking of physical devices (such as smartphones, household appliances and fitness wristbands) which have electronics, software and sensors embedded within them. These enable intercommunication through data exchange without human-to-human or human-to-machine interaction. According to Lucas et al. (2012), this process is rapidly creating a trillion-node network highly autonomous of human activity, unlike the internet and social media. This ambient technology is largely invisible but has been seen by its promoters as offering forms of light-touch interconnection, capable of a sustained transformation of social life.

Recent work by Thrift (2014) on the 'sentient city' draws on such insights to elaborate a social geography of the self-aware city. The linking of Big Data to consumption behaviour, human location and mobility through machine–machine interaction creates an invisible electronic conversation. More than half of all internet activity is robotic exchange between machines (Madrigal, 2013). This not only takes place outside human perception but also sets boundaries to human perception (Thrift, 2014: 9). In material spaces, such as cities, multiple sensors both monitor social activity and are implicated in the representation of spatial patterns through data feedback and machine learning.

While there is an element of speculative futurology in this argument, there is also a very plausible sense that relations between technological things have emerged as a potential general platform for social life. This line of argument does not get directly at power relations behind the internet of things, but it does move the discussion some way beyond the liberal light-touch world of innovators and consumers depicted by Greengard.

We have already flagged certain problems and limits to the transformational all-change argument. One is the historical argument that there are periodic cycles of technological transformation and anxiety about effects on employment and social cohesion. Transformations do happen but not entirely as their proponents plan or expect. Even if the no-real-change position is untenable this does not mean all is change, or that current changes are unprecedented in their transformative potential.

Another difficulty with the all-change position is that the rhetorical force with which it is set forth is not matched by clear unambiguous evidence. We see this in relation to difficulties in determining trends in employment of various kinds, and in problems in evaluating how far recent forms of robotic development actually work. Many of these problems raise intrinsic difficulties of understanding the future, when we extrapolate visions of the future from an evidence base which is unclear, ambiguous and subject to hyperbolic rhetoric.

In the light of these considerations, we sketch out a third alternative analytical approach to contemporary technological changes that recognizes complexity and uncertainty, couched in a sceptical sociological approach rather than prophetic mode of discourse.

Complexity and uncertainty: a sociological perspective

Analysis of future trends always has major epistemological (Adam, 2006) and ontological (Selin, 2008) limitations. For Adam, direct knowledge of the future is impossible. Even though members of all human societies want to know what will happen, neither futurology, forecasting nor the exercise of foresight can avoid this problem. We do not know with any certainty what will happen, or even if trends apparent over the last year or decade will continue, be arrested, or supplanted by significant cross-trends and alternatives. Epistemological caution is even more necessary when faced with the pervasive rhetorical certainties of technological determinists.

For Selin, 'the ontological indeterminacy of the future means that it is not possible to know the future because we are always creating and actively recreating the multiple futures, any one of which may (or may not) actually emerge' (2008: 1888). While this critical line of analysis was developed to critique predictions about nanotechnology, it is also highly relevant to debates over the impact of robotics and AI. Selin, like Adam, sees the need to critically evaluate the range of legitimizing discourses about technological change – whether regarded as inevitable and beneficial, or dangerous and dystopic. This is because stories about technological change do not simply sit above technological innovation and diffusion but help to constitute and direct or re-direct change itself. This widens the familiar political-economic emphasis on the sovereign power of the owners of technology to embrace notions of the discursive power of technological rhetoric about social change.

In a ground-breaking study, Dourish and Bell (2011) describe how the stories created by the pioneers of ubiquitous computing (ubicomp) served both to ground, for non-technical audiences, the new realities of human–computer interaction they envisioned and, for researchers, to organize, articulate and motivate the research programmes that would make these promises real. Echoing Weiser's classic 1991 *Scientific American* article 'The Computer for the 21st Century', these 'technotales' are marked by a confidence in the inevitability of ubicomp, yet tend to be written in the 'proximate future' tense. This sense that the realization of ubicomp sits just over the horizon persists, perpetually postponed, some twenty years after Wieser wrote, and at a time when many ubicomp innovations have, as he anticipated, become genuinely woven into the fabric of everyday life. For Dourish and Bell this is because ubicomp has, through the very processes of its realization, taken on forms that differ markedly from those envisioned. In particular, neat and tidy visions of homogeneous platforms and seamless interconnections do not square with the messiness that is the reality for any heterogeneous technological system. The messiness, for example, attending infrastructures requiring continual maintenance, repair or upgrading, regulatory authorities and standards committees finessing conflicting demands, or social and cultural practices that incline towards 'disconnection, seams, and discrete realms of activity' (Dourish and Bell, 2011: 22).

The third alternative to the 'no-change', and 'all-change' positions also places uncertainty and complexity at the centre of analysis. Empirical problems arise because it is hard to identify the current status of very experimental reported technologies. Do they really work and will they successfully overcome various hurdles – technical, regulatory, or in terms of social acceptability? Not everything is experimental, in the sense that driverless cars, or medical and educational robots are already in use. There is, nonetheless, an important distinction in economic history between technological innovation and diffusion that can usefully be brought into the analysis. In other words, how far and in what ways are technologies diffused? Answering such questions sheds further light on the scope for and limits of technological diffusion. This is because it brings social and political as well as economic processes into the analysis of technology and social change.

A very important longitudinal case study of the diffusion of surgical robots in Italy between 1999 and 2010 provides a detailed social scientific account of the scope and limits to technological change (Compagni et al., 2015). After the USA, Italy was the most prominent location for the introduction of surgical robots at this time. Given the uncertain, episodic and uneven character of this kind of technological diffusion, this research rejects both technological determinism and rational choice as explanations of observed patterns. Analysis is, by contrast, both organizational and social actor focused. The key question is why surgeons, administrators and health policy makers in a range of hospital and regional settings were either early adopters, subsequent adopters or have chosen not to adopt such technologies. This is explored through a mix of quantitative and qualitative methods, including over 100 interviews with adopters and non-adopters, and documentary analysis of agency and committee deliberations.

Framed within organization and management theory, this account is strong on the micro-level processes by which early adopters deploy the discursive practices of 'exemplary usage' to overcome uncertainty about the efficacy of new technology, and overcome scepticism. Early adopters were often in a peripheral structural position within smaller private hospitals looking to expanding markets in urological surgery, rather than large public hospitals more concerned with cost–benefit anxieties about large investments in new technology. Scepticism was partly overcome by earlier adopters' deployment of high-level training initiatives and peer-group fears of being left behind by ignoring what appeared as 'exemplary practice'. Even so, not all sceptics were convinced, partly on grounds of cost, and partly through difficulties faced in some surgical specialties, notably cardiac surgery, that the technology had any beneficial effect.

This case study confirms that the uptake of technological innovation is neither inevitable nor relentless – something that we must wake up to or face very negative consequences. Neither is technological diffusion dictated by an unambiguous singular rational engineering efficiency linked with innovation. Sometimes there are other rational cost–benefit calculations at work. But in other cases, as Compagni et al. (2015) point out, diffusion may happen even if it is not clear whether there are any tangible benefits from adopting new technology. This may occur (2015: 263) because of the coercive political-economic pressure of resource-holders (e.g. hospital owners or regional politicians). But it may also arise through the 'discursive persuasion' of high-status 'exemplary users' (2015: 267). There are, in other words, both macro and micro-level influences at work in what is a highly complex and uncertain process.

There is at present insufficient longitudinal and qualitative research to produce a consolidated statement of the limits of technological diffusion. Much depends on how far social robotics, as distinct from the physical robotics discussed here, evolves. Yet even without the benefit of further experience, there remain serious epistemological, theoretical and empirical problems with the argument 'this time is different'. For this reason, future research in this area would do better to develop a broader research program than is possible by focusing on the single hypothesis of radical transformation. There is an important distinction to be made here between enumerative induction, where evidence for or against a single hypothesis is evaluated, and eliminative induction where alternative interpretations can be assessed in parallel. Without such a multidimensional research program, it becomes very hard to recognize complexity and uncertainty, and thus the scope and limits of various types of technological change.

Conclusions

'This time' is both distinct from and similar to what went before. And just as before, technological change has transformative potential as well as uncertainties and limits. Yet in public debate the rhetorical momentum in business and policy making is behind the technological determinists. In this article we argue that social scientific and sociological perspectives offer ways of securing a less deterministic analytical approach that is sensitive to power and to uncertainty. While we do not address normative issues directly, the third analytical perspective sketched here has normative implications in that it raises the possibility of alternative futures, against which the robotics/enhanced AI thesis may be evaluated. The possibility of futures other than the dystopian or utopian strands of the radical change thesis, allows an array of competing hypotheses about future trends to be articulated and evaluated against a plurality of normative viewpoints. Such an exercise is crucial if a deliberative democratic discourse is to emerge around new technology.

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