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Robots and AI at work: the prospects for singularity

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This paper seeks to address emerging debates and controversies on the impact of robots and artificial intelligence on the world of work. Longer term discussions of technological 'singularity' are considered alongside the socio-technical and economic constraints on the application of robotics and AI. Evidence of robot 'take-up' is gathered from reports of the International Federation of Robotics and from case vignettes reported elsewhere. In assessing the contemporary relationship between singularity, robotics and AI, the article reflects briefly on the two 'tests' of artificial 'intelligence' proposed by the pioneer computer scientist Alan Turing, and comments on the efficacy of his 'tests' in contemporary applications. The paper continues by examining aspects of public policy and concludes that technological singularity is far from imminent.

Keywords: Alan Turing, artificial intelligence (AI), computerisation, digitalisation, new technology, robots.

A recent report by the World Economic Forum (WEF, 2017) predicted a sea change in the net effect on job totals as robotics and artificial intelligence (AI) systems are increasingly introduced into the workplace. In the past, job displacement by new forms of computerised technology was compensated for by job growth in other related areas. The WEF report suggests that this trend may be reversing, so that the net effect of robotics and AI will be to reduce rather than increase jobs. Moreover, there also appears a lack of governance of the impact, in so far as 'AI development has occurred in the absence of almost any regulatory environment' (WEF, 2017 p 50). The report follows academic commentary which also offers a prognosis of net job loss. In terms of calculating risk, Frey and Osborne (2013) suggest that almost half of all occupations and their related jobs in the United States may be under threat of disappearance in the next two decades. Ford (2015: xii) predicts that work will be transformed in a way 'defined by a fundamental shift in the relationship between workers and machines…machines themselves are turning into workers, and the line between capital and labour is blurring as never before'. More recent studies have been more cautious in their predictions. Evidence assembled by the consultants PwC from a variety of academic and government sources, suggests that whilst being disruptive to labour markets 'any job losses from automation are likely to be broadly offset in the long run by new jobs created as a result of the larger and wealthier economy made possible by these new technologies. We do not believe, contrary to some predictions, that automation will lead to mass technological unemployment by the 2030s any more than it has done in the decades since the digital revolution began'. (PwC, 2018). In terms of occupation, the evidence

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drawn together by PwC (2018 p3) identifies the likelihood of the most dramatic changes in use in the transportation sector (especially if 'driverless' cars develop), and in financial and legal services, as algorithms are increasingly applied to checking processes. There is general consensus among case and predictive studies that less-skilled manual jobs are more at risk from robotic displacement than high skill jobs. Person to person service jobs (e.g. health and social care including social work) are the least likely to be at risk.

Apart from the effect on jobs, debate has focused on the disruptive and potentially transformative effect of robotics and AI not only on the world of work but society more generally. We have seen the introduction of new concepts fed by knowledge-based digital work such as 'immaterial' (Hardt and Negri, 2000) or 'free' labour (Terranova, 2003), as well as a description of a new form of 'technological singularity'. Singularity refers to an end-point which, in the words of Good (1965) envisages a world where everything is done and made by an ultra-intelligent machine able to 'surpass all the intellectual activities of any man however clever……..(so that) the intelligence of man would be left far behind'. The debate has entered popular journalism, with a vision of 'post-capitalism' introduced by Paul Mason to include a vision 'whereby human labour becomes redundant, the long-term tendency of the rate of profit to fall is consequently made obsolete, and where knowledge-driven production tends toward the unlimited creation of wealth, independent of the labour expended'. (Mason, 2015: 136). Public policy and political considerations have entered the fray. The UK Labour Party, for example, with an eye on government has joined the debate with some vigour. Its 2018 report to Labour's shadow chancellor John McDonnell on 'Alternative Models of Organisation' warns of the dangers of job loss and suggests that 'machine learning, robotics, automation technology, artificial intelligence, the Internet of Things, digital technologies – mean the coming wave of automation may well be different'. (Labour Party, 2018 p 8). Part of the response, according to an earlier assessment by McDonnell, should be to embrace 'socialism with an iPad' by investing much more in skills and technology (McDonnell, 2015). The European Parliament of the EU has also voiced its concern and is to consider the introduction of legislation granting self-learning robots the status of 'electronic personality' which would allow them to be given legal responsibility for their actions and subject to legal action against them should they go 'rogue'. (European Parliament, 2017). However, the supposed disruptive and transformative effects of digitalisation and computerisation have been questioned. The latest major study conducted by US-based economist Robert J. Gordon of technology in the United States entitled *The Rise and Fall of American Growth* (2016) concludes that the IT revolution has led to less significant changes in productivity than a host of other technologies including the telegraph, the electric light, or seemingly more mundane innovations such as indoor plumbing and urban sanitation. The main reasons given for the caution about the degree of disruption and transformation rest on the technical, legal and social constraints to the introduction and activation of robotics and AI.

There is clearly a debate to be had, not only on the interpretation of data, but also on the balance between *disruption* of the labour market, and its potential *transformation* into a world of work where human labour is redundant. There are concrete reasons why catastrophic views for the future of human labour might be treated with caution. As Nolan and Slater (2011) remark 'The narratives are typically light on theory, resistant to grounded historical and institutional interrogation, and commonly substitute anecdote for searching empirical analysis'. A more grounded 'socio-technical' approach (MacKenzie and Wajcman, 1985) is needed to address these deficiencies of analysis and to reveal technical, legislative, economic and societal constraints to the process of change. The beneficial effects of robots and AI to the employer may also be overstated, thus restraining adoption of such new technologies. Productivity improvements, for example, may have only a short-term effect as gathering 'capital-bias' in the production process restrict the opportunities for the extraction of surplus value from the 'living labour' of human effort (Roberts, 2016).

This paper seeks to address the arguments, by contextualising the 'debate' on robots and AI within longer term discussions of technological 'singularity', and further exploring the socio-technical and economic constraints on the application of robotics and

AI in the workplace. Evidence of robot 'take-up' is gathered from reports of the International Federation of Robotics and from case vignettes reported elsewhere. In assessing the contemporary relationship between singularity, robotics and AI, the article reflects briefly on the two 'tests' of artificial 'intelligence' proposed by the pioneer computer scientist Alan Turing, and comment on the efficacy of his 'tests' in contemporary applications. The paper continues by examining further social, technical and economic constraints and concludes that technological singularity is far from imminent.

Accelerating change and singularity

Debates and on robotics and AI have a long history, focused on the prospect of technological 'singularity'. The Hungarian mathematician Neumann János Lajos (John von Neumann) first mooted the concept in the early 1950s as he reflected on the impact of the next generation of computers. He referred to an 'end-point' in computerisation where machines would be able to dominate production through processes of self-improvement. AI by 'deep' or 'machine' learning, in this scenario, will allow for the re-writing of AI's own software to outstrip the functional capabilities of the human brain, and would seemingly bring forward such an 'end-point'. Raymond Kurzweil (2005) has since revisited singularity and emphasises the nature of the contemporary period of growth in technology (spurred by digitalisation). He concludes that by 2045, the point of technological singularity will have been reached. Moore's 'Law' is cited in pursuit of this scenario (after Gordon Moore, the founder of Intel) which suggested that the number of transistors per square inch on integrated circuits had doubled every year since their invention (Moore, 1965). An adjunct to technological singularity can be found in the concept of 'economic singularity' which articulates the jobless future as human labour becomes redundant (Chase, 2016).

Within such prognoses of forthcoming singularity, the *runaway* nature of technological advancement is a common theme. A runaway process is predicated on the notion of 'accelerating change', whereby information technology has a special effect in inducing an unstoppable and unquestionable transformation of work. It depends on a supposed autonomy (Ellul, 1964: 14) in the application and effect of technology which then produces its 'runaway' quality (Heidegger, 1977: 17). In such fashion, technological singularity would be inevitable and simply a matter of time. Runaway and accelerating change have also been pertinent to longer term debates on the allegedly 'special' nature of information and communication technologies. Anthony Giddens (1999) has been most prominent in promoting such a perspective. In his view, new information technologies have been acting to engender the 'runaway' world in an unquestionable and unstoppable fashion. However, we must consider the existence of human agency in the process, both to design and to develop the technology, but also to temper and shape its use. In this respect, the *unquestioning* nature of runaway change is *highly questionable* in itself. Judy Wajcman, for example, in introducing a socio-technical perspective, suggested of Giddens' assumptions that '…he treats technology as an autonomous force rather than as a sociomaterial ensemble of humans, machines, infrastructures and everyday practices'. (Wajcman, 2016 p46). Labour is a significant agent in this process, able to modify or resist technologies which appear to run counter to its interest (Feenberg, 1991: 188). Rather than seeing runaway change, we find instead quantum movements or spurts of change, or as Thomas Hughes suggests, a 'momentum' may be more apparent. 'Momentum remains a more useful concept than autonomy… it does not support the erroneous belief in technological determinism… (and) encompasses both structural factors and contingent events' (Hughes, 1994: 80).

Over the last century, huge leaps of worker and organisational productivity have also been predicted as time and space are condensed by the new information technologies, whether they be the telegraph or telephone or the computer and the internet of things. John Maynard Keynes, reflecting on his contemporary experience with the mass use of the telephone and telegraph, suggested a working week of no more than

15 hours per week could be enjoyed as part of *The Economic Possibilities for Our Grandchildren* (Keynes, 1930). He felt that the new communication technologies of the time would massively increase productivity, and free up time for the worker. Following the computer explosion based on silicon chips toward the end of the 1960s, the 'futurologist' Alvin Toffler (1970) echoed Keynes with predications of a 4-hour working day. Then as now, everyday political discourse became infected with excitement at the possibility of a new dawn for work and society. The technocratic dream of iPad socialism described by John McDonnell was already anticipated in 1963 by the then leader of the British Labour Party, Harold Wilson. In a major speech, he enthused over the 'white heat of technology'. Social democrats, he said, could 'replace the cloth cap [with] the white laboratory coat as the symbol of British labour'.[1] As part of this zeitgeist, *The Collapse of Work* (1979) and *The Leisure Shock* in 1981 were both written by the trade union leaders Clive Jenkins and Barry Sherman of the UK white-collar union ASTMS. The books predicted catastrophic levels of unemployment as a consequence of the development of the microchip revolution, which could only be overcome by a policy of work-sharing.

The predictions on working hours proved wrong. Average working hours in the advanced industrial economies did fall in the immediate post-war period from 1950 to 1980. Much of this fall may have been associated with growing economic prosperity, social democratic politics and trade union offensives in an era of relatively low unemployment and expanding union memberships. Since the 1980s, the downward trend has been reversed as many industrialised countries have now seen average working hours increase (Lee *et al.*, 2007: 32; Pradella, 2015). This era of mass computerisation has, of course, coincided with the ravages of neoliberal capitalism, which may have acted to negate any possible positive effects of computerisation on the length of the working week. However, the optimistic predictions on productivity growth have also proved false. This is important because the theses of Keynes, Toffler and other contemporary commentators are that increasing productivity will be the key to the leisure society. There is a temporary boost to organisational and worker productivity from one-off investments in new forms of information technology, but as Henwood (2003) details such boosts appear unsustainable over time, for reasons explored later in the paper. In aggregate form, the data from the last 30 years in advanced economies actually suggest a worsening, rather than improving trend. US Conference Board data analysed by the economist Michael Roberts show us that between 1960 and 1980, average productivity growth per year in advanced economies was slightly over 4 per cent, it averaged approximately 2 per cent between 1980 and 2000 but fell further to 1 per cent and less after 2000 (Roberts, 2014).

We need to explain such paradoxes if we are to fully assess the renewed challenges of advancement in the technology of robotics and AI. Will such advances overcome counter-tendencies toward stagnation, and what may be, if any, the technical, social and economic limitations to world running toward the last ultra-intelligent machine? If limitations and constraints are obsolete or absent, then what are the prospects for singularity? To provide an answer to these questions, it is necessary first of all to review the data on robot and AI usage, and to assess the technology as it pertains to the world of work.

Robots and AI: some evidence

The International Federation of Robotics (IFR) recorded in 2016 a stock of 1.8 million operational industrial robots worldwide. A 'robot' meets the ISO definition to be 'an automatically controlled, reprogrammable, multipurpose manipulator, programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications.[2] This does not include the small number of professional service robots or robots for domestic or personal use.[3] On current trends, this would mean the probability of over 3 million by 2020. The largest sector is the automotive, with a share of 35 per cent of all purchases, closely followed by the electrical or electronics sector with 31 per cent. Others showing increases include the chemicals, rubber and plastics; metal; and food sectors. Both the auto and electrical sectors have relatively complex manufacturing processes, entailing varying degrees of skill input and supply chains. They represent industries with a history of mechanisation, sensitive to consumer demand in a competitive product market. Demand for robots has been increasing steadily since the 2008 financial crash, with Japan the biggest supplier nation. The average annual increase in sales since 2008 has been in the order of 12 per cent, but this hides considerable variance between sectors. Driving the increase has been the electrical or electronics sector, with annual increase recorded in 2016 of 41 per cent, while growth in the automotive sector appears to have peaked, recording only 6 per cent in 2016 (IFR 2017).

Three quarters of robots are sold in just five countries (IFR, 2017). These countries are China (with 30 per cent share), South Korea, Japan, USA and Germany. In some other advanced economies, the patterns of demand have been variable. In the UK, sales have been declining in the last decade but appeared to increase in 2016. Sales are down in Italy but have increased in France. Outside of Europe, sales have been decreasing in Brazil but increasing in Mexico. These patterns reflect the dominance or absence of specific industrial sectors. Where strong growth is recorded in those countries (in 2016) positively correlated with significant electronics or electrical sectors.

The reality is that robot density remains tiny. The ILO estimates that the labour force in China alone is 800,000,000. However, there remain only 68 robots in China installed for every 10,000 employees in the manufacturing industry, and the number of new robots installed in 2016 was 87,000 (IFR, 2017). In terms of robot density (outside auto manufacture) ,South Korea topped the chart in 2014 with 475 robots installed per 10,000 employees. It was followed by Japan with 214 robots per 10,000 employees, Germany with 181 and Sweden with 164 units (IFR, 2014).

The growth (from a low base) in robot and AI use can be attributed to four factors. First, is the generalised improvement in the mobility of robots. Second, are the advances in 'deep' and 'machine' learning associated with improvements in the range and scope of AI. AI application allows for greater levels of image and speech recognition, while computer algorithms can store data of past behaviour and use it to predict future behaviour, thus giving the robot the ability to 'choose' between ways and means of performing a task with the appearance that they are 'thinking'. The 'thinking' aspect depends on feedback loops or 'backpropagation' which allows algorithms utilised by AI to attempt to operate as artificial neural 'networks'. Backpropagation was a method applied by Geoffrey Hinton in 1986 as a way of mimicking the workings of the human brain and was lauded as the great leap forward in AI capability (see James, 2017 for example). However, Hinton has since expressed doubt about the method and urged the necessity to 'throw it all away and start again…. I don't think it's how the brain works. We clearly don't need all the labeled data'. (Hinton interviewed by James, 2017). Despite the emerging caveats and caution, recent publicity given to robots 'beating' humans at *Chess or Go!* is a testament to their ability to store and discriminate between data on past successful moves (programmed in by humans) during the board games. Third, is the advances produced from cloud computing, which allows the functions and tasks to be performed by robots to be programmed remotely, rather than physically on the robot itself while it is stationary. Ironically, this development means that the jobs of locally based humans whose task was to re-programme the robot will become defunct. Finally, the manufacture of robots, as with all machine-making, is subject to economies of scale and competitive market pricing, meaning that the relative cost of robots, when compared to that of human labour has been falling. This is apparent in China where from IFR data, we find that while the numbers of workers replaced by robots remained at 3 per robot between 2010 and 2016, the actual number of new robots has soared by more than 10-fold between 2009 and 2016. This massive increase was a product of the one-third drop in price of robots over the same period compared to a doubling of workers' wage rates (IFR, 2014).

Beside cost, we must also note from a socio-technical perspective that other factors are at play which constrain prospects for 'runaway' application of robotics and AI. These other factors are summarised below.

Technical limitations

Progress toward a conscious and thinking robot is likely to be slow and ponderous. Early assessments of the capability of AI referred to the work of the British computer scientist Alan Turing. In his 1950 essay *Computing Machinery and Intelligence,* he began with the statement "I propose to consider the question, "Can machines think?"" and then presented two 'tests' necessary to judge whether an 'intelligent' robot could 'think' like a human. The first test is based on the proposition that a machine would be able to 'think' if it could hold a conversation that was indistinguishable from one with a human. Turing developed a metaphor of a party game (the 'Imitation Game') which could be applied to the test, whereby a man and a woman go into separate rooms and guests try to tell them apart by writing a series of questions and reading the typewritten answers sent back. He then asked if it would be possible for a computer to 'fool' the guests into thinking a real man or woman was participating in the game rather than a computer? (see Norvig and Russell, 2016 for a review of these questions). Subsequent attempts over the following decades to develop a computer program that could pass the test included the ELIZA program in 1966, and the PARRY a decade later. The latter produced results which were no different from random application and failed to convince. In more recent decades, the development of interactive 'chatterbots' (such as Cortana and Siri) have advanced the process but have remained at the level of reactive agents dependent on pre-programmed information and subsequent machine learning rather than free-thinking intelligent machines with aesthetic and emotional as well as linguistic intelligence (features Turing was also keen to explore). However, commentators in the field of 'android epistemology' (e.g. Ford *et al.*, 2006) have since questioned the usefulness of Turing's 'thinking' test when applied to the utility of AI (see also Whitby, 1988). There is no consensus on what 'intelligence' might be, and the question may only be attempted by reference to philosophical as well as computational arguments. Copying human intelligence (however defined) may simply be a distraction as it is often not what AI is designed to do (as it can perform functions which complement rather than replace the human). Despite the caveats, the challenges posed by Turing remain live, and serve to highlight the technical limitations on what AI can and cannot do. This may be illustrated by his second test, that of a 'halting problem' whereby a computer using AI is constantly subject to feedback loops and may never 'know' when it is 'right'. The computer will continue to compute in an endless cycle of feedback and re-calculation (Walsh, 2016: 34). The inevitability of continuous feedback emerged from Turing's calculations in 1936 whereby he 'proved' mathematically that a general algorithm to solve the halting problem for all possible programme-input pairs cannot exist (see also Davis, 1958). A computer programme or algorithm is thus faced with a 'decision problem', which can only be resolved by human intervention, thus limiting the scope of applicability of AI.

The evidence on robot usage would suggest that for both tests considerable problems still exist which sit side-by-side with continuing problems of mobility and image recognition. Robots also remain machines, and are subject to breakdown, necessitating human minding and intervention which reduces their potential contribution to productivity enhancement. The problem of mimicking human mobility is proving difficult to solve and efforts to create an affordable 'plug and play' robot have stalled. For example, a leading company producing supposedly highly mobile robots, *Rethink Robots*, announced redundancies of nearly a quarter of its staff in 2013 as technical problems persisted (Tobe, 2013). To help understand such problems, one can imagine a robot attempting to catch a tennis ball in flight. The velocity and trajectory need to be finely calculated in a split second. Prior memory of the weight of the tennis ball is needed to determine how firmly to grip the ball to avoid it bouncing back out of the hand. Furthermore, the robot through prior learning must discriminate between a tennis ball, a cricket ball and a table tennis ball in terms of flight, anticipated grip and 'bounciness'. A human may remember such variables from previous experience but for a robot this is a much harder task, requiring pre-programmed levels of image recognition, weight and geometry of flight paths. A human may also recognise immediately the intent of the thrower of the ball in terms of direction or speed (and even detect 'fooling' of intent such as that perceived by the goalkeeper facing the penalty taker), by eye contact. All this is a logistical nightmare for a robot giving rise to what is known as the 'framing problem', whereby a robot will not be able to make judgements beyond the framework of the world that it has been programmed to understand (McCarthy and Hayes, 1969). We can translate such dilemmas to manufacturing. The variables for auto production, for example, are driven by consumer choice and can include scores of final assembly options such as paint, trim, electric packs, adjustable seating etc. With these problems in mind, Mercedes-Benz, a lead player in developing autonomous cars, has now begun replacing its robots with humans in its factories due to this very lack of flexibility in the robotic machine (Gibbs, 2016). Such conclusions are confirmed by Sabine Pfeiffer in her study of German auto manufacturers:

> During a normal and otherwise smooth shift, a worker responsible for the ballet of eight welding and handling robots intervenes 20 to 30 times per shift—not because of technical incidents but in order to prevent them. Although human work declined quantitatively over the years, its qualitative role increased with automation
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> (Pfeiffer, 2016: 16).

As an alternative to full robotisation of the manufacturing process, the likelihood is that auto producers will increasingly turn to the use of 'cobots' designed to undertake less complex routine tasks alongside more flexible human labour.

Following the earlier work of Hinton et al., (Rumelhart *et al.*, 1986), attempts to replicate human 'flexibility' have been constructed through artificial neural networks. Robotic 'deep learning systems' recognise a much greater range of image, colour and speech patterns than they could in the past. Big data, transferred across platforms, can also be used in algorithms to map employees' behaviours, both physically and socially (in terms of emails and correspondence etc.). However, they still depend on humans to programme and code them. There is the potential for algorithmic bias reflecting past biases (perhaps based on age, gender or race) acted upon by pre-algorithmic processes. In a notorious case, the algorithm-fed robot *Beauty.AI* only chose women of light skin when asked to judge an international 'beauty contest' (Levin, 2016). Algorithms utilised to predict who may perform best in a job (used by human resource departments in recruitment and selection, for example) may be based on past results which excluded those people from non-standard backgrounds, or those in an anglo-saxon environment with 'foreign' sounding names. Within the academic world, algorithm-based plagiarism filters used in marking assessments may be biased against second language students, who are less adept at reformulating words and phrases than native speakers. Finally, there remains the problem of consciousness, which enables a human to reflect and to understand context before deciding. Turing's second test—the ability to know when a 'right' decision has been made and to stop further computing, comes into play here. A robot can within technical limits be programmed to perform new tasks. However, expecting the robot to transfer knowledge gained in one task to another is a much more technically difficult and expensive process. Daniel Dennett (1991: 431) suggests that computers work very differently from the human mind—computers process increasingly large numbers of information serially, while the mind involves the simultaneous interaction of different mechanisms and processes.

Even if such problems could be overcome further hurdles exist. The necessary fibre-optic networks would need to be in place for high speed transmission of digitised information connected to AI to be useful. Such networks remain absent in most countries outside the advanced industrial economies. There is a general absence of a common platform and language (API-application programming interface) for computers to 'talk' to each other, which restrict the development of 'smart' factories linked together across global supply chains now integral to neoliberal capitalism. Finally, as Mahnkopf (2017) reports '…the transition of companies to the digital landscape exposes them to the dangers of cyber-attacks by individuals, inside or outside the firm, by computers, social networks, by the cloud, nefarious organizations and governments'.

Social limitations

We must also consider social limitations, which receive little attention in more apoplectic accounts. It is in this realm that the 'dialectic of technology' becomes most apparent. The limitations may entail legal constraints covering insurance liability or personal privacy. With automated vehicles (or driverless/autonomous cars and airborne craft such as drones), the insurance liability in case of injury, death or damage is likely to switch from individual (human) responsibility to the insurer. The insurer will recover the cost of the claim from the manufacturer, placing an excess cost on manufacturing. In the UK, which seeks to place itself as a forerunner in insurance for automated vehicles, parliament is currently attempting to progress the Vehicle Technology and Aviation Bill, on such a principle.[4] Most 'driverless' cars will still have a driver able to take over control, meaning a dual insurance policy will need to be constructed when the driver is in control. Such difficulties surrounding insurance liability will be confusing and likely to challenge not only the insurance industry, but also manufacturers and governments. Ironically, a fast-growing area of AI application is in the insurance and legal business, where cases are algorithmically assessed, and jobs are under threat as a result. However, there are limits, as if any appeal against decision is made, a human acting on behalf of an organisation must take responsibility. AI remains computer-based, it is software linked to hardware and cannot be sued (hence the discussions within the European Parliament on the prospects of legal 'rights' for robots and AI). The Japanese insurance company Fukoko Mutual laid off 34 employees and replaced them with an AI system to calculate payouts to policyholders. The system is based on IBM's Watson Explorer, which, according to the tech firm, possesses 'cognitive technology that can think like a human', enabling it to 'analyse and interpret all of your data, including unstructured text, images, audio and video'. (McCurry, 2017). The Watson Explorer will be able to read tens of thousands of medical certificates and factor in the length of hospital stays, medical histories and any surgical procedures before calculating payouts. However, to legitimise the process in law, the sums will not be paid until they have been approved by a member of staff.

Further socio-legal concerns include data privacy, not only of big data passed between organisations but also tracking data imposed by employers on individuals. Data are central to algorithmic processes, but as Moore has commented in a review of legislative developments:

> Personal data is not static……..Some types of data can be traced back to an individual using a collection of data points from public records which could be used to construct a picture of an individual, putting concepts of privacy under scrutiny. Indeed, previously anonymized medical records have been excavated to gain information about people; school transcripts and church congregation data resurrected. Not to mention the raft of data being collected by such behemoths as Facebook, which introduces a new range of possibilities for the mix of personal and public identification, the use of this data and legalities therein
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> (Moore, 2017)

Legislation concerning data privacy varies between countries. The European Union is attempting to address the problem with its General Data Protection Regulation (GDPR) which has the effect *inter alia* of preventing employers within the EU of using tracking information on employees (the whereabouts and actions of warehouse staff, for example) as a base from which to make HR decisions on employment, performance and disciplinary matters. These restrictions would drastically affect many business and HR practices which now rely on algorithmic feedback.

Companies centred on the 'gig economy' would be most under threat. As Moore remarks, the legislation 'potentially fully disrupts the Uber business model and operational practices', simply because 'Uber taxi drivers gain work through the use of an app that directs customers purely based on algorithm…(whereby) movements are entirely tracked and judgements about working practices made accordingly'. (Moore, 2017).[5]

The most potent form of restraint on AI and robotics is likely to be worker resistance. The relationship between technology and society not only reflects tensions within the mode of production but also norms and expectations of the capital–labour relationship. Historical accounts of automation point to many examples of resistance to Fordist and Taylorist regimes of production by workers under the period of 'modernism'. In the UK, for example, the 150,000 plus dockers in the port of east London conducted a long, but ultimately unsuccessful fight against containerisation in the decade from 1966 to 1976 (El-Sahli and Upward, 2015 p.2). Ten years later, 5,500 printworkers were sacked as they attempted to prevent the introduction of digital journalism in Rupert Murdoch's new printworks in the same east end of the city. However, much contemporary theory forming the underlying base of shifts to the 'knowledge economy' or 'immaterial labour' appears to belie the material base of digitalisation. This is despite the fact that cloud computers, for example, are rooted in materiality, and consume huge amounts of energy both working in the cloud and laying mile upon mile of fibre-optic cable to make the cloud operative. Similarly, the post-industrial perspective of 'new social movements' (e.g. Gorz, 1999), or the 'Third Way' of Giddens (1998) appear to obfuscate the material aspects of the mode and social relations of production and consequentially downplay the centrality of class struggle in shaping and re-shaping society (Upchurch and Mathers, 2011). In this respect, the end of work and end of the working class theses rely on untested assumptions of fed by the collapse of the certainties of social democratic institutions such as collective bargaining and its associated strike activity. Within this realm of thinking, the replacement society is the networked society, which reifies electronic networking to a degree that organised labour is rendered *passé*, as trade unions find difficulty in relating to the supposed reflexive and de-bureaucratised nature of the internet (Castells, 1996).

Such prognoses of organised labour's irrelevance in the face of the rise of information technology may be misplaced. Recent examples of resistance to the new technologies of personal self-tracking or the vagaries of the 'gig economy' in employers such as Uber or Deliveroo contradict these assumptions (Moore *et al.*, 2017). Evidence of gathering resistance has been assembled by Degryse (2016) for the European Trade Union Institute which reports on a host of trade union responses including the Dutch unions' campaign to Master the Robot (*De robot de bass*) and French trade unions 'right to disconnect' from electronic surveillance or emails beyond scheduled working time. So there may be nothing 'different' about digitalisation, AI and robotics from other forms of technology in its ability to crush the power of labour. Contestation will arise in from labour in different forms which may act to temper, obstruct and even sometimes embrace the new wave of automation. Returning to Marx, we can note that he related the formation and reformation of human society generally to the '…change and development of the material means of production, of the forces of production…' and lead to the conclusion that 'the mode of production of material life conditions the social, political and intellectual life process in general' (Marx, 1859). Marx here uses a dialectical approach, relating technology, and its' use, to the social relations observable within society. This infers a natural contestation between classes over technological change and indeed, resistance by the workers in the dying trades and occupations has often defined industrial relations and the societal conditions of the age. Rather than new technology heralding 'the end of the working class' we can observe that the composition of the working population continually shifts and changes with technical innovations. Technology at work is thus mediated as part of its introduction, and is a product of interaction and contestation between state, labour and capital. Resistance is not futile but inevitable.

Economics

Orthodox economics rely on the balance between supply and demand of commodities as the key explanatory factor in determining use, exchange and price. More trenchantly, there is an unquestionable faith that both demand and supply will be sustained in the short to medium term. Indeed, such an assumption is implicit in the 'runaway' approach to new information technologies based on digitalisation and computerisation. On inspection, we find that it is not the case that there is ever increasing supply and demand for new information technologies. Demand and supply are certainly tempered through the market, but the market can be saturated and constrained by personal income restraints and inequalities. On the supply side, there are concerns over the availability in the future of the rare earth metals necessary for microchip and fibre-optic production such as indium, gallium, germanium and lithium. The fact that such commodities are 'rare' makes them exhaustible and subject to competition between capitals, further driving up prices and dampening demand and any assumed 'runaway' effect. Congestion and stagnation will reduce demand and consequently restrain not only the runaway prospects but also assumed gains in productivity. Researchers at MIT have focused on this aspect and have highlighted the reasons why 'research productivity' appears to stagnate rather than continue to grow in discrete sectors such as information technology. Stagnation occurs 'Because it gets harder to find new ideas as research progresses, a sustained and massive expansion of research like we see in semiconductors (for example, because of the 'general purpose technology' nature of information technology) may lead to a substantial downward trend in research productivity' (Bloom *et al.*, 2017: 4). We may also study the effect of 'congestion' by referring to the household and personal 'adoption' rate of many new technological innovations aimed at consumers. There is usually a sharp upward curve in adoption rates of new technologies, followed by a plateau effect as demand is saturated and new products, sometimes but not always upgrading the earlier ones, enter the market. The post-war boom in cars, refrigerators and landline telephones flattened out in advanced western economies by the 1980s. Similarly, the 1970s boom in credit cards and colour televisions lasted just two decades. Is there any reason to expect that consumer behaviour toward smartphones, robotics and digital wearables will be any different?

The congestion and related effects have been econometrically tested. On productivity, key evidence published in 2015 from a data set of companies in 17 countries gathered between 1993 and 2007, suggest that while productivity increases with robotic innovation and some semi-skilled and lower skilled jobs are abandoned, 'there is some evidence of diminishing marginal returns to robot use —"congestion effects"—so they are not a panacea for growth……this makes robots' contribution to the aggregate economy roughly on a par with previous important technologies, such as the railroads in the 19th century and the US highways in the 20th century'. (Michaels and Graetz, 2015). Computers, including robots, also represent a relatively small proportion of capital stock, and furthermore, investment has been declining since the height of the 'IT Revolution' of the 1990s (Goodridge *et al.*, 2012: 34). Evidence from the United States suggest that investment in automation has even 'decelerated' in the last decade (Mishel and Bivens, 2017). This is likely to be because while upgrades in software and hardware are made (such as the constant revision of Microsoft Word, for example), the aggregate effect of such upgrading is likely to be small compared to the initial investment in the software. The management specialist Michael Porter (2001: 62) commented on this likelihood and suggests that, 'as all companies come to embrace internet technology, the internet itself will be neutralised as a source of advantage'. Returning to Marx, we must also note his description of a 'lifespan of fixed capital'. An individual employer, and capital in aggregate, may delay purchasing of new technology until they can be sure of sufficient rate of return on investment. Individual employers will thus make plans to extend the physical life of pre-existing fixed capital (including both computer hardware and software) as a way of reducing costs (see Weeks, 1981 p186 for a full explanation).

Finally, on economics, we need to consider further the relationship between technological investment and the rate of return on such investment. Orthodox economics tend to treat technology as a neutral factor in the social relations of production and in its economic benefits, without consequences for the capital-labour dynamic. However, if we draw from classical Marxist economics, we would deduce that the prime motive of investment in technology is to compete with other capitals by utilising technology to lower unit labour costs and raise profitability. There is a tension between this need to compete and the desire of the capitalist to recoup the investment made in new technology. This can be achieved by increasing rates of exploitation of its workforce and/or by shedding labour. In so doing, the phenomenon of capital-bias will emerge which serves to dampen the rate of return on new investments. There occurs a rise in the organic composition of capital measured by the ratio between constant or fixed capital, which Marx describes as a product of past or 'dead' labour, and variable capital (capital invested in employing labour-power), which activates the 'living' labour of workers in the production process. Fixed capital, embodied in machinery and previously extracted raw materials, creates no new value. It merely passes on its value in the process of becoming used by living labour. As capital-bias takes effect, then the relative share of labour in any one production process is reduced and hence the rate of return on capital investment (or rate of profit) falls correspondingly. As already described, individual capitals must adopt technical innovations to compete. In order to survive, they must match or undercut the generalised 'socially necessary labour time' within the product's sector, which determines the rate of profit as it proceeds from the degree of exploitation of the workforce. By constant investment in machinery, they are sowing the seeds of stagnation and decline, by over-reliance on fixed capital at the expense of variable. Contrary to the 'post capitalist' or immaterial visions of the nature of production, there is no reason to suggest that investment in software and the necessary computer hardware to envisage a networked production process is any different from other forms of technological investment in this respect. Furthermore, to overcome the deleterious effects of capital-bias, countervailing measures need to be applied by capital, which involve getting 'more for less' from individual workers. Instead of being a 'neutral' input, technology becomes instead a means by which to increase the rate of exploitation of those workers left behind in the individual workplace (Adler, 1988; Hall, 2010). Either that, or the workforce is reduced even further, exacerbating the negative effects of capital-bias by expanding ever more the organic composition of (fixed) capital within the enterprise.

With all these caveats in mind, William Nordhaus (2015) seeks to draw conclusions on the sum total of economic effects (both positive and negative) on the prospects for technological singularity. Two 'accelerationist' mechanisms could develop to encourage singularity, either from accelerating supply or from accelerating demand. He then applies a series of time-linked tests to both hypothetical scenarios, focusing on the key input variables such as wages, productivity growth, prices, intellectual property products and R&D. Five of his seven tests for the likelihood of singularity proved negative. These included the conditions for demand such as that for 'accelerating productivity growth' and 'rising wage growth' (real time evidence, of course, shows a decline in both factors in the last decades). The two that proved positive (including a 'rising share of capital') indicated that singularity, if it did occur, would be at least 100 years away. And as we have previously positioned, a rising share of capital may simultaneously lead not only to decreasing rates of productivity growth, but also trigger a crisis of profitability for capital in the long term. Returning to the vision of singularity which has again become to obsess social commentators, we might even posit that the dream of singularity, should it materialise, would thus be faced with a simultaneous collapse of the underlying dynamic of capitalism.

Concluding remarks

Predictions of the end of the human job because of replacement by robots and AI are lacking in sufficient analysis and evidence that cover the technical, social and economic effects. References to the 1920s/1930s, 1950s, 1970s and 1990s suggest that predictions of emerging technological singularity proved to be false dawns. Many of the 'end of work' scenarios, from J. M. Keynes, through Toffler, Gorz and Mason rest their case on ever expanding productivity resulting from computerisation, information technology, digitalisation or robotics/AI. Yet, aside from the 'Golden Age' of the 1950s and 1960s, we see declining rather than increasing productivity as the new technologies become embedded. The reasons for the failure are complex and belie any deterministic approach. First, while new technologies have the capacity to *disrupt* modes of production, their potential to *transform* is constrained by the dialectic of use and non-use conditioned by factors which go beyond mere technical innovation. Second, we need to observe the continuing technical restraints on robots and AI informed by the two Turing 'tests' constructed in the middle of the 20th century. The validity of the tests has sometimes been questioned, but within the caveats the evidence would suggest that AI's capacity to overcome these tests, while considerably enhanced in recent years, is still far from completion. This is more pertinent now, precisely when the 'rise of the robots' is once again apparent in popular and some academic commentary. This is not to say that the introduction of robots or AI into the individual workplace will not raise worker productivity in the immediate. Job displacement will always be a motive for the employer investment in robots/AI. The point is that such gains remain short-lived as congestion and other effects subsume the initial impact of investment. More importantly, robots remain as machines, they are 'dead' labour which merely pass on existing value rather than create new value. As such investment in the same will create a capital-bias effect within the factory or office, leading in the medium term to a decline in the rate of return and a consequent stifling effect on further investment.

Notes

[1] http://nottspolitics.org/wp-content/uploads/2013/06/Labours-Plan-for-science.pdf

[2] ISO 8373:2012

[3] Some figures are here https://ifr.org/downloads/press/02_2016/Executive_Summary_Service_Robots_2016.pdf

[4] https://publications.parliament.uk/pa/bills/cbill/2016-2017/0143/cbill_2016-20170143_en_2.htm

[5] In 2016, Uber central computer was hacked revealing names and details of 57 million customers and drivers (Lee, 2017).

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