High Tech, Low Growth: Robots and the Future of Work

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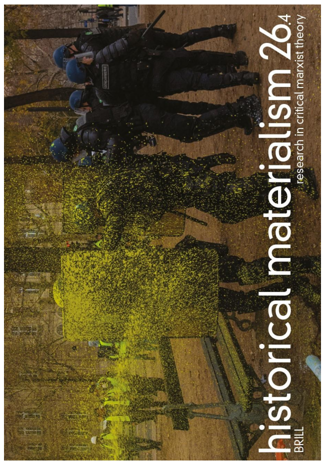
Abstract



For decades futurists, academics, and business experts have argued that automation, robots, and other new technology would eliminate millions of jobs. Yet, the workforce in the US has continued to growth, even if more slowly, to new heights. Work has changes, but the predicted ‘end of work’ failed to materialise even as technology has advanced, albeit unevenly. This article will argue that the answer to this apparent riddle lies not in the technology itself, but in Marxist political economy. The progress of robots and related technologies will be examined, but the argument is that the limits on technical progress in the actual production of goods and services are to be found in the turbulence of capitalism since the 1970s.

In the last few years, works by such techno-futurists as Martin Ford and Brynjolfsson and McAfee [1] *o*, both *New York Times* bestsellers, have contributed to the revival of an old debate about technology and the future of work, dazzling the public with mountains of information on new technology, artificial intelligence, robotics, self-driving cars and trucks, 3-D printers, and their projected destruction of jobs, vanishing of the working class—and perhaps managers and beans.

Confronted with such overwhelming accounts of technical progress, we tend to respond like the deer frozen in the headlights. The disaster rushing towards us appears unstoppable.This generation of technophiles, however, are by no means the first to describe and analyse the evolution of technology and its ‘inevitable’ impact on employment. As Ford himself notes, the 1964 report *The Triple Revolution* catalogued rising automation and predicted the inevitable loss of countless jobs.[2] Inevitability, however, failed to materialise as the US workforce grew apace even in manufacturing and despite the big recession of 1974-75. The turning point came with the bigger recession of 1980-1982 that did the sort of job destroying work automation hadn’t.

The 1990s saw another wave of popular techno-scare analyses, one of the most substantial of which was Jeremy Rifkin’s 1995 *The End of Work.*[3] The title, of course, is the message. Rifkin compiled an array of examples of the latest developments in work-related technology and the new practice of ‘re-engineering’, predicting the massive and permanent loss of jobs. Yet, over two decades later, there are more, not

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[1] Ford 2016; Brynjolfsson and McAfee, 2014.

[2] Ford 2016, pp. 30-33.

[3] Rifkin 1995.

fewer, jobs in the US and the world. Work didn't end, it just changed official statistical categories and got worse as we will see below. Like today's projections, Rifkin's were based on a lot of information, much of it anecdotal, and a lot of predictions, most of them off the mark.

For example, Rifkin cited a 1993 Andersen Consulting study that predicted the loss of 700,000 jobs in 'banking and thrift institutions' over the next seven years as a result of re-engineering. Between 1990 and 2000 commercial banking did lose jobs, 111,700, about a sixth of the prediction and this as likely due to industry consolidation. By 2010, commercial banks had gained back half of those lost jobs despite consolidations and better computers, and by mid-2017 had reached 97 per cent of the 1990 level. Computers destroyed jobs, but nowhere on the scale imagined by Andersen Consulting or Rifkin.[4]

Even more off-base was a 1990 prediction from the US Department of Labour cited by Rifkin that automation of various sorts could reduce warehouse 'labour requirements' by 25 per cent. Instead, warehouse production and nonsupervisory jobs grew by 27 per cent from 1990 to 2000 and by another 83 per cent from 2000 to mid-2017 despite recession and technological advances.[5] One reason why this prediction was so far off is that not only are there many more warehouses, but as detailed occupations to computerization broadly defined using data less labour.

Typically, the projections of techno-futurists, while looking at some big economic trends, don't really grasp how capitalism works in relation to investment whether in structures, machines, IT, or robots. Rifkin's predictions fell short not just because the technology wasn't always up to the task or the tendency of futurists to project from limited evidence, but because of the economic times in which they were made and the underlying contradictions of capitalist accumulation that gathered force even in the late 1960s and have asserted themselves since the 1970s.

Writing in the mid-1990s when the economy seemed to be on an upward course with high tech investment on the rise, he could be optimistic. But, in fact, capitalism was having deeper problems, investment would halt, and the dot.com boom go bust in a few years.

Method and Summary of Argument

The approach taken here will be different from the techno-futurists, many academics, and major institutions of capitalist thought and regulation. This study employs the dynamics of Marxist political economy in order to assess the past, current, and likely future progress of job destroying automation. The underlying context of this examination is the turbulent detailed occupations to computerization broadly defined using data reality of actually existing capitalism as it has unfolded since the 1970s and is projected to continue for the foreseeable future. The major contention here is that the susceptibility of any job to automation is secondary to the potential profitability of its actual application. This is a view of the prospects of the 'Fourth Industrial Revolution' that poses a different question than those assumed by most of the predictions, projections, and estimates cited below and many others like them. The question is not that of the susceptibility of various jobs and occupations to automation, but the practicality of their application through actual investment.

[4] Rifkin 1995 pp. 9, 151; US Census Bureau 2011, pp. 409-410; Bureau of Labor Statistics 2017a.
[5] Bureau of Labor Statistics 2017b.

The article will next empirically examine the reality of the surprisingly slow introduction of industrial robots due in part to their persistent limitations and costs; the irony that the increased use of ICT to track and guide goods within and between warehouses has actually led to rapid growth in employment in this sector; and the myth of the 'driverless truck'. In conclusion, it will be argued that the dynamics of capital accumulation, itself, as well as the turbulence of capitalism globally and in the US remain barriers to the sort of dramatic replacement of human labour by machines projected by the techno-futurists.

Susceptibility v. profitability detailed occupations to computerization broadly defined using data In addition to popular works such as those of Ford, Brynjolfsson and McAfee, and others cited above, there have been academic attempts to measure the likelihood of massive job loss due to automation or technological advances.

A frequently cited recent study by Oxford academics Carl Frey and Michael Osborne, for example, attempted to rank the susceptibility of and inscriptions from the Bureau of Labour Statistics (BLS). They conclude that '47% of total US employment is in the high-risk category, meaning that associated occupations are potentially automatable over some unspecified number of years, perhaps a decade or two.'[6] While they assume the accelerating progress of such key elements of automation as 'machine learning', 'big data', and dexterity, they make no effort to assess the economic feasibility or practicality of applying various forms of technology under today's turbulent economic conditions.

Not surprisingly, the active members of the capitalist class are also concerned about the possible competitive advantages as well as the potentially disruptive impact of all this new technology. Both the World Trade Organization (WTO) and the World Economic Forum (WEF) have published recent reports covering the 'Fourth Industrial Revolution.' As might be expected, as caretakers and practitioners of capitalism, they are somewhat more circumspect in their predictions of job loss. While rehearsing the usual arguments about how such 'creative destruction' brings new jobs, occupations, and even industries, the WTO's 2017 report cites two McKinsey Global Institute studies that claim that although 60 per cent of US occupations could involve some automation,[6] only '5 percent of occupations could be entirely automated using current technologies.' Its own estimate is that about 9 per cent of jobs in the US and 21 OECD countries are 'susceptible to full automation.' The WTO report notes that costs are a factor in the introduction of new technology, but goes no further is assessing the likelihood that such investments will be made.[7]

The WEF's 2016 report on *The Future of Jobs* estimates that between 2015 and 2020 there could be a net loss of 5.1 million jobs to automation in the fifteen countries, including the US, their survey of senior executives covers. As they point out, however, there are 1.86 billion workers in those countries so that this projection seems even more modest than the WTO/McKinsey estimates. When the WEF survey asked executives what they thought the main 'drivers' of change were only 9 per cent answered 'Advanced robotics and autonomous transport', while even fewer named 'Artificial intelligence and machine learning' or '3D printing.' In comparison, 44 per cent, the highest percentage, answered 'Changing work environment and flexible working arrangements'. Could they have meant some version of lean production

[6] Frey and Osborne 2017, p. 265.
[7] World Trade Organization 2017, pp. 90-100.

methods and related new management practices? The only economic barrier to new technology mentioned in the survey was 'Pressure from shareholders, short-term profitability.'[8]

The forward march of the robots stumbles

One of the few attempts to quantify the actual implementation and impact of robots on US industry is the 2017 National Bureau of Economic Research study, *Robots and Jobs: Evidence From US Labor Markets,* by Daron Acemoglu and Pascual Restrepo (A&R). This received a lot of media attention, which usually took its findings to indicate catastrophic job loss in the not too distant future. Using a rather complex simulation of 'labour markets' and data from the International Federation of Robotics (IFR) for 19 industries (15 manufacturing, 4 service) A&R conclude that from 1990 to 2007, just before the Great Recession took hold, the introduction of robots in the US cost between 360,000 and 670,000 jobs or about 21,000 to 40,000 jobs a year on average. They also predicted a tripling or even quadrupling of the number of robots between 2015 and 2025 that would destroy jobs at about the same rate per robot (5.25 workers per 1 robot). [9]This presumably could mean a loss of as many as 2.7 million jobs over ten years or about 270,000 a year if robots increased by four times. That is a lot, but is not the 'end of work' in a workforce that is now composed of over 153 million men and women and that has grown by 14 million since 2010 despite a sluggish recovery and a large reserve army of labour. [10]

The Economic Policy Institute (EPI) criticised A&R's simulation model as 'highly stylised' and based on 'stringent and likely unrealistic assumptions' and concluded 'we find nothing in their report that establishes that automation broadly defined (including robots and nonrobot automation such as information technology) explains recent trends.' In any case, EPI argued, 40,000 jobs a year is hardly a massive loss if employment was growing in other areas, as it generally was, albeit in low-wage occupations and slowly since 2008.[11] Since robots are heavily concentrated in manufacturing, A&R's figures are too small to explain the loss of 2.5 million production and nonsupervisory jobs.

Other growth projections are even more modest. The IFR's projections for 2015 to 2020 show only a doubling of annual robot shipments for the US from 27,504 to 55,000, while the Boston Consulting Group estimates US robot spending to increase by one-and-a-fifth-times to $24 billion from 2015 to 2025. However, their estimate for 2015 of $11 billion in robot sales equalled less than 3 per cent of GDP expenditures on 'Machinery' that year.[12]

In global terms, the US is actually behind most of the rest of the industrial world. The IRF's report *World Robotics 2017* shows that while global shipments of industrial robots have grown significantly, those from 'The Americas' have never amounted to more than 18 per cent of the world total and by 2016 were down to 14 per cent of which 20 per cent came from Canada, Mexico, Brazil, and the rest of Latin America.[13]

Further evidence for the relatively slow growth in robots lies in their uneven

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[8] World Economic Forum 2016, pp. 3-28.
[9] Acemoglu and Restrepo 2017, p. 36.
[10] Bureau of Labor Statistics 2017c, Table A; US Census Bureau 2011, p. 377.
[11] Mishel and Bivens 2017, p. 6.
[12] International Federation of Robotics 2017, p. 23; Bureau of Economic Analysis 2017a; Sanders and Wolfgang 2014.
[13] International Federation of Robotics 2017, pp. 15, 23

application across industries. According to a Brookings study, as of 2015 half of the nation's 233,305 industrial robots were in auto with a huge concentration in the Midwest and upper South, the site of most car and truck supplier and final assembly plants. Of those 116,653 robots, 30,000 or over a quarter belonged to General Motors alone. [14] Despite rapid growth in robots in a few US industries, the *only* industry with extensive use of robots globally as well as in the US is auto—and that after more than a half-century after their first introduction. In 2014, the US auto industry deployed 117 robots per 1,000 workers. No other industry came as close as 10 per cent of that level and most had less than 1 robot per 1,000 workers in spite of significant increases in some industries.[15] In other words, the introduction of robots has been both highly uneven and, for the most part, slow.

Even in auto where robots have been used since the 1960s and have proliferated more than in any other industry, total employment in auto and auto parts in January 2017 was 945,000, compared to the all-time high of 1,004,900 in 1978, or 94 per cent of the industry's highest employment level. [16] This is possible because today's auto workforce produces many more cars and light trucks than that of the 1970s.To be sure, this workforce is now spread over a different group of companies, located in different geographic areas, heavily de-unionised, and subjected to two-tier wage patterns, gutted benefits, and intensified labour even where there is a union. What all this indicates is that job losses and gains don't correspond directly to the increased use of robots. Competition and the ups and downs of the car and truck market continue to be major factors in employment levels along with various methods of work intensification. More broadly, the level of output and sales; i.e, the realization of surplus value, remains a factor in employment levels in almost any industry.

That is not to say that automation and robots don't displace workers. But they have done so along with recurrent economic rises, changes in plant structure and layout, lean production, alternative shift patterns, and other forms of work reorganization and intensification that have had a strong effect on auto and other manufacturing jobs. Manufacturing saw 2.5 million jobs lost, as a result of which there was a rise in the number and proportion of those in the reserve army of labour. The question remains, however, as to the underlying causes of this massive job loss.

Behind the loss of manufacturing jobs

Martin Ford sees the massive loss of manufacturing jobs that is the major contributor to the rising reserve army almost totally as the result of new technology.[17] Robots are one factor in the loss of manufacturing jobs—though not even the main one given their limited use so far in most manufacturing industries shown in A&R's and the IFR's figures. Determining just how much job loss is due to technology and how much to changes in and the reorganization of work in the past thirty or so years with any precision is probably impossible.

As we will see below, however, the level of investment in both information processing and industrial equipment across the US economy has declined as a proportion of new private investment, while the growth in the ratio of capital stock to GDP has slowed down to a crawl. At the same time, the spread of lean production methods, work reorganization, and more recently the monitoring and measuring of work by

[14] Munro 2107; Hunt, 2017.
[15] Acemoglu and Restrepo 2017, p. 41, p. A-14.
[16] Bureau of Labor Statistics 2017d; Davies, 1993, p. 41.
[17] Ford 2016, pp. 54-55.

electronic and biometric technology has increased. So, although technology plays a role, the rate of investment in robotics and automation has decelerated, while that of economic turbulence and work intensification by other means; that is, essentially class war waged by capital, has increased.

The major sources of job loss in manufacturing came not from robots or imports, but from the volatile course of the economy as huge numbers of manufacturing jobs were destroyed in the recessions of 1980-82, 199091, 2000-2001, and 2008-10, and large productivity gains between recessions due mainly to the implementation of capital's major tools of class conflict *de jure*: lean production methods beginning in the 1980s; work reorganization; the introduction of 'alternative work schedules'; the reduction of break time; and the accelerated monitoring, measuring, and standardisation of work via computerisation and new surveillance technology.[18]

The intensification of work through the reduction of rest-time per minute has been accomplished through lean production methods by *Kaizen* (continuous improvement) by teams, computerised job measurement systems like Six Sigma that rebalance jobs to the lowest employment-to- output level, and more recently by electronic and biometric methods of work measurement and monitoring. The classic case was the GM- Toyota NUMMI plant in California where beginning in 1986 the number of seconds of actual work per minute rose from 45 to 57 seconds. While most factories are not likely to meet the 57-second standard, an increase of a few seconds per minute in a plant with a few thousand workers can create hundreds of extra hours of work at no cost to the company and without any change in technology.[19]

The introduction of 'alternative work schedules' beginning in the 1990s allowed manufacturing firms to take advantage of shift lengths that maximised the curve of productivity—generally ten hours as opposed to eight.[20] Another job-busting non-tech strategy is the simple reduction of break time. One study of workers 'performing routine tasks in middling occupations' found that on average break time in the US had been reduced from 13 per cent of the work day in 1985 to 8 per cent by 2003.[21] Though this survey was not limited to manufacturing, this is a strong indication of the role of simple work intensification as a major factor in relative job loss. This continued in auto in 2016 as the United Automobile Workers granted Ford a reduction in break time of one minute per hour worked.[22] With 53,000 production workers this amounts to just over 7,000 extra hours of work per 8-hour day at no extra cost to Ford and a potential loss of nearly 1,000 jobs.

To be sure, technology, particularly software, plays a role in lean production methods. But its role is not primarily the direct replacement of workers, *a la,* robots or computer numerical controlled machines, but of forcing the workers themselves to reduce the workforce through increased productivity. This difference is important. What, then, of the progress of robots in industry?

Any self-confident techno-booster will argue that the use of robots is accelerating and

[18] The argument against the role of imports in job loss is developed in detail in Moody 2017, pp. 8-13, 195.
[19] Moody 2017, pp. 13-19; Parker 2017, 173-194. Despite high productivity, Toyota closed NUMMI in 2010 in order to go completely non-union in the US.
[20] Moody 2017, pp. 16-17; Moody and Sagovac 1995, pp. 15-17; Shaikh 2016, pp. 135-139.
[21] Gimenez-Nadal and Sevilla-Sanz 2015, pp. 3-11.
[22] Feeley 2016, 4-6.

the future promises an escalation the likes of which we have never seen. Look at all those gains in artificial intelligence (AI). What about Moore's Law of exponential growth in computer capacity, as the number of transistors per chip doubles every two years? The problem here is that most industrial robots don't require the most advanced versions of AI or super-high levels of computer capacity. They are, as even Martin Ford puts it, 'blind actors in a tightly choreographed performance.'[23] The choreography being in the program or algorithm. Due to 100 years of Taylorism and three decades of lean production methods, most industrial production jobs are basic and low or middling skill in nature. On the one hand, that makes these jobs a potential target for robotization. At the same time, however, it means that the advances in industrial robot performance have been minimal---from 3 positions to 6 or 7 since the 1960s; that is, over more than half a century, for standard industrial robots such as are used in auto. Furthermore, they still lack dexterity and mobility.

In addition, as Ford points out, 'industrial robots require complex and expensive programming', so their deployment is costly.[24] While computers may be able to unravel the human genome, win at *Jeopardy,* and more recently at the ancient Chinese game of *Go,* industrial robots are mostly deployed to perform simple tasks. Moore's Law does not apply here. In fact, as we will see below, Moore's Law has, as Robert J. Gordon puts it, 'gone off the rails.'[25] Thus, one reason for the relatively minor role of robots in job loss is that their development has not been the smooth process many imagine.

Part of the reason for that is that they are subject to 'Moravec's paradox.' As robotics expert Hans Moravec put it, 'It is comparatively easy to make computers exhibit adult-level performance on intelligence tests or playing games, and difficult or impossible to give them the skills of a one-year-old when it comes to perception and mobility.'[26] In other words, it is difficult to translate all the great leaps in artificial intelligence and computer capacity into the physical and mechanical functioning of robots without which they are of limited use in industry. So, while computers are out-smarting people in some endeavours, robots remain clumsy or limited operatives in factories, warehouses, and elsewhere.

With their faith in the inevitable improvements of all thing digital, Brynjolfsson and McAfee predicted with complete confidence in their 2014 book, *The Second Machine Age,* that the Pentagon-sponsored Defence Advanced Research Projects Agency's (DAPRA) Robotic Challenge launched in 2014 would see much of the problem of mobility overcome. In fact, when the contest took place in 2015, as the *Economist* reported of the robots' mobility, 'They fell on their faces. They fell on their backs. They toppled like toddlers, they folded like cheap suits, they went down like a tonne of bricks.'[27] Such physical limitations, of course, make them shaky investments. This, however, is only part of the reason for their slow adaptation to the work of producing and moving material things.

[23] Ford 2016, 3.
[24] Ford 2016, 5.
[25] Gordon 2016, pp. 588-589.
[26] Brynjolfsson and McAfee 2014, pp. 28-29.
[27] The Economist2015.

To be sure, there are robots with more advanced AI able to solve problems and learn. Some, like Rethink's Baxter, can be fitted with sensors to detect the presence of humans in order to work alongside them.[28] There are also advances in the use of robotics in medicine, biotechnology, and some other areas. Our concern here, however, is with the impact of automation on those workers who produce the bulk of the nation's goods and services. Most industrial robots that are actually used in manufacturing and auto in particular perform basic operations such as painting, welding, and simple assembly. A new generation of 'collaborative robots' or 'co-bots' provides extra muscle for assembly line workers, acting as an extension of the worker. In 2016 these accounted for only 3 per cent of global industrial robot sales, but are expected to increase to perhaps a third.[29] No doubt these will increase productivity, but they don't directly replace the worker.

The ultimate reason the progress in the application of industrial robots has been so slow even in auto and why an exponential acceleration of their use is highly unlikely in the foreseeable future lies not in technology *perse,* but in political economy. No technology will be invested in unless it can be expected to increase profitability, and if sufficient profits are available—and these are the problems of this era. Before examining that, a look at technological advances in transportation and warehousing is called for given the growth of the logistics industry in the last two decades or so.

People-less pickers & the modern warehouse

The big winners in blue collar jobs in the US have been those in transportation (mostly trucking) and warehousing. Together the number of production and nonsupervisory workers in this broad sector, which is the heart of logistics, grew from 2,943,500 in June 1990 to 4,407,100 in June 2017 by 1,463,600 or by half again.[30] Perhaps ironically, it is technology that has made these gains possible. There have been big gains in the tracking and guidance technology in logistics as a whole, such as electronic data interchange (EDI), enterprise resource planning (ERP), global positioning systems (GPS), barcoding, and more recently radio frequency identification (RFID). Ironically perhaps, it is these gains that have enabled the growth of today's just-in-time (JIT) logistics industry as manufacturing extended its JIT supply chains around the midwest and south and imports, mostly from the west coast, had to be delivered across the whole nation. This includes those imports that don't stop in the US but go across the US 'land bridge' to east coast ports and on to Europe and elsewhere and are not included in import statistics. This technology has meant increased employment in transportation, warehousing, and a number of ancillary occupations as the industry has grown and created enormous 'logistics clusters' located next to major urban concentrations employing tens and even hundreds of thousands of workers each—most of whom are blue collar, manual workers.[31]

In understanding this development, it is important to distinguish between the sort of information and communications technology (ICT) that allows the faster tracking and guidance of goods or monitoring and measuring ICT, on the one hand, and automation such as robots that directly replaces human labour, on the other. Contemporary supply chain management and logistics more broadly depend mainly

[28] Ford 2016, pp. 5-6.
[29] Glaser 2017.
[30] Bureau of Labor Statistics 2017e.
[31] Moody 2017, pp. 59-63.

on ICT that has enabled the rise and spread of global supply chains in which speed and JIT norms are central goals. As one expert put it, 'An information supply chain parallels every physical supply chain.'[32] The physical movement of goods, however, still rests for the most part on the older technology embodied in trucks, trains, planes, ships, and the mostly basic warehouse equipment.

As part of the 'logistics revolution' of the last twenty-five or so years, the number, size, and functions of warehouses has changed dramatically. Over 60 per cent the nation's 17,000 or more warehouses were built after 1998 and are much larger in square feet on average. Whereas older pre-1990 warehouses averaged about 10,000 square feet, now 27 per cent average between 25,000 and 50,000 square feet, while another 37 per cent measure 100,000 square feet or more. Many are far larger than these averages. This expansion in size has meant more workers. Most modern warehouses are characterised not by storage, but by the movement of goods and materials along supply chains in which speed has become a central factor in competition. Some even engage in manufacturing functions associated with packaging, 'customization,' and 'postponement' which involves last minute additions to increase product value and competitiveness. Most unloading and loading is still done by hand aided by computers, barcodes, and RFID tags. Far rarer is the use of robots to unload very large shipments of uniform packages, which are mostly used by production firms in off-site warehouses. Most warehouse vehicles, pallet trucks, forklifts, pickers, etc. are still operated by humans and do not involve automation or robotics. Thus, despite some increases in automation, labour still accounts for 65 per cent of average operating costs even though warehouse wages are relatively low, while the number of warehouse production and nonsupervisory employees has grown from 356,800 in June 1990 to 830,700 or by two-and-a-third-times by June 2017.[33]

Within the new warehouses, of course, some technologies do replace human labour. Aside from ICT software which is omnipresent throughout logistics' systems, there are various Automatic Storage and Retrieval (AS/AR) systems that employ robotics technology to pick items or bins and Automatic Guided Vehicles (AGVs) that move goods, pallets, and packages around. In those highly publicised Amazon 'fulfilment centres' automatic pickers, drawn by barcodes or RFID tags pick items for same- day or next-day delivery. All very futuristic. In fact, however, the Kiva robots that do the picking do not handle the product itself only the shelves or bins that hold them which are given to a worker who then prepares the items for dispatch. Thus, as of late 2017, Amazon employed 125,000 warehouse workers in 140 fulfilment centres in the US, 80,000 of them hired since they began using the Kiva robots and bought the company in 2012, with plans to hire 50,000 more workers.[34]

[32] Sheffi, 2012), 159. This view of a seamless supply chain in which goods move smoothly in one direction and information, or for that matter money, move in the other is an idealization. Real supply chains involve multiple suppliers competing for larger shares of total value added, multiple 'customers' attempting to hold down the cost of supplies and to capture the lion's share of market value. Some are dominated by a single 'customer' like Wal-Mart, which forces suppliers to compete on lower prices. Supply chains frequently overlap with firms competing in and between chains for a larger share of each other's business, etc.

[33] Lisa Harrington 2008; *Cisco-Eagle 2017*; Bureau of Labor Statistics 2017f; Waters and Rinsler 2014, pp. 6, 93; Richards 2014, pp. 67-70, 105-114; U.S. Census Bureau 2001, p. 665; U.S. Census Bureau, 2014.

[34] Wingfield 2017; Bernton and Kelleher 2015; Green and Pelison 2017; Gordon 2016, p. 596; Brynjolfsson and McAfee 2014, p. 32.

While fulfilment centres capture media attention, by now almost half of the warehouses in the US and a larger percentage of those built since the late 1990s are cross-docking transhipment facilities. These are seen 'as being the future for warehousing.'[35] These are the major 'nodes' in the just-in-time supply chains that are the arteries and veins of contemporary US capitalism. Cross-docking is used by Big Box retail firms, notably Wal-Mart, by manufacturers using just-in-time supply systems, as well as by transportation and third-party logistics companies (3PLs). Cross-docking facilities by-pass storing, racking and picking, and don't require much or any AS/AR technology or robotics. In these crossdocking warehouses, trains or trucks, often carrying containers, arrive at a receiving dock where their contents are unloaded, sorted, and put on pallets by hand, then transferred to a dispatch dock, possibly by an AGV or an 'automated' conveyer belt, to be loaded by hand on a waiting truck for dispatch to a factory, retail outlet, or any one of hundreds of locations such as hospitals, hotels, offices, etc. [36] As noted above they move not only domestically produced goods and commodities, but imports as well. Ironically, the increase in imports is a factor in employment growth in this sector.

The use of AGVs is growing, but their number is still modest. In 2015 some 15,515 'logistics' AGVs were installed in 'non-manufacturing environments' in the US according to the IFR. [37] Some would go to the nation's 17,000 or more warehouses, but many would be used in other settings as well. So even as the use of AGVs has increased in recent years, warehouse employment has also grown. Growth may well slow down if industrial output and imports slow down, but so long as the quantity of domestic and imported raw materials, commodities (like grain), and goods keeps coming, employment in this industry is likely to grow as warehouses increase in numbers and size—even as AS/AR systems and AGV's proliferate.

Two recent surveys of warehouse managers and professionals show some surprising, indeed counterintuitive results. One by Peerless Research Group for *Supply Chain Management Review* shows that despite some growth as of 2017 only 10 per cent of respondents said they used 'some form of automated order picking,' 7 per cent employed voice and/or scan verification, and a mere 5 per cent used 'Robotic or other automated technology.' The most frequent use of technology in most warehouses is that associated with communications, tracking inventories, labour productivity matrices, barcodes, RFID, and hand or wrist held identification scanners, rather than 'big ticket, fixed automation.'[38] [39] A 2013 survey by Zebra Technologies of 'warehouse IT and operational personnel' found that 35 per cent of their respondents planned to build more warehouses, another 38 per cent to expand theirs, and 45 per cent to hire more workers by 2018. Many also planned more automation, but much of this was 'pen and paper to automation' in record-keeping, stock counting, along with hand-held computers, barcode or RFID identification technology. Perhaps most revealing of what warehouse management was really focused on is the statement from one consultant to *Supply Chain Management Review* that 'There is an increasing emphasis on continuous improvement—on streamlining and standardising—as a means of managing costs and delivering more value to customers.' Once again, lean production methods come to the rescue.

[35] Richards 2014, p. 10.
[36] Richards 2014, pp. 6, 10.
[37] International Federation of Robotics 2016,1.
[38] Michel 2017, pp. 55-57
[39] *Zebra Technologies* 2015, pp. 2-9; Michel 2017, p. 57.

Driverless trucks?

What about driverless trucks? Won't that development end the growth of employment in transportation, destroying a million or more trucking jobs? As it turns out, there is no such thing as a driverless truck—at least not yet. And not for the foreseeable future. German car and truck maker Daimler, which accounts for 40 per cent of the US truck market, 'has invested heavily in self-driving technologies', according to the *Financial Times.* But Daimler's leading self-driving engineer Derek Rotz told the *FT* he does not expect to see a fully driverless truck in his lifetime.

'That's quite frankly something we are not looking at,' he says. Otto, the technology start-up now owned by Uber, that produced the technology for the famous 2016 120-mile self-drive of a beer-hauling truck in Colorado has since shifted its efforts away from trucks to more feasible (and hence profitable) self-driving cars, probably for Uber taxis, according to the same *FT* article.[40]

While self-driving cars appear more advanced, even they are not yet driverless in all circumstances. As Brynjolfsson and McAfee, impressed as they were by Google's self-driving cars, wrote: 'To be sure, there are still many situations that Google's cars can't handle, particularly complicated city traffic or off-road driving or, for that matter, any location that has not already been meticulously mapped in advance.'[41] For whatever reason, Google's 'self-driving car project' spun-off to become the independent technology company Waymo, which says of its on-the- road experience, 'All of this experience is bringing us closer to making fully self-driving cars a reality.'[42] In other words, they're not completely driverless yet. '

Nor was the high-profile Colorado beer run which had a driver, who had to drive the truck on and off the Interstate and to its final destination. The reason is that while these self-driving trucks can cruise the highway without a driver at the wheel, they can't get on and off the highway themselves or manage off-highway and urban traffic. Truck weight and changing load weights present problems not yet solved. Long continuous drives produce heavy wear and tear on sensor-systems, requiring regular maintenance and placing limits on distance.

The technology is not yet suited to perform in rain and snow or other inclement weather conditions or on poorly maintained roads. Even if selfdriving on the highways becomes common, humans will be required to drive the truck on and off the highway and to its final destination. Selfdriving trucks may also present a problem in the intermodal transfer of containers which is at the heart of today's JIT logistics supply chains. Nor can they as yet refuel or unload cases of beer by themselves.

Furthermore, a 2016 report by the American Transportation Research Institute (ATRI) points to a number of legal, liability, and infrastructural barriers to fully driverless trucking. The latter include road maintenance, which is currently at an all-time low, and highway infrastructure needed to support some of the sensor technology such as wireless local area networks (WLAN). In addition, vulnerability to hacking of the software that coordinates the various automated functions in order to highjack or disable the truck remains a major concern. The ATRI report lists 'Cyber Security' at the top of responsibilities manufacturers of self-driving trucks must address.

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[40] Hook 2017.
[41] Brynjolfsson and McAfee 2014,19.
[42] Goggle+ 2017.

In any case, according to the *FT* most investment in the development of sensors, speed-control, automatic breaking, and other self-driving technology are for safety and fuel economising features in conventional driver-controlled trucks.[43]

The Society of Automotive Engineers (SAE) ranks self-driving or autonomous vehicles by a six-level scale of automation, from L0 to L5. Only L5 is completely autonomous 'under all conditions a human driver could perform.' L0 through L4 all require a driver present at all times, even when not at the wheel. So far, according to the ATRI researchers Jeffrey Short and Dan Murray only a handful, such as the Otto beer truck, have reached L4 and these can perform only on well-maintained highways. None have made the L5 level. Short and Murray quote one estimate that by 2035 there could be 60,000 L5 Class 8 trucks (weighing 33,000 pounds or more such as 18-wheelers) sold annually. There are currently 3.45 million Class 8 trucks in use, they point out, and that will grow so that no more than a tiny percentage of fully autonomous trucks are likely to be taking the jobs of truckers any time soon. Even then, ATRI says of L5 trucks, 'that does not mean a driver would not be onboard or necessary.'[44]

Perhaps all the flaws will be corrected eventually and other barriers removed, but for now, with the sole exception of air transportation, the transportation industry continues to spend more of its investment on conventional trucks than any other type of equipment according to the government's Bureau of Economic Analysis (BEA) figures, while in 2014 the American Trucking Association said there was a shortage of 40,000 truckers.[45] In any case, the biggest barrier to the exponential spread of automation in general lies in the political economy of contemporary, turbulent capitalism.

The political economy of automation

The underlying methodological problem with techo-futurists such as Ford and Brynjolfsson and McAfee, as well as their major critic Robert J. Gordon, is that they are technological determinists. Neither the problems of profitability nor of class conflict enter their analyses. For them history moves forward as a result of technological innovations by bold entrepreneurs. They argue that there has been no human progress from the time of Rome to the invention of the steam engine. Brynjolfsson and McAfee actually produce a figure showing that the curve of human social progress is led by technological change, and in particular the invention and application of the steam engine by James Watt between 1765 and 1776. They state forthrightly that the industrial revolution was 'the first time our progress was driven primarily by technological innovation—and it was the most profound time of transformation our world has ever seen.'[46]There is no recognition here that there was something besides entrepreneurial genius behind this technological innovation and

[43] Hook, 2017; Short and Murray 2016, pp. 4-14.
[44] Short and Murray, 2016, pp. 6, 11-12.
[45] Hook 2017; Bureau of Economic Analysis, 2017c.
[46] Brynjolfsson and McAfee 2014, 6-7. Figure 1.2 is misleading in that it neglects the social and cultural advances; periods of growth; and huge scientific advances in math, navigation, ship construction, mechanics, astronomy, printing, artillery and firearms, etc. that preceded the industrial revolution by a century or more. These advances, however, were the results or enablers of the period of expanding trade and conquest by European powers, while the industrial revolution was made possible by capitalism's 'intensive as distinct from extensive expansion' that Wood points to. For those influenced by neoclassical economic and technological determinism there is no distinction between trade and commerce, which are ancient, and capitalism which is not.

its application along with many other innovations in what became the industrial revolution—namely the prior development of capitalism with its competitive drive for 'improvements' in production and profitability.

As Ellen Meiksins Wood summarised the distinct nature of capitalism as it arose first in agrarian England prior to the industrial revolution, 'This system was unique in its dependence on intensive as distinct from extensive expansion, on the extraction of surplus value created in production as distinct from profit in the sphere of circulation, on economic growth based on increasing productivity and competition within a single market—in other words on capitalism.' What drove this need to intensify the extraction of surplus value 'was not the emergence of steam or the factory system but rather the need inherent in capitalist property relations to increase productivity and profit...the factory system was result more than cause.'[47]

At the same time, these techo-futurists tend to rely on mainstream neoclassical economic assumptions. One assumption is that machines, just like humans, can produce value as well as physical products or services (use values) of various sorts. The counter assumption here will be that while machines can produce *use values,* only human labour can produce value. In other words, the classical Marxist view of the social relations of production and value creation at the heart of capitalist dynamics and limitations.

Following neoclassical assumptions, for most techo-futurists, whether academic or popular, markets and knowledge are assumed (perhaps unconsciously) to be 'perfect' and the spread of new technology, therefore, rapid and even within and between industries as leading firms adopt the new methods. As Howard Botwinick argues, however, Marx's view of the impact of actual capitalist competition is one of uneven development due to the prior existence of accumulated fixed capital and differential profit rates among competing firms. Not all firms can afford to jettison their old machinery and purchase new technology simultaneously. In addition, there tends to be a leapfrogging effect as late-comers adopt a more advanced version of the new technology, leaving the initial innovators behind. As Botwinick writes, ' *Rather than creating identical firms, competition therefore creates a continual redifferentiation of the conditions of production.'* (emphasis in original) [48] The implication of this is that technology does not simply spread rapidly or universally under conditions of real capitalist competition even in times of growth.

We can see the unevenness of the spread of robots across industries in the figures A&R reproduce from the IFR showing that only auto has adopted robots extensively. But even within auto the spread of robots was neither even nor rapid. While GM introduced its first robots in 1961, Ford waited until the 1970s. Many 'service' occupations, by contrast, have yet to feel the force of automation, while even those that have, such as warehousing and hospitals, continue to create jobs even in the face of automation. Outside of auto and to a lesser extent computers and electronic products most companies are still waiting despite all the hype.

From the vantagepoint of political economy, there are both fundamental and contingent reasons, including timing, why the progress of implementing automation has been relatively slow and why it is likely to remain so. One contingent reason for the slow pace of capital investment in the latest technology is found in the very

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[47] For an analysis of the rise of capitalism and its agrarian origins prior to the industrial revolution, see Wood 2002, pp. 67, 97-115, 174-175, *passim.*

[48] Botwinick 1993, pp. 124-133.

success employers have had in imposing relatively high levels of productivity in manufacturing and some related industries and flat or declining real wages in general through lean production and the more open forms of assault on labour over the past three decades or more. In manufacturing in particular the combined impact of recurrent crises and work intensification eliminated millions of production jobs even while output doubled between the early 1980s and today with significant ups and downs to be sure. This combination has, in effect, done what robots were supposed to do, but at much lower costs to capital.

At the same time, more and more of the new jobs in growing sectors of the economy, such as many services and warehousing, are low-paid and largely without benefits. In some cases, this is accompanied by rising productivity. While real wages in warehousing, for example, were almost flat, productivity in general (not refrigerated) warehousing rose by an average of 5 per cent a year from 1987 to 2009.[49] With productivity high in relation to wages in key industries, and low-wage jobs proliferating, the incentive for large scale investment in costly and potentially risky technology has been reduced, while that in low-wage industries has increased.

As Marx noted in his discussion 'Machinery in Large-Scale Industry', 'In the older countries, machinery itself, when employed in some branches of industry, creates such a superfluity of labour ('redundancy of labour' is how Ricardo puts it) in other branches that the fall of wages below the value of labour-power impedes the use of machinery in those branches and, from the standpoint of the capitalist, makes the use of machinery superfluous...'[50] In other words, as manufacturing shed workers, many have been forced to move to low wage jobs, thus putting further downward pressure on wages. That the wages of many of these workers are below the value of their labour-power is indicated by the fact that 30 per cent of the workforce relies to some extent on one or another form of public assistance.[51] This, in turn, removes the incentive to automate these low-wage jobs.

The rise of new jobs in areas such a social reproduction, healthcare, maintenance, waste management, cleaning, material handling, etc. is not a function of Schumpeterian 'creative destruction' or a spin-off of technology, as mainstream economists and the apologists at the WTO or WEF argue, but of the now affordable investment in these necessary functions mostly performed in the private sector at pitiful wages. Thus, one of the mechanisms behind this shift in employment to these lower- paid 'service' jobs is this sizable reserve army of labour which both supresses wages and provides desperate workers. As Marx put it, 'But if a surplus population of workers is a necessary product of accumulation or of the development of wealth on a capitalist basis, this surplus population also becomes, conversely, the lever of capitalist accumulation, indeed it becomes a condition for the existence of the capitalist mode of production.'[52] Without a 'surplus population' the expansion of capital into new areas is impossible. The turnover in the reserve army is a consequence not only of technology, but of the various aspects of lean production in reducing the manufacturing workforce even though this sector produces more than ever, on the one hand, and an enabler of growth in low-wage employment in, on the other.

[49] US Census Bureau 2011, pp. 409, 417.
[50] Marx 1990, p. 516.
[51] Cooper 2016.
[52] Marx, 1990, 784..

More fundamental to the uneven progress of automation, however, is the rate of profit that is the driving motor of capitalism. Capitalist competition, both domestic and international, drives firms to invest in machinery or new technology to lower labour costs and increase profits. But there is a problem, a contradiction. As the share of fixed capital increases, the *rate* of profit tends to decline, even if the mass of profits increases to some extent as they have. Martin Ford, no Marxist, wrote in an earlier work, *The Lights in the Tunnel,* 'the more machines begin to run themselves, the value that the average worker adds begins to decline.'[53] Since in Marxist political economy it is human labour-power that creates the value that eventually translates into money and profit, that means a falling rate of profit. Profits, in turn, determine the level of investment. As Marxist economist Michael Roberts puts it, 'The movement of profits leads the movement of investments, not vice versa.'[54]

Furthermore, as Anwar Shaikh points out in terms of capital's willingness to move from one industry or firm to another 'it is the rate of return on the new investment, not the average rate of profit on all vintages, which is relevant to the mobility of capital.'[55] This is important as much of the innovation in technology comes from relatively new start-up firms. As we will see below, the survival rate of such high-tech firms barely exceeds a third. This applies to robotics firms as well. As the magazine *Canadian Business,* warns investors 'robotics is a long-term play.' Some, it points out lose money. As one investment counsellor told the magazine 'You don't know when there's going to be a payoff.'[56] This is not music to the ears of most of today' short-term-oriented investors who are the potential providers of new investment.

The argument here is not that capitalism as a system is incapable of strong technological advance. Indeed, its competitive dynamic tells us that over the long haul it should be accumulating capital and innovating through such investment. Here is where timing comes in. The rate of profit has been increasingly turbulent in Western capitalism at least since the late 1960s. This led to the slump of 1974-75 and the 'stagflation crisis' that characterised most of that decade. Profit rates rose in the 1980s and 1990s when capital investment in relation to total labour costs (the organic composition of capital) was relatively low and productivity rising, but never achieved anywhere near the high levels of the post-WWII boom era. They then collapsed with each recession and became somewhat weaker after 2000.[57] Investment decisions for the past forty years or so have been made in the context of increasing crises, volatile ups and downs, relatively slower growth, and turbulent profit rates. Thus, Rifkin's predictions and even those of the earlier *Triple Revolution* faltered on the unfolding volatility of capitalism that had its origins in the late 1960s decline in profit rates—itself a consequence of the capital spending spree of the 1950s and 960s.

As a result, all the neoliberal redistribution of income and wealth upward for the last thirty years or more has not encouraged large-scale investment in expensive industrial technology. Rather to a greater degree than in earlier times much of this money, when not just sitting in some off-shore tax haven, has gone into government bonds, mergers, stocks, derivatives, or at best more conventional plant and equipment. While the 'financialization' of capital can be exaggerated, one indicator of

[53] Quoted in Roberts 2016, p. 263.
[54] Roberts 2016, p. 27.
[55] Shaikh 2016, p. 264.
[56] Borzykowski 2016.
[57] Shaikh 2016, pp. 2.11, 66; Roberts 2016, pp. 223-224.

the movement from new investment in real capital assets (and the short-term mindset of today's capitalists) has been the shift of the share of profits toward dividends rather than internal investment; i.e., the redistribution of profits upward. Whereas, in the 1960s, during the postwar boom, an average of two-thirds of after-tax profits were internally retained and invested with the rest going to dividends, by the twenty-first century retained profits had fallen to 40 per cent on average, while the proportion of dividends had soared. [58] In so far as capital funds its investments from retained profits, which at the aggregate level is generally the case,[59] this is another indication of the slower growth of investment in labour-saving or -enhancing machinery and technology.

The derailing of Moore's Law mentioned above is, itself, a result of economic rather than technological forces. Gordon cites Hal Varina, a founder of Intel and now chief economist at Google, to the effect that research on increasing computer capacity in PCs and laptops ceased 'because no one needs a superfast chip on their desktop.' The problem, he said, was one of 'demand.' No one was going to invest in further computer capacity customers couldn't use and wouldn't pay for. So, research shifted elsewhere and transistor density no longer doubles every two years. As Gordon summarised it, 'Moore's Law died because there was no demand for the engineering expense necessary for it to continue.'[60] Thus, investment in this aspect of technology ceased.

High tech in slow motion—the trend

The slowing down of investment in high tech equipment is not just a theoretical proposition. According to political economist Anwar Shaikh, 'the appropriate measure of technical change is the ratio of current GDP to current-cost capital stock.'[61] This, of course, is the *economic* measure of change, not a measure of the efficiency of the technology, but as such gives us a guide to capital's investment behaviour. Appendix I produces this ratio for the stock of fixed capital equipment from 1980 to 2015.

What this shows is that while there has been growth in this ratio over this 35-year period from 1980 to 2015, the rate of growth has been slowing down significantly decade-by-decade, nearly grinding to a halt between 2010 and 2015 despite some growth in the economy. During the 1980's this ratio grew by an average of 1.8 per cent a year, itself not all that strong. But in the 1990s the annual rate of change slowed by half to 0.9 per cent, then dropped to 0.3 per cent from 2000 to 2009. From 2010 to 2015, during the period of recovery, the rate of growth in the ratio of technical change all but vanished at 0.08 per cent a year.

Looking further into the course of capital investments, we can see that investment in new 'information processing' and 'industrial equipment', as defined by the Bureau of Economic Analysis (BEA), has not taken the course techno-futurists' predictions would suggest. As Appendix II on New Private Investment in Equipment, compiled from BEA data, shows, investment in both information processing and industrial equipment has fallen as a proportion of total equipment investment since the early 1990s, while that in transportation equipment has risen—no doubt as a result of the

[58] Gordon 2016, pp. 619-620; Bureau of Economic Analysis, 2017d.
[59] Shaikh 2016, pp. 616-618.
[60] Gordon 2016, pp. 446-447, 458.
[61] Shaikh 2016, pp. 810-812. Capital stock in equipment includes not only the industrial and logistics equipment discussed above, but 3-D printers and other miraculous devises available as capital as well.

expanding logistics sector. Growth in investment in information processing equipment was surprisingly slow at an annual average of 2.4 per cent over this 23-year period. That in industrial equipment was faster at about 5.8 per cent a year, but very little of this is digitally-driven, robotic, or high-tech in nature, according to descriptions in the BEA's Handbook *Concepts and Methods* and as we saw above in the case of 'Machinery.' 'Other equipment' grew by 10 per cent annually, but this category includes mostly old-tech items such as farm equipment, furniture, construction equipment, etc. The biggest gain came in transportation equipment which grew at 11 per cent a year.[62] Roberts also notes that growth in investment specifically in new technology has decreased in recent years. [63] Economic Policy Institute figures show the same trend.[64]

The economic factors that limit direct investment in technology have also limited spending on Research and Development (R&D), which is essential for advancing the use of new technology of all kinds. According to the OECD's technology indicators, a ratio analogous to that in investment, annual US R&D spending as a proportion of GDP grew from 2.55 per cent in 1990 to 2.79 per cent in 2015. Growth of this ratio, however, was virtually static in the 1990s, rose by a mere .76 per cent a year from 2000 to 2009, and then fell to less than half at .3 per cent a year from 2010 to 2015.[65]

A further indication of the slowing down of investment in technology is the decline in the rate of business start-ups, on the one hand, and their high level of failure, on the other. Many of the firms producing work-related forms of new technology are relatively new, typically small startups like Otto mentioned above, or Tesla, Starsky, and Peloton all of which work on self-driving technology. The rate of start-ups, however, has been falling since the late 1980s when it was 13 per cent of all firms to 10 per cent in 2007 just before the Great Recession, after which it fell further to about 8 per cent.[66] At the same time, start-ups in information technology have the lowest survival rate over four years of 37 per cent compared to 45 per cent for manufacturing, the next lowest survival rate, and 58 per cent for FIRE firms with the highest rate.[67] One result of the poor performance of start-ups is that the proportion of those employed by firms five years old or less has fallen from 19.2 per cent in 1982 to 10.7 per cent in 2011.[68]

Another common measure of the growth of technology and its application is that of the increase in occupational employment associated with computerization: the BLS category of Computer and Mathematical Occupations. This remains an above-average growth group, but this measure, too, has slowed to a crawl from 12 per cent a year from 1983 to 2000, then to 3 per cent from 2000 to 2014. The BLS projections on future occupational growth show a further decline in the annual rate of growth for computer and mathematical workers to just over 1 per cent from 2014 to 2024.[69]Thus, by almost any measure the advance of new technology in *economic* terms does not substantiate the techno-futurists' predictions.

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[62] Bureau of Economic Analysis 2016a, pp. 6-13-6-21.
[63] Roberts 2016, pp. 256-257.
[64] Mishel and Bivens 2017, pp. 8-10.
[65] OECD 2017.
[66] Gage 2012.
[67] Haltiwanger, Jarmin, and Miranda 2012, p. 3; US Census Bureau, 2011, p. 506; Gage 2012; *Statistic Brain* 2017; Sanders and Wolfgang 2014, p. 7.
[68] Gordon 2016, p. 585.
[69] Hogan and Roberts 2015; U.S. Census Bureau 2001, pp.380-1

Given all the gains in technology these futurists describe, the mystery of this poor and declining performance lies in the volatility of the US and world capitalist economies since the 1970s and the continuing problem of profitability. Profitability was not strong enough and could not be sustained long enough under these circumstances to justify large and continuous investments in new technology of any kind. The problem was compounded by the rapid rise in corporate debt over these years. As a result, as Roberts argues, 'this increase in debt means that companies must raise profitability or be forced to reduce investment in productive capacity to service rising debt.'[70] It appears they have done the latter. Future investment in the US and world-wide auto industry, the major user of robots, is further limited by the persistence of global overcapacity in car and light truck production.[71] Yet another indication that large scale investment is not likely in manufacturing in the near future is the relatively low level of capacity utilization which has fallen from above 80 per cent in the 1990s to an average around the mid-70 per cent rate since, compared to the mid-to-high 80 per cent level of the 1960s.[72] Short an economic miracle, the pace of automation and the march of the robots in much of industry is likely to be bumpy and slow.

In the face of the underlying problem of profitability, capital has turned other means of increasing the profits of their own firms besides lean production. Overseas investment is one such strategy, but while some firms profit from this the overall net position of the US has been negative since 1989.[73] Furthermore, it has only intensified the competition that underlay both crises and turbulent profits rates. A more recent tactic in the fight over the distribution of surplus value has been the growing concentration and centralization of capital via mergers and acquisitions along with the return to a focus on major lines of production and the rejection of the conglomeration of an earlier period.[74] This, of course, is less a method of increasing total surplus value than of seeking to increase one's share of it by playing 'beggar thy neighbour.' This, too, appears to lead to yet another *cul de sac* for capital.

Conclusion

While the past is not always a guide to the future, for there to be a substantial increase in investment in automation there would have to be a prolonged period of stable economic growth and rising profit rates. That has not been the case and is not likely to improve as the very slow and drawn out recovery of the US economy since 2009 shows. A prolonged period of stable growth would most likely require a catastrophic depression on the scale of the 1930s to clear the way for a new period of substantial growth through the massive destruction of older, less efficient assets. In all likelihood, it would also bring rising worker discontent and, at least, the possibility of an alternati*ve.* Should the alternative be postponed yet again and a sustained period of rapid growth bring on the rapid elimination of living labor from production via automation, advanced robotics, etc. the system would certainly face yet another crisis of profitability.

[70] Roberts 2016, p. 106.
[71] Welch 2008; Bryant 2012.
[72] Federal Reserve 2017; Council of Economic Advisers 2011, p. 253.
[73] BEA 2017e.
[74] Moody 2017, pp. 50-54.

For the techno-futurists, however, the massive productivity gains inherent in the rise of automation in its various forms would be the salvation of the system, the road to higher productivity and profits, though also the destroyer of employment. But technology, for all the AI gains or improvements in robots, does not introduce itself to the factory, warehouse, or 18-wheeler. It has to be introduced through actual investment that promises substantial increases in profit rates to the capitalists who advanced the money, and the hope that that will materialise on a scale big enough to bring about the robot revolution in the foreseeable future seems like the biggest piece of futurism of them all.

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Appendix I

Technical Change: Ratio of nonresidential fixed capital stock in equipment to GDP at current cost ($Billions)

Year	GDP	Equipment	=
2015	18,120.7	6,352.1	2.85
2014	17,427.6	6,137.8	2.84
2013	16,691.5	5,895.7	2.83
2012	16,155.3	5,670.6	2.85
2011	15,517.9	5,478.3	2.83
2010	14,964.4	5,268.0	2.84
2009	14,418.7	5,182.7	2.78
2008	14,718.6	5,267.6	2.79
2007	14,477.6	5,020.9	2.88
2006	13,855.9	4,784.0	2.90
2005	13,093.7	4,481.8	2.92
2004	12,274.9	4,257.2	2.88
2003	11,510.7	4,040.8	2.85
2002	10,977.5	3,968.7	2.77
2001	10,621.8	3,912.3	2.72
2000	10,284.8	3,805.5	2.70
1999	9,660.6	3,578.7	2.70
1998	9,089.2	3,384.7	2.69
1997	8,608.5	3,235.2	2.66
1996	8,100.2	3,104.0	2.61
1995	7,664.1	2,959.2	2.60
1994	7,308.8	2,785.0	2.62
1993	6,878.7	2,642.4	2.60
1992	6,539.3	2,554.4	2.56
1991	6,174.0	2,482.2	2.49
1990	5,979.6	2,423.7	2.47
1989	5,657.7	2,300.6	2.46
1988	5,252.6	2,178.0	2.41
1987	4,870.2	2,055.3	2.37
1986	4,590.2	1,964.7	2.34
1985	4,346.7	1,858.0	2.34
1984	4,040.7	1,758.8	2.30
1983	3,638.1	1,670.5	2.18
1982	3,345.0	1,619.9	2.07
1981	3,211.0	1,528.4	2.10
1980	2,862.5	1,369.9	2.09

Source: BEA, 2017f *Current Dollar and ‘Real’ Gross Domestic Product,*
BEA, *Current Cost Net Stock of Private Equipment by Industry,* Table 3.1E.
Growth: 1980-1989 = 18.2% or 1.8% per year 1990-1999 = 9.3% or 0.9 per year
2000-2009 = 3.0% or 0.3 per year 2010-2015 = 0.4% or 0.08% per year

Appendix II New Private Investment in Equipment by Type ($Billions) *

Type Equipment	1992	2005	2010	2015
Private Equipment	480.0 (100%)	864.6 (100%)	822.9 (100%)	1177.0 (100%)
Information Processing	199.3 (42%)	259.8 (30%)	273.8 (33%)	311.3 (27%)
Industrial Equipment	91.8 (19%)	159.4 (19%)	50.1 (18%)	215.3 (18%)
Transportation Equip.	110.4 (23%)	246.7 (29%)	205.4 (25%)	395.0 (34%)
Other Equipment	72.6 (15%)	189.0 (22%)	185.5 (23%)	242.4 (21%)
Residential Equipment	5.9 (1%)	9.6 (1%)	8.3 (1%)	8.7 (1%)

*Percentages do not always equal 100% due to rounding.

Source: Bureau of Economic Analysis, Relation of Private Fixed Investment in Equipment and Software (by type) in the Fixed Assets Accounts to the Corresponding Items in the National Income and Product Accounts, August 2, 2011; Bureau of Economic Analysis, Relation of Private Fixed Investment in Equipment in the Fixed Assets Accounts to the Corresponding Items in the National Income and Product Accounts, September 7, 2016c