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Summary Report of the Waterloo Symposium on Technology and Society

Inaugural event

Robotics and the Age of Automation:
Preparing for the Coming Disruption

By Mark Sedra

SUMMARY

In the inaugural Waterloo Symposium on Technology and Society, held on April 16, 2019, Martin Ford explored the ways in which AI and automation are outpacing humans in a range of sectors, from education to law, agriculture to healthcare, and beyond. He presented a pragmatic view of what the future of work will look like. But Ford also sought to answer an existential question: can accelerating technology disrupt our entire economic system to the point where a fundamental restructuring is required? In other words, is today's technological revolution fundamentally different than those of previous eras, such as the industrial revolution and the rise of the internet? In past eras of technological disruption, the elimination of some categories of jobs was offset by the emergence of new types of complimentary work. Today, rapid advances in machine learning has paved the way for machines that are wholly autonomous, rendering a large segment of the labour force obsolete. The prospect of an economy without human labour is more real than ever, yet we have not meaningfully grappled with its societal implications. Government policy has struggled to keep pace with the frenetic pace of technological innovation. This paper will summarize the ideas presented by Ford and situate them within wider philosophical and policy debates. It will explore different policy options, from universal basic income to education system reforms, that private and public sector actors can enact to better prepare our society for the coming disruption.

The Waterloo Symposium on Technology and Society seeks to promote public discourse in Canada and beyond on the societal challenges and opportunities created by innovations in four primary areas: artificial intelligence, robotics, big data and social media.

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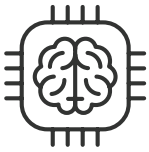
INTRODUCTION

Few would disagree that rapid advances in automation and artificial intelligence (AI) have placed society on the precipice of a massive disruption. Where opinions differ is on the scale of that disruption and its wider societal implications. On April 16, 2019, the Centre for Security Governance (CSG) convened the first Waterloo Symposium on Technology and Society to explore this pressing issue. One school of thought in the debate surrounding the rise of automation and AI holds that it will have a devastating and irreversible impact on the economy and labour market. Elon Musk, the billionaire CEO of Tesla and SpaceX, has warned that increased reliance on robots will mean that "no job is safe…the robots will be able to do everything, bar nothing" (quoted in Clifford 2017). According to Musk, "people are not as afraid of the potential of robotics and artificial intelligence as they should be because they don't fully understand its potential" (ibid.). He calls for proactive government regulation of the industry combined with a historic expansion of the welfare state to avert a looming crisis.

On the other side of the debate are those who feel that such predictions are overly alarmist and ahistorical. They concur that automation will have a transformative impact on the economy marked by massive displacement in the labour market. However, as a 2017 McKinsey & Company report stated, "the scale of shifts in the labor force over many decades that automation technologies can unleash is not without precedent" (Manyika et al. 2017). This optimistic view holds that the effects of automation are "of a similar order of magnitude to the long-term technology-enabled shifts away from agriculture in developed countries' workforces in the 20th century" (ibid.). Indeed, despite the fact that the proportion of the overall Canadian workforce involved in agriculture dropped from one-third at Confederation in 1867 to less than two percent today, people have found alternative employment and food is more plentiful than ever (Hasselback 2017). By extension, rather than leading to mass long-term unemployment, the current explosion of automation will create new employment opportunities, just as the mechanization of agriculture did in the past.

The initial waves of alarmism and reassurances by technology experts, political scientists and economists have gradually given way to "a more complicated, mixed understanding that suggests that automation will bring neither apocalypse nor utopia, but instead both benefits and stresses alike" (Muro et al. 2019, 2). Martin Ford, the keynote lecturer at the first Waterloo Symposium on Technology and Society, echoed this more nuanced appraisal. A renowned technology thinker and author of the New York Times best-selling book, *Rise of the Robots: Technology and the Threat of a Jobless Future*, Ford argued: "We are very likely on the leading edge of…a disruption that will completely redefine the way businesses operate and compete.



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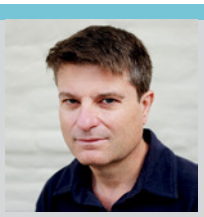
Martin Ford

KEYNOTE SPEAKER:



MARTIN FORD

The founder of a Silicon Valley-based software development firm and the author of the *New York Times* best-selling book, *Rise of the Robots: Technology and the Threat of a Jobless Future*.

PANELISTS:

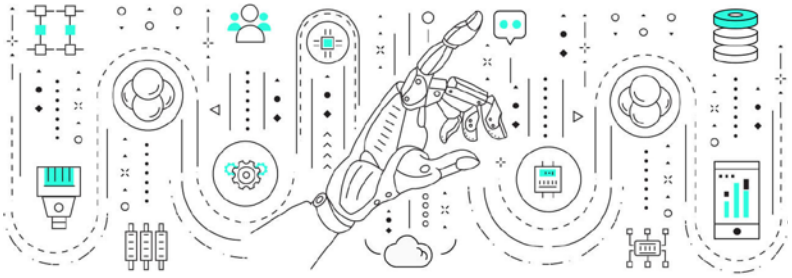
Ryan Gariepy: Chief technology officer and co-founder of Clearpath– the largest and fastest-growing robotics company in Canada.

William Melek: Professor in the Department of Mechanical and Mechatronics Engineering at the University of Waterloo. He also serves as the director of mechatronics, the director of the Laboratory of Computational Intelligence and Automation and the director of RoboHub.

Joël Blit: Assistant professor in the Department of Economics at the University of Waterloo and senior fellow at the Centre for International Governance Innovation (CIGI).

And I also think that ultimately it will put a tremendous amount of stress on the economy and society." He recognized that there is good reason to be skeptical that the outcome of this disruption will differ from those of previous generations, such as the agricultural revolution. "There is a lot of historical evidence to suggest that people do adapt to the economy," Ford emphasized, "that new jobs are created. That things in the long run will work out." However, he also admitted that we may be at a point "where the technology is finally available to us that we could possibly see a different outcome." In his wide-ranging keynote lecture, Ford celebrated the tremendous benefits of automation while urging society to take steps to increase its resilience to offset inevitable adverse consequences.

This paper will summarize Ford's main arguments and highlight key insights from the expert panel discussion that followed his lecture. To complement the summary, the paper will draw on analysis from other experts and organizations engaged in the ongoing debate. It will be divided into three sections: The first will give a sense of the scale of the automation revolution and explain how it differs from previous disruptions caused by technological change. The second section will identify the challenges and opportunities this disruption will create. Finally, the paper will explore what steps can be taken by governments, the private sector and civil society to maximize the benefits of automation and mitigate its deleterious effects.



Pictured (left to right): Ryan Gariepy, William Melek, Martin Ford, Joël Blit and Mark Sedra.

I. WHAT IS DIFFERENT ABOUT TODAY'S TECHNOLOGY-DRIVEN DISRUPTION COMPARED TO PREVIOUS ERAS?

There remains a great deal of disagreement among social scientists and technologists over the broader societal impact that automation portends. Speaking about the labour market, Boston University economist Pascual Restrepo, a co-author of an influential 2017 US National Bureau of Economic Research Working Paper studying the impact of robots on the US labour market, asserted that "the process of machines replacing human labour is not something that is new. It's been going on for 200 years" (quoted in Barlow 2017). Indeed, Ford traced it back to the Luddite rebellion of the early nineteenth century that saw British textile workers rebel against the introduction of textile machines. In 1964, a group of prominent American scientists and social scientists, including famed chemist Linus Pauling (recipient of two Nobel Prizes) and economist Gunnar Myrdal (a future Nobel Prize winner), sent a 14-page memo, dubbed "The Triple Revolution," to President Lyndon Johnson, warning that the United States was on the brink of total economic chaos because of industrial automation.

Such concerns have only grown over time, as the world entered what MIT researchers Erik Brynjolfsson and Andrew McAfee call in their 2014 book the "second machine age" (Brynjolfsson and McAfee 2014). Unlike the "first machine age" that denoted the nineteenth- century Industrial Revolution, where humans were required as operators, in the "second machine age" human involvement has become increasingly redundant. Since it is estimated that the labour of one industrial robot can substitute for up to six humans, anxiety over the implications of rising automation has understandably risen (Barlow 2017). However, despite the fact that the United States alone lost an estimated six million manufacturing jobs between 2000 and 2009, at a time when industrial robots were becoming ubiquitous in the manufacturing sector, in 2019 unemployment rates were at historic lows (Surowiecki 2017). The loss of these jobs, according to many economists critical of automation doomsayers, is a coincidence and more due to the rise of globalization and the migration of jobs to cheaper labour markets than it is the rise of robots (ibid.).

Contrary to the idea that automation will lead to a jobless future, Wim Naudé and Paula Nagler (2016) have gone so far as to claim that "there is actually the possibility that technological innovations can lead to more job and income opportunities, and to more equal societal outcomes." Ford admitted that "there is a lot of historical evidence to suggest that people do adapt to the economy. That new jobs are created. That things in the long run will work out." However, things could be different this time. As Savvas Chamberlain, the founder and former CEO of the high-tech firm DALSA, noted in his introduction of the symposium series, "if we look at the history of technological innovation, until about the early 1990s technological advancements benefited and raised the standard of living of all sectors of our population" but ever since "these advancements have principally benefited the top one percent of our society (see Appendix 1)." Building on this fundamental difference, Ford identified three factors that may make the current technological disruption qualitatively different from previous ones.

1. Exponential Acceleration

The pace, scale and type of technological change under way sets the current period apart, exemplified by the exponential growth in areas like computing power, communications bandwidth and memory capacity (see Appendix 1). From the 1950s to today there has been something in the order of 30 doublings in computer power. This extraordinary level of technological innovation has facilitated widespread automation and displaced large segments of the labour market. And contrary to the optimistic view of some economists, not all of these lost jobs have been replaced. Ford cited statistics from the US Bureau of Labor that show that despite a 40 percent increase in private sector business output from 1998 to 2013 and a population increase of 40 million during the same period, the total amount of labour performed remained static. In the words of Ford, this "points to something quite remarkable happening."

The pace of automation shows no sign of abating. In 2018, robot sales in the United States peaked for the eighth year in a row according to the International Federation for Robotics (IFR). Robot density in the US manufacturing industry reached 200 robots per 10,000 employees in 2017, up from 176 in 2015 (IFR 2019). The 2017 McKinsey & Company report estimated "that about half of all the activities people are paid to do in the world's workforce could potentially be automated by adapting currently demonstrated technologies," amounting "to almost $15 trillion in wages" (Manyika et al. 2017). Researchers at the Brookings Institution found that "approximately 25 percent of US employment (36 million jobs in 2016) will face high exposure to automation in the coming decades (with greater than 70 percent of current task content at risk of substitution)" (Muro et al. 2019, 3). Almost every profession in our society, the McKinsey study admitted, has at least "partial automation potential" (Manyika et al. 2017). It is this breakneck speed of change that makes this disruption unique.

2. Advancements in Machine Learning

Major advancements in machine learning, fuelled by the availability of large data sets, have greatly expanded the scope of activities that can be automated. Ford explained that "machines are, at least in a limited sense, beginning to think. They are taking on true cognitive ability. Machines and algorithms are making decisions, they are solving problems, and most importantly, they are learning." These new capacities have opened up new, previously unanticipated parts of the labour market to automation; robots are increasingly taking on white-collar knowledge jobs in addition to repetitive manual labour. Ford noted that the number of people in corporate finance departments in the US private sector declined by 40 percent over a recent 10-year period, a trend driven by the rise of smart accounting software. In the legal field, systems have been created to review documents, generate contracts and conduct case law research. Most trading on Wall Street today is algorithmic, with the fintech industry growing rapidly. The health sector is another field that is poised for a major wave of automation. New diagnostic and radiology software can increasingly outperform human doctors. Speaking about the automation of healthcare, Mohamed Owais Qureshi and Rumaiya Sajjad Syed (2014) acknowledged that "robots can do some jobs better, cheaper, and faster than humans. They can transcribe and store information that help doctors and nurses diagnose their patients." However, they also warned that such automation must be undertaken in a manner that improves "the employment and motivation of employees in this sector" (ibid).

Another worrying labour market indicator, according to Ford, is that the incomes of university graduates are declining. In the United States, half of college graduates are unable to find jobs that leverage their core skills, due, in part, to the automation of entry-level jobs. According to Ford, this is something that will pose a major challenge to society: "Historically, education has really been the only tool we have in the toolbox, when it comes to adapting to the implications of advancing technology. The only solution we've had to the impact of technology on the job market has been to send people back to school, to give them more education and training." The emergence of machines capable of learning could close one critical avenue to facilitate job substitution.

3. The Ubiquity of AI

AI is now being used everywhere: on your smartphone, in the grocery store checkout line and at your bank. Few people will be able to go through their day without using AI in some form. The rapid spread of AI over the past decade will only accelerate the pace of automation, acting as a force multiplier. Ford compared the impact of AI in today's world to the introduction of electricity:

> AI is truly becoming a general-purpose technology. By this I simply mean that it is going to scale across everything. It is going to impact across the board. It is in many ways going to be comparable to electricity… And no one would ever say what industries are most impacted by electricity. That seems like a silly question. Everything relies on electricity. The same is going to be true of artificial intelligence. It will scale across every aspect of the economy. Every employment sector. Every industry. There is no area that it will bypass.

The wide scope and scale of AI penetration of the economy will make it harder to substitute lost jobs. It is true that many new jobs in the labour market will emerge over the coming years that we are not able to anticipate today, in order to address new demands created by our automated economy. Twenty years ago, for instance, few would have predicted the need for social media marketers, web designers or data scientists. However, as Ford noted, these new job types are not a major share of total employment. In fact, in the United States, 90 percent of the workforce is engaged in occupations that existed 100 years ago, such as food services, retail and health care. "It is pretty clear," Ford said, "that a lot of these traditional areas of work will be disrupted in the near future." Echoing this, University of Toronto professor David Ticcoll (2017) claimed that "the focus on labour substitution in Canada and everywhere else vastly underestimates the breadth and numbers of at-risk jobs." The problem is that "innovations don't just automate jobs and tasks. They can also make them functionally irrelevant or economically unviable. It's not just about labour substitution: it's also about labour obsolescence" (ibid.). An example that Ticcoll cited to illustrate this phenomenon is automobile insurance. If self-driving vehicles take over the car market over the next 20 years, as many people predict, the entire personal automobile insurance market could evaporate.

Taken together, these three factors seem to indicate that something new is happening with this technological disruption. As with previous eras, this period of change presents major opportunities to improve the quality of life for societies across the world, but where it differs is that it also brings unprecedented systemic risks.

II. THE CHALLENGES AND OPPORTUNITIES OF WIDESPREAD AUTOMATION

In a 2014 New York Times op-ed, Thomas Friedman rightly asserted that the current unrelenting drive toward automation has imbued the current generation with "more power to improve (or destroy) the world than any before" (Friedman 2014). Indeed, the current technological disruption presents a series of distinct risks and opportunities to modern economies and societal order, which will be briefly explored in this section.

Opportunities

Perhaps the most obvious benefit of automation is that it has the potential to massively increase economic productivity. McKinsey & Company estimated that "automation could raise productivity growth globally by 0.8 to 1.4 percent annually" up to 2065 (Manyika et al. 2017). Another study by Michael Koch, Ilya Manuylov and Marcel Smolka (2019) found that businesses that adopted robots in their production process were more likely than those that didn't to create jobs in subsequent years. In other words, "robots are creating new opportunities for some firms, while simultaneously leading to job losses in non-adopting firms" (ibid., 30). The auto industry, one of the centres of gravity for industrial automation, demonstrates how increased productivity from automation could boost productivity: US Bureau of Labor statistics show that between 2013 and 2018, employment in the US automotive industry actually increased by 22 percent, from 824,400 to 1,005,000 jobs (IFR 2019). This is despite the fact that "robot density in the automotive industry increased by 52 percent between 2012 and 2017, from 790 to 1,200 industrial robots in operation per 10,000 employees (units)" (ibid.). As Carolyn Wilkins, the Bank of Canada's senior deputy governor, put it in an April 2017 speech, "productivity growth is the only game in town when it comes to raising the economic and financial well-being of people over a long period" (quoted in Hasselback 2017). It is a fallback to a classic economic formula: greater business productivity boosts consumption. As manufacturing becomes more efficient and the cost of goods drops, people will spend more, driving economic growth. This logic, however, hinges on consumers having the discretionary income to pay for these more affordable consumer goods. In the absence of stable jobs, the formula breaks down.

The optimists don't deny that automation will create some pain: "Communities that have been more exposed to automation," a 2017 LSE study admitted, "do not tend to be doing well in terms of employment and wages" (quoted in Gaskell 2018). Mark Muro et al. (2019, 6-7) showed how some geographic areas and demographic groups are more vulnerable to the impacts of automation than others, notably the industrial Midwest in the United States, where men and young workers have been most hard hit. York University economist Matias Cortes acknowledged that there is little doubt that the new economy will create "clear winners and losers" (quoted in O'Brien 2019). However, to most economists, the benefits outweigh those costs, and any harm could be mitigated, at least partially, with government intervention.

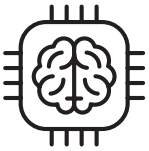
An argument can be made that we should celebrate the trend of robots taking over back-breaking manual labour from humans. Ryan Gariepy, the chief technology officer of Clearpath Robotics,

one of Canada's largest robotics firms, affirmed this during the panel discussion of the symposium: "It is important to remove these dull, dirty and dangerous jobs from humans…but on the other hand we need to, together as a society, make sure there is adequate support at the right times." The hope is that the labour market will evolve with automation, with most workers moving from doing the work to managing and complementing smart machines. University of Waterloo engineering professor William Melek, another panellist, envisioned "a future that will be more reliant on co-bots, where humans and robots work on collaborative tasks." After all, humans will still be needed to program the robots and critically, as Melek explained, "we have not figured out a way to incorporate creativity using AI to power robotics operation." Machines may be able to sort a box per second as compared to every six seconds for a human worker, but they still lack the visual perception, dexterity and creativity to handle unexpected situations, such as if a box falls.

Challenges

When it comes to the creation of new occupations in response to automation, Ford laid out two concerns: will there be enough new jobs created and will there be a skill mismatch that will prevent workers from transitioning to new professions? Ford believes "workers may struggle to transition into…new occupations" if they "require a very high level of technical skill or creativity." The pessimists surrounding automation worry that "tomorrow's jobs will be insufficient in number, inferior in quality and badly paid" leading to "net growth in unemployment, underemployment, precarious jobs, and economic inequality" (Ticoll 2017). There is growing evidence that such predictions are beginning to pan out. Ford showed how wages in the United States have remained stagnant since the 1970s, with many workers today making less in inflation-adjusted terms than their parents did. The fruits of massive increases in productivity brought about by automation have been largely captured by people at the top of the economy – investors, executives and corporate elites. Prior to the 1970s, as productivity increased, wages invariably followed. These two trend lines have been decoupled in the age of automation. With workers "being left behind" and economic inequality increasing, growing numbers of citizens have felt politically disaffected and disillusioned – this sentiment has been a driver of the populist political movements that have cascaded across the United States and Western Europe in recent years.

With each new decade, the global economy is producing fewer jobs than the previous one, indicating a deep-rooted structural change. "It is almost as though," Ford explained, "the job market is…losing its elasticity; it's losing its ability to spring back where it was before…I think the primary culprit is technology." In the aftermath of the 2011 recession, jobs have gradually come back, but they are not the same jobs. Middle-class jobs are getting wiped out. The jobs created in the recovery period are weighted to undesirable jobs, such as low-paid service jobs or insecure jobs in the gig economy. This has been dubbed job market polarization, a global phenomenon that should be a cause of great concern. It has contributed to wealth inequality with its myriad of destabilizing effects.



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It is important to sound a note of caution when attributing inequality solely to automation or the rise of AI. A host of other factors have contributed to inequality, including globalization and the offshoring of jobs, the decline of the organized labour movement and the weakening of social welfare institutions. According to Naudé and Nagler (2016), "while technological innovation may have contributed to rising inequality, its actual contribution has probably been dwarfed by the institutional-governance weaknesses." While it would be a mistake to lay exclusive blame on technology for growing inequality, it will likely become a more omnipresent factor as time passes and automation becomes even more pervasive, particularly without active government intervention to regulate it. Ford was adamant: "there is every reason to believe that this impact [of automation] is going to accelerate going forward." After all, McKinsey & Company estimated that "half of today's work activities could be automated by 2055" (Manyika et al. 2017).

While many economists claim that the wealth created by productivity growth will turbocharge the economy and trickle down to workers through new types of employment or government support, rising inequality and declining consumerism could foster economic stagnation or even a "downward deflationary spiral." An argument can be made that inequality driven by technology is already producing unusual effects in the economy, with a new recession appearing on the horizon. As Ford explained, the last economic crisis started when people couldn't pay their mortgages. What if the next wave of automation leads to unemployment or lower wages? It could produce comparable or even worse outcomes.

What the debate about the labour market and economic conditions often overlooks is the psychosocial impact of job losses. A very large percentage of people derive their sense of purpose and dignity, not just their economic livelihood, from their career. Accordingly, widespread job losses, even if blunted by social programs or subsidies, could have a pernicious effect on societal well-being and cohesion. The opioid crisis, according to Ford, teaches us something here, as it is partially tied to disruptions in employment. The scourge has hit hardest in areas that have seen the steepest disruptions to the labour market, such as the US Rust Belt. Then there is the problem of what Melek called "social robotics… the ethical considerations of robots making decisions." The increasing weaponization of AI and robotics has raised deep ethical and legal quandaries, igniting a grassroots movement to ban autonomous weapons systems. There is also the concern of human bias being baked into robot programming, effectively reproducing societal injustices and inequities. Algorithms, it has been shown, reproduce bias. As the process of automation moves forward and touches every part of our lives, we must examine our basic values and reflect on the society we wish to reproduce. This makes the robot revolution both a challenge to societal cohesion and an opportunity for societal renewal.

III. WHAT SHOULD WE DO NOW?

With the pace of automation only increasing, there is an urgent need to take steps to increase our societal resilience to its systemic impacts. Joël Blit was adamant in his remarks at the symposium that "what we should not do is kill AI and robotics. It's not a technological problem. It's...a policy problem." According to Blit, this technological revolution "can make us all richer. We just have to figure out what the right policies are so that everyone benefits and not just a few." This is, in many ways, the crux of the challenge of automation, ensuring the undeniable benefits of the technology reach all parts of our society and curb the inequality that is growing with such pernicious effects. Government will invariably have to play a leading role in meeting this challenge. As Ford stated, "the impact of technology is going to be so disruptive that ultimately government is probably going to be the only tool in the toolbox that we have that is really capable of addressing this." The problem is that at the moment, many Western governments appear unprepared and ill-equipped to fulfill this indispensable role. A Mowat Centre report on the future of work in Canada concluded: "absent transformational policy change to recognize the new world of work, Canada's social policies and programs will prove woefully inadequate to sufficiently insure enough people to meet the challenges ahead" (Johal and Thirgood 2016, 1). Governments need to embrace the technological revolution while taking aggressive steps to regulate it and redistribute the wealth and advantages it generates. There are five policy areas in particular where government action is urgently needed and could make a major impact in blunting the deleterious effects of technological change.

1. Investment in Technology

If governments hope to manage the disruptive effects of robotics and automation and maximize their benefits, they need to have a seat at the innovation table. Investing in these new technologies, whether it is through research grants to educational institutions, seed funding to early stage companies or joint ventures with established firms, will give government some influence over the direction of the industry. New partnerships with the private sector will give government leverage to facilitate the development of new jobs. The Canadian government has seen the importance of investing in innovation, launching a $950 million Innovation Superclusters Initiative that seeks to drive research and innovation in five priority areas: AI, advanced manufacturing, digital technologies, protein industries and oceans (Government of Canada 2019). The initiative, which brings together Canadian businesses, academic institutions and non-profit actors, is expected to generate 50,000 new jobs and $50 billion in economic growth over the next decade. It is the type of investment that governments must make to ensure that they are able to assume a role in steering the technological revolution. Considering the transformative potential of robotics and automation, allowing market forces to be the sole driver of change in the industry carries too many risks.

2. Strengthen the Safety Net

Strengthening the social safety net is widely considered to be a crucial element of government strategies to mitigate the potential harmful effects of automation. This could include increasing unemployment insurance benefits and the launch of more robust programs to support vocational

training and re-skilling. A more transformative measure, which has received growing attention in the public and private sectors in recent years, is the introduction of a universal basic income. While the idea is controversial in some circles, Ford called it "almost inevitable." In a 2016 interview with CNBC, Elon Musk admitted that "there is a pretty good chance we end up with a universal basic income, or something like that, due to automation" (quoted in Clifford 2017).

Ford argued that finding "a way to build an economy that works for everyone" in the age of automation requires programs that will "guarantee that everyone has got some livable amount of income even if they don't have a job that provides that income." In his view, "the simplest, most straightforward way…to do that is probably going to be some kind of guaranteed minimum income or universal basic income." The concept is not new, having been around in some form since at least the 1930s, but has never gained the traction that it has now. Several Western countries, including the Netherlands, Finland and Canada, have run experiments testing the efficacy of such programs. Demonstrating how the concept still polarizes public opinion, a Canadian universal basic income pilot program in the Province of Ontario was discontinued while still in the early stages when the Conservative government came to power in 2018 (The Canadian Press 2018).

The concept may seem radical, upending a basic tenet of capitalism – that labour is rewarded, confers value and is the key to societal advancement. However, if, as Ford stated, "you really understand the trends that seem likely to unfold, and the impact that it is going to have" then this appears to be a logical evolution of the modern welfare state. Despite this fact, Ford acknowledges that recent political turbulence across the West shows that "it will be a difficult and politically fraught transition to make."

3. Re-focus Education and Re-Skilling

One area of action where there is wide consensus is the reform of the education system from kindergarten on up. "We need to change the way we operate for the 21st century economy," said Ticcol, emphasizing that "more people need STEM skills – science, technology, engineering and mathematics" (Quoted in Vieira 2017). William Melek stressed this point during the symposium panel discussion. By expanding STEM education programs in primary and secondary school now, our workforce will have the requisite skills for the new economy two decades from now. Our education system must also focus on skills that machines have trouble replicating, like leadership, creativity and critical thinking. The ethical and policy questions posed by increasing automation also create new opportunities for the social sciences, which will need to create a cadre of leaders that can set the rules and ethical boundaries for the new machine-driven economy.

When it comes to vocational training or re-skilling, Melek highlighted the gap between government funding for primary research to make Canada a global hub for industrial automation and its support for worker retraining. More workplace training is needed to ensure that the Canadian labour force can keep up with rapid changes in automation. Melek cited a new initiative at the University of Waterloo, which he dubbed "reverse co-op," that brings people from industry into university labs to encourage co-learning. Education is no panacea, but it will play a key role in enhancing societal resilience during the coming disruption.

4. Re-imagine Taxation

Expanding the social safety net to mitigate the unintended negative effects of automation requires new sources of revenue that will not solely be offset by increases in economic productivity. Reforms of the tax system will have to generate some of these new revenues. However, the gradual automation of the labour force creates new challenges to the tax system. The reality is that it is easier to tax people than robots and algorithms, which is problematic in an economy that requires fewer people to function. Bill Gates, the founder of Microsoft, has famously advocated for the taxing of robots, or more precisely, the companies that operate them. Not only could such levies fund the expansion of the welfare state, but it would, in Gates' words, "slow down the speed" of automation to make it more manageable and palatable for anxious publics (quoted in Delaney 2017). Blit told the symposium panel that the challenge of taxation in the age of automation is global in scale and must be tackled immediately: "If you think it is hard to tax them now, you just wait to see what will happen in 20 years," he said, referring to the global multinational companies automating their operations.

5. Establish a New Regulatory Regime

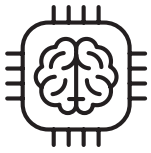
The wide array of challenges posed by automation demands that government assume a robust regulatory role. The absence of government regulation of the social media industry over the last decade provides a cautionary tale of the dangers of a laissez-faire approach. Current global challenges of online misinformation, the undermining of personal privacy and criminal exploitation of data, could have been blunted if government regulatory agencies had engaged the emerging technology earlier. Now, these agencies are playing catch-up, trying to put the genie back in the bottle of a massive industry whose societal impact is still being understood. It is, as Ford said, "hard to predict the impact technology will have," which is why a proactive government role is needed.

Issues like the weaponization of robots and AI and the danger of human bias being reproduced in autonomous systems are areas where government has a clear regulatory role. The accumulation of data by some firms, which is essential for the operation of many automated systems, can make them disproportionately powerful. Governments should not only regulate how those firms manage, secure and use that data, but also ensure that they don't become too big to fail. Regulation provides a means to protect citizens and keep a level playing field in the new economy.

CONCLUSION

The potential of automation and AI to improve the quality of life for humanity is enormous. As Martin Ford said, it will "become the most important tool in our toolbox for solving the biggest problems that we face. And that includes, for example, climate change, clean energy development, and global poverty." But with any transformative technology, there are bound to be unintended consequences. The first Waterloo Symposium on Technology and Society explored what those may be. The potential disruptive effect on the labour market, causing some to pronounce the end of work, and its associated impacts on community social capital, were identified as omnipresent challenges to be addressed. There was a wide consensus at the symposium that government must play an indispensable role to mitigate the painful effects of the technological revolution. Governments will be forced to expand engagement in some areas and stake new ground in others, whether it is as a regulator, redistributor, gatekeeper or investor. The capacity of society to withstand the shocks of automation and flourish will depend, to a large degree, on our government's ability to adapt to these new roles in a timely manner. It will have to work with the business community and civil society to forge a new social contract.

The world has survived other systemic technological disruptions and adapted, albeit painfully. However, as Ford showed, there are strong indicators that this disruption may be different. This should not cause us to retreat from this technology – instead we should embrace it with our eyes open. It is imperative that we, as Ford suggested, "engage in an honest discussion about both sides of this technology." We need to be ready to capitalize on its unquestioned benefits but be resilient in the face of its likely drawbacks. In the end, our shared purpose must be, as Ford concluded, "to build a future where these technologies work for everyone and not just for a tiny number of people just at the top."



The capacity of society to withstand the shocks of automation and flourish will depend, to a large degree, on our government's ability to adapt to these new roles in a timely manner.

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APPENDIX 1

Opening Remarks by Savvas Chamberlain ahead of the first Waterloo Symposium on Technology & Society

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April 16, 2019

Balsillie School of International Affairs
Waterloo, Canada

Good evening.

First, I would like to tell you how this Waterloo Symposium on Technology & Society series was conceived. Then I shall give you a brief history of the semiconductor revolution which is fueling these technological innovations and advancements in our society.

The Waterloo Symposium on Technology & Society seeks to promote public discussion in Canada and beyond on the societal challenges and opportunities created by innovations in four primary areas: robotics, artificial intelligence, big data and social media.

About a year ago, Mark and I had lunch at a restaurant in Waterloo. We discussed income inequality highlighted in the excellent books by the economist Thomas Piketty.

Over the past 30 years there has significant technological advancements and innovations in the areas of robotics, artificial intelligence, big data, social media, and quantitative and synthetic biology. We both agreed that presently there is not enough public debate about the effects of such rapid technological change on different sectors of Canadian society.

It is well accepted that rapid technological change will produce, alongside positive gains to GDP, significant negative effects on some sectors of our population. This symposium series attempts to initiate discussion on this issue and possibly influence federal and provincial policies going forward.

If we look at the history of technological innovation, until about the early 1990's, most advancements benefited and raised the standard of living of all sectors of our population. However, since that time there is a consensus of the top world economists that these rapid technological advancements have principally benefited the wealthiest one percent of our society. A very small benefit trickles down to the rest of the population.

It is my opinion that these technological innovations were the result of the inventions of the monolithic integrated circuit and planar process around 1958 by Robert Noyce (Fairchild Semiconductor), Jack Kilby (Texas Instruments), Kurt Lehovec (Sprague Electric Company) and Jean Hoerni (Fairchild Semiconductor).

APPENDIX 1 (continued)

The billion-transistor integrated circuits of today rely on Hoerni's breakthrough planar technology idea. Before I get to the microprocessor, let me talk a bit about Moore's Law.

In 1965, Gordon Moore predicted that the number of transistors on a silicon chip will double every 18 months. The speed of the transistors will double, while the cost of the silicon integrated chip will decrease. This deduction by Moore turned out to be correct. Meanwhile, the semiconductor industry started believing and implementing a roadmap based on this prediction, referring to it as Moore's Law. It gave birth to the semiconductor revolution.

Let me now tell you how this revolution started and evolved.

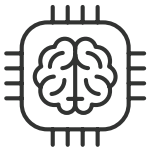
In March 1971, under the leadership of Robert Noyce at Intel Corporation, Intel delivered to Busicom the first commercially available microprocessor. The chief designer of this microprocessor was Federico Faggin. The silicon chip had 2,300 transistors. By 2010 the Intel Core silicon chip processor, fabricated on the 32 nm process, had 560 million transistors. Other microprocessors were introduced after that with some of the silicon chips in 2014 having more than a billion devices on the same chip. The growth in computer power continued at an exponential rate, with the computing costs coming down at roughly the same rate.

In 1975, the cost of computing for an IBM mainframe, for 1 million instructions per second, was $1 million dollars. By 2000, with the Intel Pentium 4 chip, that cost had decreased to $1. In 2019, the cost of 1 million instructions per second computing capability is in the fraction of a cent range.

Of course, a lot of you remember the introduction of the IBM personal computer on August 12, 1981. It was affordable by the masses.

We can safely conclude that the introduction of the microprocessor 48 years ago spurred today's revolutionary technological advancements. The exponentially decreasing cost of computing enabled many technologies to advance rapidly.

Turning back to Moore's Law, my professional career grew during the Moore's Law period, and of course I benefited from these advancements. In 1968, I designed a 10x10 image sensor having approximately 500 transistors on the same silicon chip. When we were forced to sell DALSA Corp on February 12, 2011, DALSA had a silicon image sensor with more than 50 million devices on the same silicon chip.



The exponentially decreasing cost of computing enabled many technologies to advance rapidly.

Savvas Chamberlain

APPENDIX 1 (continued)

This symposium series is held in Kitchener-Waterloo, which has a technology community that has been at the forefront of some of these technological advancements.

Some of you in this audience also participated in the advancement of these technologies and the computer revolution. I shall briefly tell you what I remember about it.

In 1967, under the leadership of the first Dean of Mathematics, Professor David Sprott, the University of Waterloo acquired the IBM 360/75; this IBM computer model was, in 1969, the first modern computer in the world. The UW Faculty of Mathematics was the first of its kind in North America and perhaps the first throughout the world, in pioneering Computer Science. Paul Dirksen and Paul Cress wrote the WATFOR 360 compiler which, under the then leadership of Wes Graham, became the WATFIV compiler for the IBM360 computer that was then used throughout the world.

Other contributions include, in 1999, the invention and development of the BlackBerry® by Mike Lazaridis, which led to the present evolution of the smart phone. In 2001-2002, DALSA Corp of Waterloo provided to NASA the image sensor for the camera used on the Mars Rover. This gave us, for the first time, pictures from Mars.

Back to Moore's Law again. Well, in 2014 the Semiconductor Association declared the death of Moore's Law at the age of 51.

Technological innovations will continue with the advent of affordable supercomputers and we shall see that more unthinkable applications will materialize.

However, we should not have illusions that the innovations and technological advancements will now cease. Innovations of inclusion of MEMS on the same silicon planar chips is well on its way. They now incorporate onto the same silicon chip microprocessors, memory, logic and additional MEM sensor devices. New applications employing cheap computing will proliferate at a tremendous rate.

Back to our symposium: We want to drive forward debate in Canada on the measures that need to be taken to ensure that the benefits of technological advancements accrue to the entire population and not just to the top one percent.

I shall now give the floor to Mark Sedra to introduce this evening's keynote speaker, Martin Ford.

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