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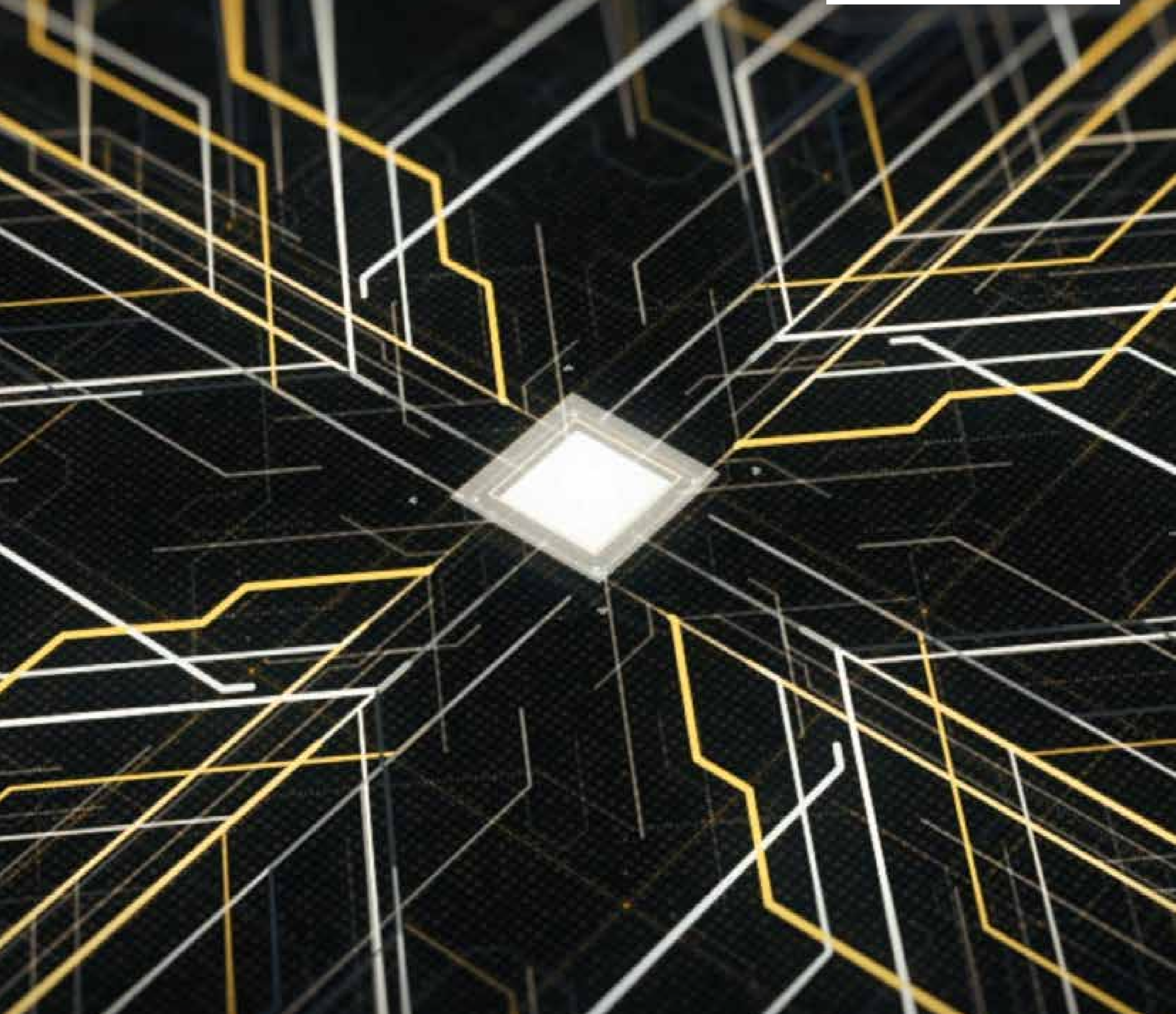

ARTIFICIAL INTELLIGENCE

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Founded by Margaret Thatcher in 2009 as the intellectual hub of European Conservativism, New Direction has established academic networks across Europe and research partnerships throughout the world.

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Dear reader,

Artificial intelligence is without doubt one of the most profound technologies that is already having an impact on our economies and societies — and will increasingly do so in near future and beyond. Whether it is about spurring innovation or tackling inflation via better-managed supply chains, AI-based solutions are growingly part of the answer. Whichever big industry we look at, AI systems are increasingly being deployed; from medicine and finding new ways of curing diseases to transport and the pursuit of self-driving cars, to name just a few examples.

The articles encompassed in this special issue magazine can be divided in two broad categories. One looks at the opportunities of the technology, with the experts discussing how AI is or can be applied in various industries and sectors and, more broadly, how the technology can help promote economic and social growth. The relevant limitations and shortcomings are also bluntly addressed.

The second category of articles focus on the EU and its approach to AI. When it comes to this specific technology, the region is falling behind other advanced economic powers. However, it does not have to be this way. Our distinguished writers critically discuss not only what is currently wrong, but offer solutions on what the EU and the Member States must do.

I am hopeful this magazine will add to the much needed debate on the importance of artificial intelligence and its various aspects.

Yours sincerely,

Tomasz Poręba MEP
President, New Direction

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Artificial intelligence: IT'S FRIGHTENING AND PROMISING, AND THE EU SHOULD PLAY A LARGER ROLE

Elisabeth Braw

Senior Fellow, American Enterprise Institute

Artificial intelligence is no longer just the subject of science-fiction movies. On the contrary, the far-reaching technology based on teaching machines to "think" is now present in virtually many parts of daily life. And AI's advance will continue as even more aspects of daily life –from toys to smart cities – become unthinkable without the technology. But AI is hard to define, and that makes it even harder to regulate. Unsurprisingly, today there are virtually no international rules and standards governing the development and use of AI. US and Chinese companies, meanwhile, are forging ahead in developing ever-more sophisticated forms of it. The EU could play a key role in bringing some order to this crucial but potentially highly dangerous technology – but it should also incentivise businesses and especially researchers to innovate at the same speed as Chinese rivals.

Apple's FaceID is extraordinarily convenient: you log in by just having your phone look at your face. No need to remember passwords or passcodes, and you'll never have to go through the annoying process of resetting a password because you've forgotten what it was. The reason your iPhone can log you in is, of course, that it has been taught to "think". By scanning thousands of infrared dots around your face, it can decide whether you are the phone's legitimate user and grant, or not grant, you access to it. Siri, Alexa, and Cortana, too, have been taught to perform tasks that have traditionally been the domain of humans. Today they and other digital assistants like them are so common that we simply take their skills for granted. Navigation tools, cars, and other tools we use on a daily basis all have at least some AI in them, which is why, for example, we no longer need to ask other human beings for directions when we're lost in a new city. It wasn't that long ago that we had to compose our Gmail messages ourselves. Now Gmail – aided by AI – suggests responses to emails we receive. And AI is increasingly powering smart cities. It tells driverless subway trains how to drive, it makes traffic flow more easily, it regulates street lights, it tells residents and visitors how to get from A to B.

All these uses of AI make life extraordinarily convenient. And this is not the end of the convenience, because researchers and companies are finding ever more uses for AI. That's especially true for China. Consider this: between 1997 and 2017, China's share of the world's research papers in the field of AI grew from 4.26 per cent to 27.68 per cent, making China the country with the largest share of AI research papers in the world. The EU's share of AI papers in the same year was 25.5 per cent, down from 29 per cent in 2015. China remains ahead, though 2018 figures show the EU and the US are far ahead in research papers per one million AI workers: 98.1 in the United States, 81.4 in the European Union, and only 21.8 in China. In 2021, however, Chinese researchers overtook America-based ones as the most cited on AI – a statistic considered a standard measure of influence. All this means that China has turned into a fierce rival in the development of today's and tomorrow's most cutting-edge technology – a far cry from the situation just two decades ago, when China focused on simpler technology while the United States and European countries led the development of new frontiers.

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China is forging ahead in development and application of AI because researchers and companies have a massive laboratory at their disposal: the Chinese population. Already today, facial-recognition cameras blanket the country, documenting residents' activities around the clock. Already two years ago, the Chinese government made facial recognition mandatory for smartphones, and today the country is also blanketed with, among other things, facial-recognition cameras that keep every person under constant watch. Such cameras, made by Chinese firms, are also used in many European cities, not to monitor law-abiding citizens but to identify criminals. (In October 2021, the European Parliament called for a ban on such cameras in the European Union.)

Indeed, an AI development and implementation race is happening, led by China. In order not to become dependent on Chinese AI, the EU needs a vibrant AI scene: research, development, and commercialisation. Yes, the EU can hope that the United States will remain as strong or stronger than China in AI, but that's hardly a strategy.

The ugly side of AI is, of course, that AI-enabled tools could become the menacing robots featured in movies. Indeed, in a just-released book former Google CEO Eric Schmidt and former US Secretary of State Henry Kissinger warn that such tyranny by machines will come to pass unless humanity collectively decides to stop it. Today, however, there's virtually no global regulation of AI, and it is governed by no global ethical and technical standards. Indeed, the field is a free-for-all, where companies develop technical standards and hope that enough others will adopt their standards that they become the default setting. The Chinese government is pushing very hard for its AI industry, hoping to make Chinese firms the global technical default standard, which would massively increase sales. If other governments don't join forces and push for global technical and ethical standards, Chinese standards are likely to become the default. This would, of course, raise enormous ethical questions in democratic countries – because the use of Chinese technology brings ethical considerations as well. Is it acceptable to use technology that has been developed using ordinary civilians with no say in the matter? Is it acceptable to use technology from manufacturers whose products are being used to monitor Uyghurs?

This state of affairs presents an opportunity for the EU. Not least through GDPR, the EU has established itself as a regulatory superpower. Today many countries fear the AI free-for-all and the default role Chinese technology will play if the international community doesn't create ethical and technical standards. To be sure, such standards would face hurdles: countries would need to decide which global agency should be in charge of them (the International Telecommunication Union, perhaps?), and they would also need to agree on, and have the ITU police, such standards. China will certainly oppose any moves to restrain its current position of strength, but because fears about its AI are spreading rapidly, the EU could present draft rules and invite other countries to sign up to them. Faced with such global commitment to technical and ethical AI standards, and the risk of lost business if it didn't join, China might conclude it should join too.

> ***In order not to become dependent on Chinese AI, the EU needs a vibrant AI scene: research, development, and commercialisation. Yes, the EU can hope that the United States will remain as strong or stronger than China in AI, but that's hardly a strategy.***

Talos Reborn: ARTIFICIAL INTELLIGENCE AND THE WORLD ECONOMY[1]

Francisco L. Rivera-Batiz

Columbia University

One of the key questions regarding Artificial Intelligence (AI) is how it will affect the global economy. AI represents the embodiment of intelligence in non-human agents. This includes machines and software that utilize various information or inputs (often big data), identify existing and new patterns based on some given objectives, and produce outcomes or perform tasks while learning from previous analyses or experiences. And even though its inputs, objectives and programming are created by humans, AI can execute tasks, make recommendations, or make decisions without direct human supervision.

How will the scientific and technological breakthroughs associated with AI change the world economy? It is the purpose of this article to show that the socioeconomic impacts of AI are likely to be deep, with potentially major effects on the world economy and society in general.

AI and Automation

The economic consequences of AI represent a topic that connects to a long-standing debate on the consequences of automation. However, AI differs sharply from traditional automation, constituting a much more encompassing and far-reaching phenomenon.

Automation refers specifically to technologies that automate tasks performed by humans. In the past, these tasks have been largely routine, that is, rules-based tasks that machines or robots can perform faster and more efficiently than humans. Economists have studied the consequences of this type of automation, focusing on its productivity effects, on the one hand, versus the substitution of machines for workers, particularly blue-collar workers, on the other.[2]

Most economic studies of the impact of AI so far have followed these, earlier, studies of automation, focusing on how AI-based machines and software can substitute workers in *both* routine and non-routine tasks, blue-collar *and* white-collar jobs,[3] etc. These are important to consider. But the consequences of AI are much deeper than these. Its universe of impacts is likely to dwarf those of traditional automation. The reason is because, as an extension of human intelligence, AI is bound to generate waves of new inventions and technological breakthroughs. And in contrast to most previous waves of innovation – such as in the motor vehicle, home appliances, aviation, and information technology revolutions—AI may be linked to technological change in a wider array of industries, from finance and financial security to medicine and pharmaceuticals, from automobiles and traffic congestion to national security and defense.

The Impact of AI on Innovation and Technological Change

Because it can allow human intelligence to surpass its limits, AI has the potential to greatly extend the frontiers of science, technology, and creativity. It is as if the number and efforts of human scientists and inventors dedicated to innovation were multiplied many times. Commenting on the power of AI in the field of mathematics, Oxford University mathematician András Juhász has stated that, when guided by human intelligence and intuition, "machine learning provides a powerful framework that can uncover interesting and provable conjectures in areas where a large amount of data is available, or where the objects are too large to study with classical methods."[4] From this perspective, AI can help not only to create new

1 In Greek mythology, Talos was a bronze giant built by Hephaestus, the god of invention. It had autonomous intelligence and its objective was to protect the humans in the Island of Crete from invaders and from local injustices See Adrienne Mayor, *Gods and Robots: Myths, Machines, and Ancient Dreams of Technology* (Princeton, NJ: Princeton University Press, 2018).

2 See, for instance, Laura D'Andrea Tyson, "Automation and the Future of Work in Germany: A Summary of Research and Policy Recommendations" Governing Work in the Digital Age Project Working Paper Series (Berlin: Hertie Graduate School, 2021); and Daron Acemoglu, Claire Lelarge, and Pascual Restrepo, "Competing with Robots: Firm-Level Evidence from France," *American Economic Review*, Vol. 110, May 2020.

3 Didem Özkiziltan and Anke Hassel, "Artificial Intelligence at Work: An Overview of the Literature," Governing Work in the Digital Age Project Working Paper Series (Berlin: Hertie Graduate School, 2021).

4 Alex Davies, Petar Veličković, Lars Buesing, Sam Blackwell, Daniel Zheng, Nenad Tomašev, Richard Tanburn, Peter Battaglia, Charles Blundell, András

theorems in mathematics but in many other fields.[5] The potential is enormous.

The creation of new goods and services through the assistance of AI is already occurring. Electronics and engineering companies, such as General Electric, have used AI to create new designs for jet engines and for diesel motors that minimize emissions. Medical technology firms, like Medtronics and Philipps-Biotelemitry, are focusing AI efforts to design more precise surgical equipment and robotics in orthopedics and to develop software that uses AI to provide more accurate diagnoses of various diseases, such as diabetic retinopathy, which is one of the main causes of blindness worldwide. These innovations are improving human productivity and well-being and stimulating economic growth.

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Consider in more detail the pharmaceutical and biotechnology industries. The process of discovering new drugs and medicines is highly complex, involving the search for molecular combinations and structures that researchers often navigate during many years of costly efforts. AI, however, can accelerate this process by dozens or perhaps even hundreds of times, potentially leading to many more medicines.[6] Such was the case of the antibiotic Halicin, discovered by an MIT-led team with the help of AI. The researchers constructed a neural network — an AI algorithm inspired by the brain's architecture — that learned the properties of molecules and then was trained to spot molecules that inhibit the growth of the bacterium Escherichia coli.[7] The new antibiotic was discovered in a fraction of the time taken without AI and is quite distinct from existing antibiotics.[8] AI is being used as well in the search for a range of medicines and vaccines, including mRNA vaccines of the type developed to combat COVID-19.

The promise of AI in generating new products can be remarkable and unexpected. This is the case of AI's involvement in the creation of artistic products, such as paintings, music, and prose. Think, for example, about the AI-based software programs which "study and learn" existing schools of art (their styles and patterns) in generating new images.[9] The more advanced programs produce paintings that ordinary observers cannot differentiate from paintings created by humans, an accomplishment reached in music and prose as well. In October 2019, Christie's, the New York auction house, sold the painting Portrait of Edmond de Belamy, an AI-generated print in the style of 19th-century European portraits, for $432,500.[10]

Another industry where AI is leading to substantial technological progress is the financial services industry and, more specifically, the financial technology sector (fintech). AI-guided software is being used to assist and improve the delivery

Juhász, Marc Lackenby, Geordie Williamson, Demis Hassabis and Pushmeet Kohli, "Advancing Mathematics by Guiding Human Intuition with AI," *Nature*, Vol. 600, 70–74, 2021.

5 For a discussion of the impacts of AI in the natural sciences, see Jack Leemng, "How AI is Growing a Foothold in the Natural Sciences," *Nature*, Vol. 598, 2021.

6 Bowen Lou and Lynn Wu, "AI on Drugs: Can Artificial Intelligence Accelerate Drug Development? Evidence from a Large-scale Examination of Bio-pharma Firms," *Marginal Information Systems Quarterly*, Vol. 45, September 2021.

7 Jo Marchant, "Powerful Antibiotics Discovered Using AI," *Nature*, News, February 2020.

8 J.M. Stokes, K. Yang, K. Swanson, W. Jin, A. Cubillos-Ruiz, N.M. Donghia, C.R. MacNair, S. French, L.A.Carfrae, and Z. Bloom-Ackerman, "A Deep Learning Approach to Antibiotic Discovery," *Cell*, Vol. 181, April 2020.

9 Marcus Du Sautoy, The Creativity Code: Art and Innovation in the Age of AI (Cambridge, MA: Harvard University Press, 2019).

10 See Ian Bogost, "The AI-Art Gold Rush is Here," *The Atlantic*, March 6, 2019.

of complex financial services to customers. For instance, by combining new client information with existing volumes of data on credit decisions, and quickly analyzing it, AI-assisted financial services can accelerate and make more accurate and faster credit decisions. AI software can also analyze big data sets and provide financial advisors with more sophisticated assessments of investments and portfolios.

It can be implied from these examples that the most significant economic effect of AI is likely to be its impact on the rate of technological progress, in increasing what economists call total factor productivity (TFP). This represents a major development for the world economy, as there has been a significant slowdown of TFP growth in the United States, Europe, and in an array of other countries in recent decades.[11] AI has the potential to reverse this trend.[12] Since TFP growth is at the core of improvements in income per-capita, AI can be a game changer in the world economy. Its potential accomplishments in health, medicine, finance, information, communications, transportation, climate change, and a range of other fields have the capacity to generate great wealth.

A New Era of Globalization?

AI is likely to propel globalization to a new stage. This is because of the boost it can provide to global value chains (GVCs), e-commerce, and the flow of information and ideas across borders.

Beginning in the eighties, world production was revolutionized by the computer and information technology (IT) revolutions. By allowing more efficient global management and coordination networks, the IT breakthroughs permitted a growing fragmentation/unbundling of production. As a result, the multi-country manufacturing referred to as global value chains (GVCs) boomed. All over the world, final products—from automobiles and cell phones to pharmaceuticals and medical devices—are now produced in one country using inputs from many others, organized mostly by large multinational companies.[13] According to United Nations (UN)-World Trade organization (WTO) data, close to 80 percent of global exports of goods and services now occur through GVCs. But the growth of GVCs has been slowing down during the last decade. The use of AI can reverse this recent trend. It can improve and speed-up the complex management and coordination of inputs, supply, inventories, warehousing, and transportation links within and among countries. By more accurately monitoring and responding to sudden demand changes, AI can increase the ability of multinational firms to move goods and services smoothly across the globe through GVCs.[14] It is unlikely that the supply chain disruptions that plagued some countries in 2021 would have been so damaging with fully functioning AI systems.

And it is not just trade through GVCs that would benefit from AI. Cross-border e-commerce is growing at an astounding rate as well, and it is likely to propel cross-border trade to greater levels in the future. It is estimated that AI-based recommendation engines already account for 30 to 40 percent of sales among leading e-commerce companies.[15] And AI-based digital platforms are allowing small and medium-sized businesses to export all over the world.

AI can also foster globalization by stimulating the flow of information and ideas. Digital data flows – from information about customer preferences to the results of research studies—have multiplied quickly in recent years. AI has contributed to these flows and their distribution worldwide. The value of trade in ideas has not been adequately recognized, but recent research suggests that it can provide significant growth benefits for both high-income and developing countries.[16]

11 Emily Moss, Ryan Nunn, and Jay Shambaugh, "The Slowdown in Productivity Growth and Policies That Can Restore It," (Washington D.C.: The Brookings Institution, 2020).

12 See Erik Brynjolfsson, Daniel Rock, and Chad Syverson, "Artificial Intelligence and the Modern Productivity Paradox: A Clash of Expectations and Statistics," Initiative on the Digital Economy Research Brief (Cambridge, Mass: Massachusetts Institute of Technology, 2018).

13 For a discussion of GVCs, see Mariana Spatareanu, ed., *Foreign Direct Investment and the Multinational Enterprise*, in Francisco L. Rivera-Batiz, ed. *Encyclopedia of International Economics and Global Trade* (Singapore: World Scientific Publishers, 2010).

14 See Joe McKendrick, "AI Adoption Skyrocketed Over the Last 18 Months, *Harvard Business Review*, September 27, 2021; Joshua P. Meltzer, "The Impact of Artificial Intelligence on International Trade," (Washington DC: Brookings Institution, 2018).

15 Jacques Bughin, Jeongmin Seong, James Manyika, Michael Chu and Raoul Joshi, Notes from the AI Frontier: Modeling the Impact of AI on the World Economy, Discussion Paper, McKinsey Global Institute, 2018.

16 Chang-Tai Hsieh, Peter J. Klenow and Ishan Nath, "A Global View of Creative Destruction," Working Paper (Palo Alto, CA: Stanford University, 2021).

The Challenges of AI

The promise of AI is only matched by its great challenges. It has the potential to increase inequality among nations and within countries, concentrate market power in a few firms, and be captured by governments to restrict human and civil rights and to generate dangerous and destabilizing military software and weapons.

First, AI is a highly human capital-intensive industry that requires substantial R&D investments. It also utilizes vast amounts of computer power. Only a few nations tend to be heavily active in the AI field, mostly high-income countries (such as the US, UK, Germany, and Japan) and a few middle-income countries (like China and India).[17] This means that the income gains generated by AI will be concentrated in a few, mostly rich, nations that have access to the appropriate skilled labor and computing infrastructure. Furthermore, since AI itself and its inventions may not be freely copied, whether because of patents or intellectual property rights, most of the profits associated with AI will be highly concentrated in a few countries and in a few hands, further increasing global inequality. It is true that the gains from AI can spillover to poor countries. For instance, the electronic use of fintech services can expand the access of financial transactions to areas that mainstream financial institutions do not serve, and it is being used by microlending institutions serving poor populations in developing countries.[18] But the fact that those technologies are supplied by inventions and applications originating in high-income countries means their profits will largely go to the latter. Similarly, the development of new drugs or other AI-inventions is likely to face the same fate as that of COVID-19 vaccines, which have greatly benefited the inventors in high-income countries but have reached developing country populations only with great delay, despite significant global efforts.[19]

The promise of AI is only matched by its great challenges. It has the potential to increase inequality among nations and within countries, concentrate market power in a few firms, and be captured by governments to restrict human and civil rights and to generate dangerous and destabilizing military software and weapons.

Second, some of the sectors where the new inventions are originating are highly concentrated, lacking competition. Whether one is talking about giants in the social network, internet, pharmaceutical, financial, or other industries, their oligopolistic nature fosters the proliferation of strategies involving the manipulation of information and prices in such a way that can reduce economic welfare.[20] Such is the case of price discrimination, in which firms charge different prices depending on the characteristics of consumers.

But perhaps of even more concern is the potential use of AI by governments to invade the privacy of individuals, violate civil and human rights, and manipulate political and social attitudes.[21] AI software used for traffic control purposes can serve to reduce congestion and traffic accidents, which can save lives, raise worker productivity, and make more time available for leisure purposes. Many metropolitan areas have already deployed AI traffic technology solutions. In the US, 66 percent of cities are investing in smart city traffic technologies.[22] In China, the digital cities plan, proposed back in the early 2010s, has led to a push towards the use of AI in traffic management, with China's leading high-technology companies — such as Alibaba, Tencent, Didi Chuxing, Baidu, and Huawei — getting involved in what is a close private-public collaboration. But these technologies can also be used by governments to follow and track individuals without their knowledge or permission. Various forms of AI-produced software can be utilized to restrict freedom of the press, crush dissent, and suppress political opposition.

Over the centuries, human intelligence has produced revolutionary discoveries and inventions that have greatly increased the standard of living in most of the world. But they have also brought the world to the brink of nuclear war and to the verge of devastating global climate change. AI is not in a different category. For instance, consider its creative potential. Just as it can be used to generate marvelous new paintings and music it can also be utilized to create sophisticated fake images and videos that can sprout hate, conflict, and even civil war.[23]

Most dangerous perhaps is the development and proliferation of AI-based military applications and weapons. Autonomous robots and weapons, intelligent defense software, and AI-based strategic military analyses are being developed by departments of defense and military agencies in the US, China, and Russia, among others. Their superiority over existing military systems serves as a great stimulus for countries to develop and deploy them. But they can give rise to serious dangers, as their performance is still based on the reliability of data collected, security systems that may subject to hacking, and software that can be reproduced or stolen by terrorist organizations or rogue states. It can also lead to a renewed race to develop new AI weapons and related systems, raising the risk of conflict and war, just as the proliferation of nuclear weapons did.[24]

Conclusions

The serious negative consequences arising from AI need to be managed through policies that seek to counteract or minimize them. The impacts on the labor market require government policies that support those workers who are displaced. Increased investments in education, particularly in science, technology, engineering, and math (STEM) fields, can foster the nascent development of AI industries in developing countries, as they already have in China and India. Multilateral institutions, from the World Bank to the World Health Organization, need to be much more deeply involved in the low-cost transfer of AI technologies and infrastructure to developing countries. Public and/or non-governmental organizations must be empowered to control unethical uses of AI. International institutions, such as the United Nations, need to monitor and discourage the use of AI in the violation of basic human and civil rights. And new global treaties and accords will have to be developed to control the proliferation of AI-based military equipment and systems.

The AI revolution is rapidly enveloping the world economy.[25] Its promise is matched by its challenges. Still, AI is being created by humans and ultimately only high-quality domestic and international human governance — in the public and private sectors — can ensure that the great possibilities opened by AI do not also open a Pandora's box of problems and inequities in the global economy, with potentially disastrous consequences.

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18 See Davide Strusani and Georges Vivien Houngbonon, "The Role of Artificial Intelligence in Supporting Development in Emerging Markets," Emerging Markets Compass (Washington D.C.: The World Bank, 2019).

19 A. Michael Spence and Joseph Stiglitz, "The Pandemic and the Economic Crisis: A Global Agenda for Urgent Action," Institute for New Economic Thinking Report, March 2021.

20 See Daron Acemoglu, "Harms of AI," NBER Working Paper 29247 (Cambridge., MA: National Bureau of Economic Research, 2021); Anton Korinek, Martin Schindler, and Joseph E. Stiglitz, "Technological Progress, Artificial Intelligence, and Inclusive Growth" Working Paper WP/21/166 (Washington D.C.: International Monetary Fund, 2021).

21 Shoshana Zuboff, *The Age of Surveillance Capitalism: The Fight for a Human Future at the New Frontier of Power* (NY: Public Affairs, 2019).

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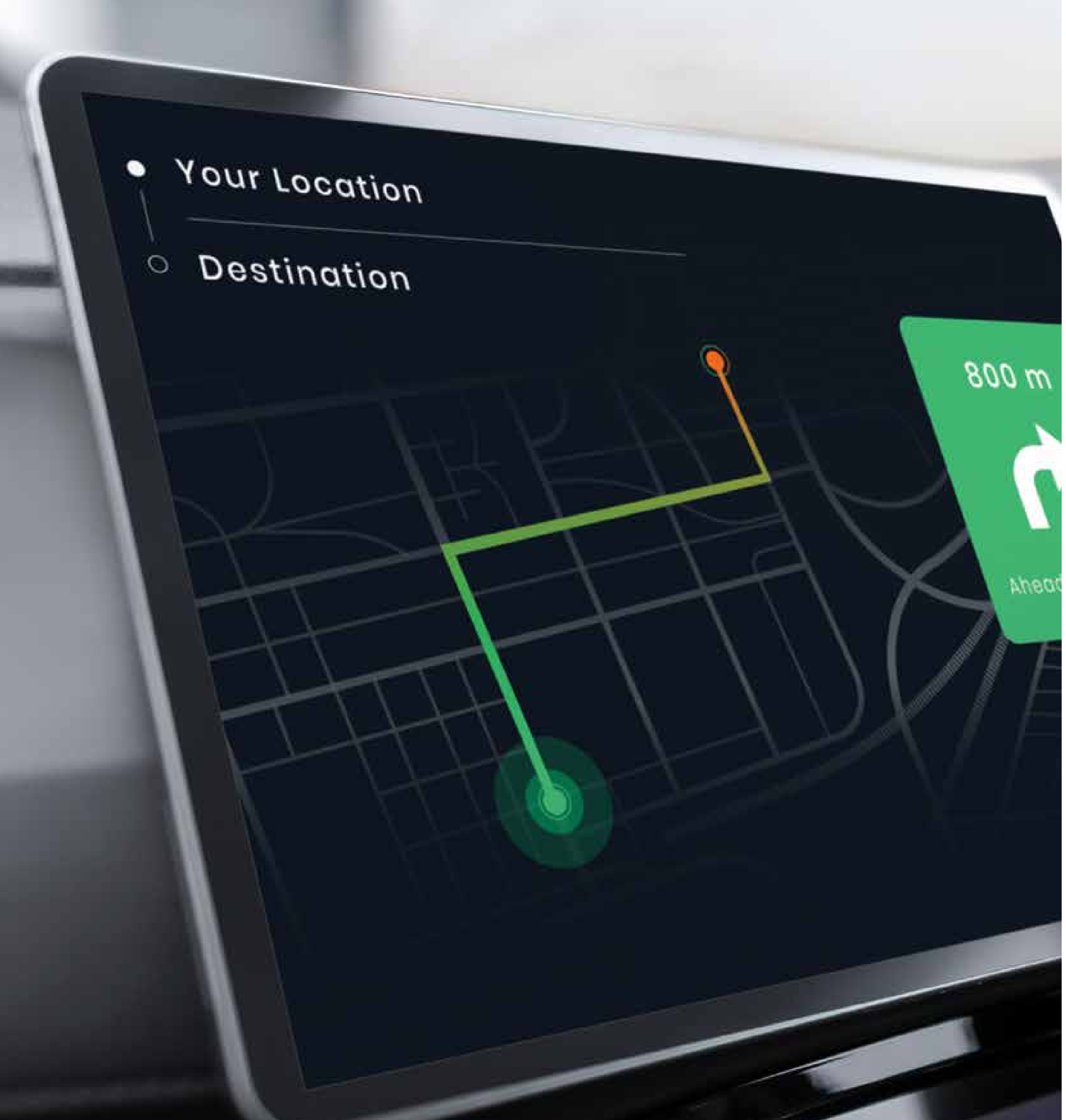
23 Kai-fu Lee and Chen Qiufan, *AI 2041: Ten Visions for the Future* (New York, NY: Currency Publishers, 2021).

24 Forrest E. Morgan, Benjamin Boudreaux, Andrew J. Lohn, Mark Ashby, Christian Curriden, Kelly Klima, and Derek Grossman, *Military Applications of Artificial Intelligence: Ethical Concerns in an Uncertain World* (Santa Monica, CA: RAND Corporation, 2020).

25 Richard Baldwin, *The Globotics Upheaval: Globalization, Robotics, and the Future of Work*, (New York: Oxford University Press, 2019).



THE IMPORTANCE OF AI FOR CARS

Tomasz Poręba

Member of European Parliament, President, New Direction

The automobile industry is one of the prime examples where AI has had and continues to have a large impact. While much attention within the context is usually devoted to the future of autonomous vehicles (AVs) and, especially within the EU,[1] the related liability questions, AI is already at the heart of a modern-day car.

Albeit much less visible, there is a multitude of in-vehicle AI-powered systems deployed in contemporary automobiles, even the very cheapest ones. ADAS (advanced driver-assistance systems), more commonly known as driver-aids, include traffic sign recognition, lane departure assistant, and blind spot monitoring. A modern iteration of adaptive cruise control can not only follow the car in front — a function originally running without AI — but also keep a distance from a cyclist in an urban environment. Meanwhile auto emergency braking aid can warn a driver of a pedestrian crossing the street while preconditioning the brakes and, as a last resort, initiate an emergency stop. Based on driver's inputs or even by scanning a face, drowsiness detection systems are helping to prevent dangerous traffic situations where drivers fall asleep behind the wheel.[2] Furthermore, virtual voice assistants embedded in cars' infotainment systems can help the driver to adjust the temperature in a car, make a call or find a destination, thus making driving less distracting and safer.

AI in cars is also used in more subtle ways. For example, the servicing intervals in modern cars are dynamic, meaning, they can arrive earlier or later depending on the driving style, driving conditions and a number of other on-board and off-board data.[3] Whereas this may not be a headline grabbing AI application, it is improving the customer satisfaction, also by extending cars' longevity. What is more, predictive maintenance is reducing costs for companies with large fleets as vehicle downtime is reduced. Indeed, the market for anticipating repairs before vehicles break down and predicting maintenance at the correct time is predicted to grow substantially,[4] and the business potential is so promising that there is an increasing number of companies offering relevant solutions.[5]

In addition to the above, AI in the automobile industry is deployed in various other ways, including in-vehicle manufacturing and even design processes.[6] Within the context of electric cars, AI helps with development of batteries that recharge faster and are safer.[7]

Without doubt, the biggest and most talked about innovation in automobile industry is the self-driving capability. For years, various companies have been developing the relevant technology. Among the players, Waymo, a subsidiary of Alphabet, is seen as one of the leaders in AV technology. Working on a driverless technology for almost a decade and having spent billions of dollars on development,[8] Waymo One became the first commercial project, launched in late 2018, with the company offering a fully autonomous ride-hailing service in Phoenix, Arizona.

The American car manufacturer Tesla, led by tech titan Elon Musk, has also made gradual progress over years in the self-driving technology front. While the company has been misleadingly labelling its driver-assistance systems as "full self-driving" capability

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5 See, for instance, Intrado (2019) Global Autotech Predictive Maintenance Startup CARFIT Completes New Seed Funding Round With CIC Capital Ventures and PlugandPlay, October 16. Available at: https://www.globenewswire.com/news-release/2019/10/16/1930645/0/en/Global-Autotech-Predictive-Maintenance-Startup-CARFIT-Completes-New-Seed-Funding-Round-With-CIC-Capital-Ventures-and-PlugandPlay.html

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8 Harris, M. (2017) Google Has Spent Over $1.1 Billion on Self-Driving Tech. IEEE Spectrum, September 15. Available at: https://spectrum.ieee.org/cars-that-think/transportation/self-driving/google-has-spent-over-11-billion-on-selfdriving-tech

“Investment and research into self-driving technology continues, thus proving the importance of it. According to one estimate, the AI market in automotive systems will increase more than fivefold in five years, reaching EUR 24 billion by 2025.

for years,[9] Tesla is getting closer to the aim. To a select number of participants the company has lately been rolling out rough and allegedly early test versions of what is supposed to be a truly self-driving technology.[10]

It must be acknowledged that despite the achievements in the autonomous driving field AI is not delivering the progress many had hoped for. Already in late 2015 Musk said that Tesla is just two years away from launching a self-driving car, adding “I think we have all the pieces… It’s a much easier problem than people think it is.”[11] Then in 2019 Musk claimed, again, that “I think we [Tesla] will be ‘feature-complete’ on full self-driving this year, meaning the car will be able to find you in a parking lot, pick you up, take you all the way to your destination without an intervention this year. … That is not a question mark.”[12] In the same year he also promised that in 2020 on-demand robot taxi fleet would be launched.[13] Similarly, John Zimmer, president of the ride-sharing group Lyft, predicted in 2016 that “within five years a fully autonomous fleet of cars will provide the majority of Lyft rides across the country [United States].”[14]

Two years later, not only has Tesla not delivered on its promises, but it is much more subtle in its tone. GM’s subsidiary Cruise has also missed its 2019 deadline for launch of the robo-taxis.[15] Meanwhile Uber, the ride-hailing company which also had big plans for self-driving taxis, in late 2020 decided to cancel the project altogether, selling it to a startup.[16] Indeed, the talk about fully autonomous vehicles is becoming much more cautious.

Waymo’s CEO at the time, John Krafcik, in 2018 said bluntly that he does not envision when fully autonomous vehicles will become a reality and that AVs will require human assistance in the foreseeable future.[17] And most recently Krafcik said that the rollout of self-driving cars is “a bigger challenge than launching a rocket and putting it in orbit around the Earth…because it has to be done safely over and over and over again.”[18] Even Tesla by 2020 considered the

9 O’Kane, S. (2018) Tesla stopped promoting the ‘Full Self-Driving’ option for its cars. The Verge, October 20. Available at: https://www.theverge.com/2018/10/20/18000884/tesla-full-self-driving-option-gone-musk-autopilot ; Szymkowski, S. (2021) Tesla’s Full Self-Driving Beta rolls out to more drivers as Musk reports high demand, March 8, Cnet. Available at: https://www.cnet.com/roadshow/news/tesla-full-self-driving-elon-musk-demand/

10 Kolodny, L. (2021) Tesla had to roll back and reissue the latest beta version of its driver assistance software, citing unspecified issues, CNBC, October 25. Available at: https://www.cnbc.com/2021/10/25/tesla-rolled-back-fsd-beta-v-10point3-and-reissued-10point3point1-update.html

11 Korosec, K. (2015) Elon Musk Says Tesla Vehicles Will Drive Themselves in Two Years, Fortune, December 21. Available at: https://fortune.com/2015/12/21/elon-musk-interview/

12 Marshall, A. (2019) Elon Musk Promises a Really Truly Self-Driving Tesla in 2020, Wired, February 19. Available at: https://www.wired.com/story/elon-musk-tesla-full-self-driving-2019-2020-promise/

13 Higgins, T. (2019) Tesla’s Elon Musk Promises Robot Taxis by Next Year, The Wall Street Journal, April 22. Available at: https://www.wsj.com/articles/teslas-elon-musk-promises-robot-taxis-by-next-year-11555974437

14 Zimmer, J. (2016) The Third Transportation Revolution, Medium, September 18. Available at: https://medium.com/@johnzimmer/the-third-transportation-revolution-27860f05fa91#.hbzb5mdg0

15 Hawkins, A. J. (2020) Exclusive look at Cruise’s first driverless car without a steering wheel or pedals, The Verge, January 21. Available at: https://www.theverge.com/2020/1/21/21075977/cruise-driverless-car-gm-no-steering-wheel-pedals-ev-exclusive-first-look

16 McGee, P. and D. Lee (2020) Uber abandons effort to develop own self-driving vehicle, Financial Times, December 7. Available at: https://www.ft.com/content/e55ce767-0ede-4096-aa3b-1d26671f3772

17 Gurman, M. (2018) Waymo CEO Says Self-Driving Cars Won’t Be Ubiquitious for Decades. Bloomberg, November 13. Available at: https://www.bloomberg.com/news/articles/2018-11-13/waymo-ceo-says-self-driving-cars-won-t-be-ubiqitious-for-decades [Accessed 25 March 2019]

18 McGee, P. (2021) Rolling out driverless cars is ‘extraordinary grind’, says Waymo boss, Financial Times, January 4. Available at: https://www.ft.com/content/6b1b11ea-b50b-4dd5-802d-475c9731e89a

“If the EU wants to be in the driving seat of the autonomous vehicle revolution, it should also follow suit and match its commitment with ambitious funding. If the block continues focusing primarily on regulation, it will without doubt lose out and may never catch up with China and the United States.

possibility that the driverless cars may never arrive, as per their April filing to the United States Securities and Exchange Commission: “There is no guarantee that any incremental changes in the specific equipment we deploy in our vehicles over time will not result in initial functional disparities from prior iterations or will perform as expected in the timeframe we anticipate, or at all.””[19]

The challenge of making self-driving technology fully functional is well summarised by then Argo AI’s Head of Technology Alexandre Haag who notes that achieving “90 percent is fairly easy. Getting to 95 percent starts to get interesting. And then you still need to go way beyond that. Nine point nine nine nine nine… Adding each nine is ten times harder. When you’re at 95 percent, you’ve just scratched the surface.”[20] With the delays, some companies are slightly changing direction. The original brief was to enable AVs to drive anywhere, despite the circumstances. Now, including Waymo,[21] one can witness that the self-driving capacity is achieved only in a certain territory with which the AV systems are familiar.

Whereas AVs have not arrived yet and are essentially behind the schedule, this should not be seen as a vindication for those that have been sceptical about them. On the contrary, despite the setbacks, investment and research into self-driving technology continues, thus proving the importance of it. When assessing the potential of AI in the car industry, it is far from maximised. According to one estimate, the AI market in automotive systems will increase more than fivefold in five years, reaching EUR 24 billion by 2025.[22]

The real story about AVs is not about when they will arrive or how many setbacks and delays there have been. The AI-powered progress towards AVs — and, in the process, the continuous improvements to ADAS and conditional self-driving — is radically changing the auto industry. At the moment there are no big car companies that are not pursuing the self-driving technology, let alone any that have dismissed it outright. Although rarely are carmakers going the route of Tesla by developing the self-driving technology alone and in-house, most others including Ford, Volkswagen, Mercedes and General Motors have entered “strategic partnerships” with AV startups.[23] Most recently, Volvo has teamed up with China’s DiDi Chuxing‘s self-driving division,[24] while Toyota spent over half a billion dollars to acquire the autonomous driving unit of Lyft.[25]

19 Lin, C. (2021) Tesla admits it may never achieve full-self-driving cars, The Fast Company, April 28. Available at: https://www.fastcompany.com/90630440/tesla-admits-it-may-never-achieve-full-self-driving-cars

20 Hawkins, A. J. (2018) Audi pulls the curtain back on its self-driving car program. The Verge, December 18. Available at: https://www.theverge.com/2018/12/18/18144506/audi-self-driving-car-volkswagen-luminar-lidar

21 Waymo’s self-driving taxis have only been launched in the East Valley of Phoenix, Arizona. See: Waymo (2021) Now taking riders in Metro Phoenix. Available at: https://waymo.com/waymo-one/

22 Intellias (2020) Adoption of AI in the Automotive Industry: Is It Worth the Effort?, February 24. Available at: https://www.intellias.com/adoption-of-ai-in-the-automotive-industry-is-it-worth-the-effort/

23 Walz, E. (2021) Toyota Enters into a Strategic Partnership with Silicon Valley Startup Aurora on Autonomous Driving Technology, FutureCar, February 10. Available at: https://www.futurecar.com/4411/Toyota-Enters-into-a-Strategic-Partnership-with-Silicon-Valley-Startup-Aurora-on-Autonomous-Driving-Technology ; Hawkins, A. J. (2020) Mercedes-Benz and Nvidia team up to develop next-generation supercomputers for cars, The Verge, June 23. Available at: https://www.theverge.com/2020/6/23/21300614/mercedes-benz-nvidia-computer-orin-self-driving-adas-ota

24 Traugott, J. (2021) Volvo’s Latest Initiative Will Put BMW On Notice, CarBuzz, April 22. Available at: https://carbuzz.com/news/volvos-latest-initiative-will-put-bmw-on-notice

25 McGee, P. and K. Inagaki (2021) Toyota buys Lyft’s self-driving unit for $550m, Financial Times, April 27. Available at: https://www.ft.com/content/c0c15356-403c-4379-83f6-f31cb2a1392e?segmentId=b0d7e653-3467-12ab-c0f0-77e4424cdb4c

Indeed, the race towards AI-powered AVs, coupled with the arrival of electric vehicles and connected cars, has resulted in a paradigm shift within the automobile industry. Previously cars used to be mainly compared and advertised based on their technical specs (maximum speed, acceleration to 100 km/h), their driving dynamics and their levels of comfort and luxury. These characteristics have become secondary at most as the only real important selling points nowadays are whether a car is electric, connected (i.e. car's infotainment running on a good operating system and having over-the-air software updates, etc.) and self-driving.

Some countries are actively promoting policies that accelerate the path towards AVs. For instance, China's policy roadmap aims to have every other new car sold in the country to be equipped with the necessary hardware for self-driving by 2025.[26]

If the EU wants to be in the driving seat of the autonomous vehicle revolution, it should also follow suit and match its commitment with ambitious funding. If the block continues focusing primarily on regulation, it will without doubt lose out and may never catch up with China and the United States.

It is beyond doubt that not only is AI improving cars, but has also changed the industry with no avenue for return. Although self-driving cars may not come as soon as hoped for, the industry players that do not embrace the paradigm shift will be rendered insignificant. Musk has said that "a car that does not have the hardware for full self-driving, it is like buying a horse."[27] Just as horses were replaced by internal combustion engine vehicles in the past, AI is driving another change that carmakers — and the society — have to accept.

26 Tabeta, S. (2020) China wants self-driving tech in half of new cars by 2025, Nikkei Asia, November 12. Available at: https://asia.nikkei.com/Business/Automobiles/China-wants-self-driving-tech-in-half-of-new-cars-by-2025

27 Belvedere, M. J. (2019) Elon Musk: Any other car than a Tesla in 3 years will be like 'owning a horse', CNBC, April 23. Available at: https://www.cnbc.com/2019/04/23/elon-musk-any-other-car-than-a-tesla-in-3-years-like-owning-a-horse.html

THE TRIPLE CONSTRAINT ON ARTIFICIAL-INTELLIGENCE ADVANCEMENT IN EUROPE

Skills, data and financing shortcomings constrain artificial-intelligence innovation in Europe.

Mia Hoffmann & Laura Nurski

Bruegel

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Shortcomings in Europe in human capital, data and the financing available all hold up adoption by European firms of artificial intelligence. These same barriers also constrain European AI research and development. Table 1 shows how barriers in terms of skills, financing and data come into play differently at each of the three stages of innovation (see Hoffmann and Nurski 2021, for a detailed discussion).

Table 1: Outcomes of and barriers to successful AI advancement

	AI research	AI development	AI diffusion
Who does it?	Universities, private research laboratories	Technology companies (big tech & AI start-ups/scale-ups)	(Non-AI) firms across all sectors of the economy
Indicators of success			
	Number of paper/conference citations	Number of AI start-ups Number of AI unicorns Number of AI patents	% of firms adopting AI
Inputs (or barriers) to success			
Skills	Academic AI researchers	AI PhDs & Master degrees	Computer science degrees
Financing	Public funding	Venture capital	R&D subsidies or tax deductions
Data availability	External (public & private) data for testing techniques	External (public & private) data for training models	Internal data for fine-tuning models

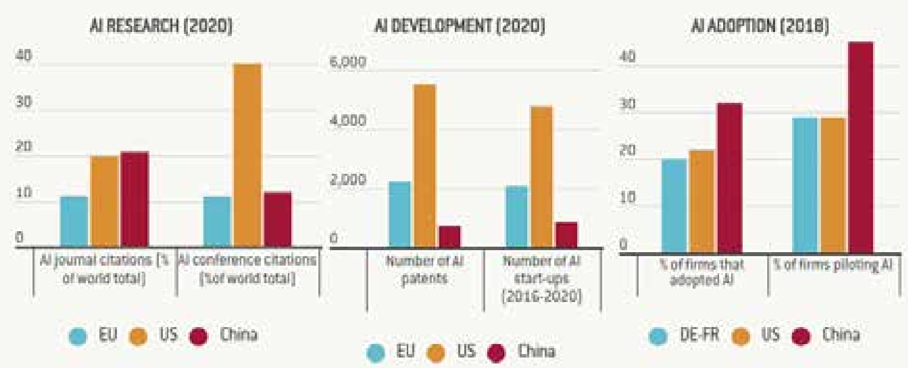
Source: Bruegel, see Hoffmann & Nurski (2021) for full table.

A head-start in AI research, development and diffusion can generate economic and geopolitical benefits. Rapid AI adoption in the private sector promises productivity gains and a competitive edge on global markets. Growing demand for AI technologies will generate economic benefits in countries that are home to developers of cutting-edge AI products. AI development also arguably reinforces strategic autonomy by reducing dependence on foreign technology and providing opportunities for policymakers to shape international standards. Countries affiliated to scholars conducting frontier AI research may benefit from knowledge transfers to students and spillovers to the private sector (Gofman and Jin 2020), and the ability to set research priorities through policy. Unsurprisingly, more than 30 countries now have national AI strategies, including the US and China (Zhang et al 2021).

AI innovation outcomes in the EU, the US and China

Measuring advancement requires different metrics for the three stages of innovation – research, development and diffusion. AI research can be considered successful when it leads to journal and conference citations; AI development can be considered successful when it leads to patents or unicorns (start-up companies valued at $1 billion or more); and AI diffusion can be considered successful when firms pilot or integrate AI into their operations. In each of those areas, Europe is proving less successful than its international counterparts (Figure 1). Europe's skills, data and financing shortcomings contribute to this.

Figure 1: Comparing outcomes of AI success in the EU, the US and China



Source: Bruegel based on Duranton et al (2018), CBInsights and Zhang et al (2021). Note: a) Patents: Only ~8% of patents filed provide information on the geographical affiliation, therefore the data presented here has limited reliability. As a share of all global AI patent filings, the US accounts for 3.2%, the EU27 for 1.3% and China for 0.4%. b) Start-ups: the number reflects the sum of start-ups that received funding of at least $400,000 over the past five years (2016-2021).

AI skills availability in the EU, US and China

A skilled labour force is a key enabler of technological advancement. Competitive universities and academic talent enable countries to participate in frontier research. Skilled researchers generate productivity and quality spillovers to their teams and co-authors (Azoulay et al 2010). High levels of intellectual capital and skills have been found to boost innovation performance in high-tech firms (Buenechea-Elberdin et al 2017), and the number and success of AI start-ups depend on the specialised expertise of their founders (Gofman and Jin 2020). Finally, the availability of digital skills among staff is central to AI adoption (Kinkel et al. 2022). Four-fifths of EU companies consider the lack of skills in the labour force to be a critical barrier to AI adoption (European Commission 2020).

Figure 2: AI skill availability in the EU, US and China

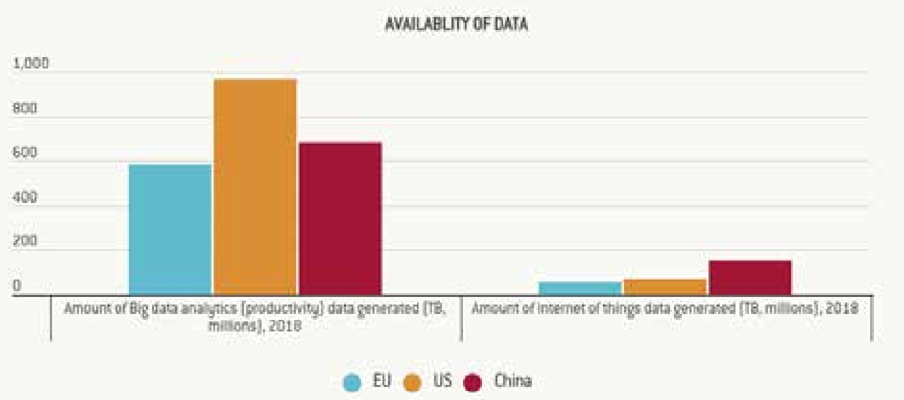
Source: Bruegel based on Anderson et al (2020) and Castro et al (2019). Note: The Chinese estimate for skills intensity in business relies on only one observation and was therefore removed.

The metrics shown in Figure 2 reflect skill endowments of the three economies for each stage of AI advancement. The EU has an excellent skills base in terms of AI research (column 1), but appears to have less of an advantage when it comes to leveraging this expertise in the private sector. The indicator for skill intensity in business shows that the EU has on average less than half as many AI researchers employed in top AI firms than the US. Moreover, the ability of EU firms to adopt AI systems and adjust them to their operational needs is limited by the relatively low availability of programmers and data engineers in the labour market, as proxied by the number of computer science degrees (column 3). Here, in line with the AI adoption estimates, the Chinese labour force appears better equipped to serve the needs of business.

Data availability in the EU, US and China

Data availability is the second important driver of AI advancement. The ability to process and store huge amounts of data has been one of the key enablers of recent AI research and development (Stoica et al 2017). Combined with advancements in scalable computer systems, the emergence of massive amounts of (public and private) data have allowed core AI algorithms, such as deep learning and reinforcement learning, to be explored at unprecedented scale and scope. For AI adoption by regular companies, however, the availability of internal company data is a more crucial determining factor, as AI technologies need to be fine-tuned to the specific context of each organisation. This algorithmic fine-tuning requires adoption of previous 'basic' technologies such as data storage and computing power, because, unless data can be collected, stored and transformed, companies cannot begin to learn from it or use it to support intelligent decision making (Zolas et al. 2020). More than half of EU companies have cited lack of internal data as a major or minor obstacle to AI adoption (European Commission 2020).

Figure 3: Data availability in the EU, US and China



Source: Bruegel based on Castro et al (2019).

The availability of data in digital form is determined by both the amount of data generated and its accessibility to researchers and companies. Large datasets of productivity data and data generated from connected devices and appliances can, for example, be used to train machine-learning algorithms in retail or industrial settings and are especially relevant to AI research and development. Data generation in the EU is significantly lower than in the US and China (Figure 3), likely driven by low levels of digitisation in European economies. Unfortunately, lack of information on firm-level data collection prevents us from making comparisons about internal data availability.

AI financing in the EU, US and China

Intuitively, access to financing is crucial for AI start-ups to scale-up and realise their ideas. Venture capital appears particularly suited to fill this gap since, in addition to providing funding, VC investment is associated with beneficial impacts on firms' operations (Kerr et al. 2014). Similarly, financial constraints are a major barrier to technology adoption in regular non-AI firms. Complex technologies such as AI require significant operational and organisational adjustments, the costs of which can be prohibitively high for some firms (Hoffmann and Nurski 2021b; Ghobakloo and Ching 2019). Governments wishing to stimulate AI adoption should consider subsidies or tax incentives.

Figure 4: AI financing availability in the EU, US and China

Source: Bruegel based on OECD.AI (2021) and Zhang et al (2021).

Compared to American and Chinese counterparts, European firms face dire budget constraints when it comes to AI (Figure 4). In 2020, VC flows into EU start-ups represented less than one quarter of the flows to China, and less than one tenth of those to the US. The same is true for private investment in

AI. According to the OECD's AI Policy observatory, based on 13 government agencies, total public AI R&D funding stood at $3.6 billion in 2019, the vast majority accounted for by US and EU spending (data on Chinese public R&D investment is not available for comparison) (Galindo-Rueda and Cairns 2021).

Policy recommendations

Compared to China and the US, lack of financing seems to be the most crucial barrier that Europe faces overall. Acquisition of the technology and adaptation of operational processes around AI prove constraining for regular businesses (Hoffmann and Nurski 2021). International comparisons often focus on the EU's shortfall in VC investment in AI, which is crucial for AI development. But to stimulate adoption of AI among regular non-tech firms, governments might better look to tax deductions or subsidies that support the acquisition of AI technology and related services.

Lack of availability of AI skills seems the main factor holding back the final adoption of AI in regular firms. International comparisons show that despite the EU's large number of academic AI researchers, Europe doesn't deliver the same amount of skilled labour to private firms, resulting in a lack of skilled data scientists who can put AI to practical commercial use. This suggests that the labour market is a binding constraint on AI adoption and an area to which the EU and member states should pay attention. Improving opportunities for adult learning and making data skills part of more educational curriculums are the first steps to take.

Finally, in terms of data availability, data generation in the EU appears to be trailing behind the US and China, a result of Europe's lagging digital transformation of businesses and public administration. While access to external (private and public) data is necessary for AI research and development, the availability of internal company data is more crucial for AI adoption by non-R&D-firms – for example, fine tuning of AI algorithms for the purposes of specific businesses. Governments should therefore first promote the digitisation of business and administration, and support the investments needed to improve technological readiness necessary for AI adoption. Next, policymakers can focus on opening up public (anonymised) data and improving cross-country accessibility and comparability of datasets.

Alleviating these most pressing constraints in terms of skills, financing and data would go a long way to promote AI advancement in Europe.

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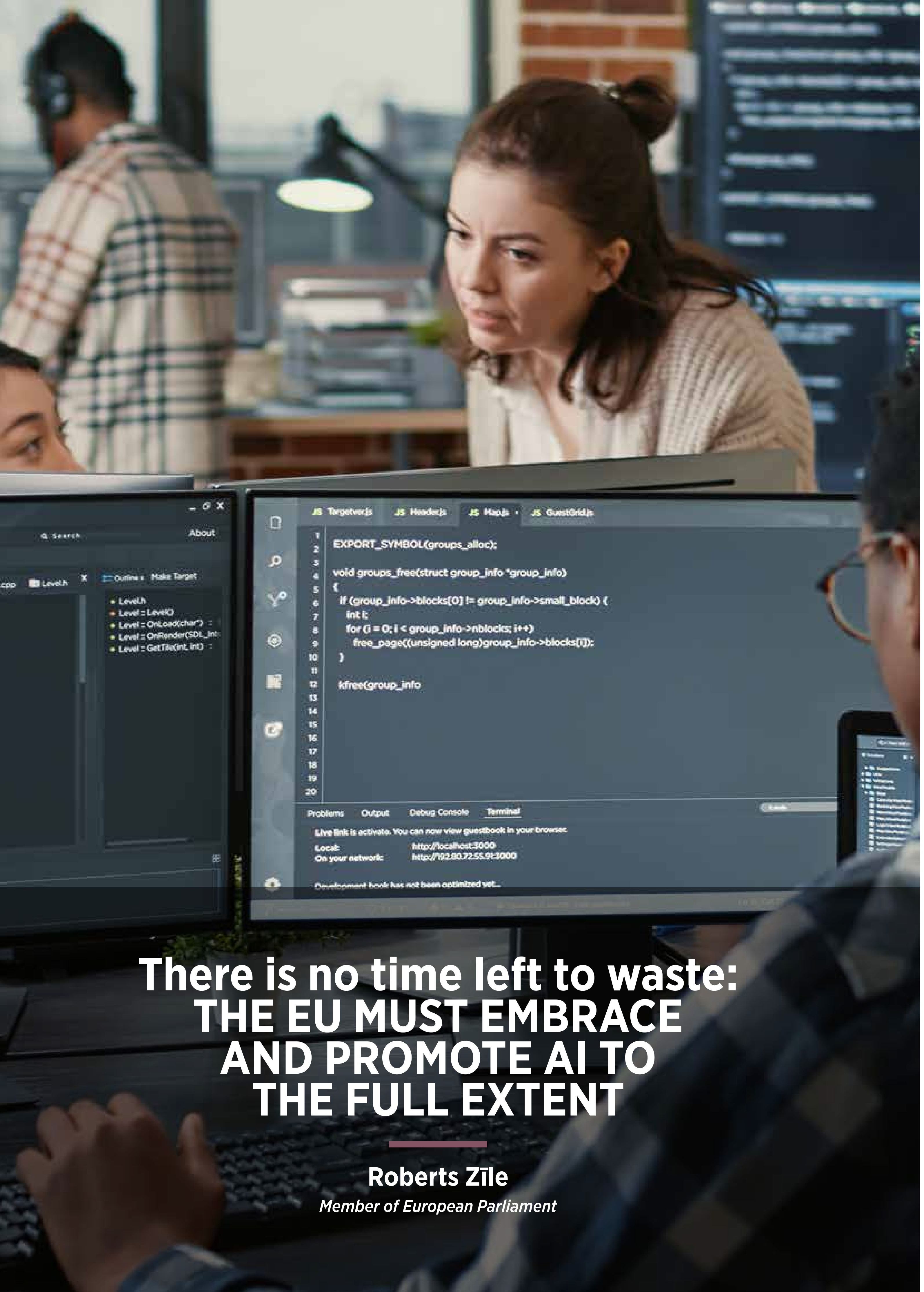

There is no time left to waste: THE EU MUST EMBRACE AND PROMOTE AI TO THE FULL EXTENT

Roberts Zīle

Member of European Parliament

Artificial intelligence, whatever one thinks of it, is increasingly becoming one of the most important technologies characterising this and the forthcoming decades, if not the 21st century overall. It is not anymore about near or distant future; AI is already here. Whether it is a voice assistant on our phones, the use of online translation services or algorithms adjusting our social media feeds, the technology has hundreds of subtle applications to date. Meanwhile the medical field, thanks to AI, is improving the quality of drugs and developing tools to predict high-risk coronavirus variants. Other sectors, including transport, logistics banking and lately education are also applying the AI systems to improve the quality of their products and services. Within the next five to ten years we are likely to see next-level advanced driving aids in our cars, if not full-self driving technology, which will help reduce car accidents and traffic-related death rates. There are dozens of other notable examples.

The EU's stance on AI is that of caution, if not outright fear. The European Commission's proposal on AI Act, which seeks to set "the global gold standard" in the area, is concentrating more on categorising the AI applications according to their risk level — i.e. limited, high, unacceptable — than stimulating the actual growth and uptake of the technology. Whereas the hopeful argument is that having clearly defined the risks related to AI will unleash the potential of the technology, a more sobering take is that the EU's approach with its underlying provisions may end up achieving the exact opposite. One study calculates that the AI Act, if adopted in the current form, would cost the European economy over EUR 30 billion over the next five years and reduce investments by 20 percent.[2] SMEs, which constitute the vast majority of the EU's economy, would incur prohibitively high compliance costs, were they to employ a high-risk AI system, thus essentially making it economically unattractive.

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If we assess the broader picture, AI has a potential to add vastly to the global economy, by one estimate as much as EUR 13.5 trillion by the end of the decade.[1] Even if this figure ends up 10 times lower, it is still notable. That, however, is all dependent on the level we both stimulate the development of AI and embrace its vast applications. In this sense, a geographical divide has already clearly emerged. Indeed, when it comes to AI, there are growing differences in approach between the EU and other major economies.

It can and is argued that the EU needs "trustworthy" AI and avoid risk at nearly all costs, in line with the "gold standard" approach. However, such stance creates an unfavourable investment climate. In fact, the region is already losing out. The gap in AI investment between the EU and other major economies is vast and growing. According to Stanford University's AI Index Report, private AI investment in the United States was below USD 5 billion in 2015, but by 2020 was already over USD 23.5 billion. Meanwhile in the EU it was just USD 2 billion in 2020.[3] To put it within a context, US-based Meta, Facebook's parent

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1 PwC (2017) Sizing the prize: What's the real value of AI for your business and how can you capitalise? Available at: https://www.pwc.com/gx/en/issues/analytics/assets/pwc-ai-analysis-sizing-the-prize-report.pdf

2 Mueller, B. (2021) How Much Will the Artificial Intelligence Act Cost Europe? Center for Data Innovation. July 2021. Available at: https://www2.datainnovation.org/2021-aia-costs.pdf

3 Zhang, D. et al (2021) Artificial Intelligence Index Report 2021, Stanford University, March 2021. Available at: https://aiindex.stanford.edu/wp-content/

company, plans to spend USD 10 billion a year over the next decade on developing its metaverse.

Indeed, most successful AI and technological companies either emerge from and or move to the United States and, to lesser extent, other countries like Israel and the United Kingdom. According to CB Insights' list of top 100 AI startups in 2021, only six originate from the EU.[4]

The public investments in AI also remain low at the EU level. The Commission notes that through Horizon Europe and Digital Europe it plans to invest EUR 1 billion per year.[5] Whilst Member States have additional investment packages at both EU and national levels. Indeed, prior to the AI Act proposal, a group of 14 Member States from the Eastern, Northern and Southern countries including my native Latvia[8] communicated their joint position paper in which they stressed the importance of striking the right balance between regulatory burden and the need for innovation.

Yet a softened approach to AI is unlikely to prevail, for fear and skepticism about AI is still high on the agenda. The zero risk bias — a tendency to eliminate any risk, whatever the broader cost — is largely prevailing in Brussels. The European Parliament's

> ***The future waves of automation and the replacing of tasks and workers by robots will be mostly achieved thanks to innovation — and successful application — of AI-based solutions. Europe badly needs this given the low productivity growth and the demographic challenges. Unfortunately, the long-term economic benefits are no easy sell to the voters — even if in the long term AI will not destroy more jobs than it creates, if past automation waves is something to go by.***

AI budgets, this still compares unfavourably to the likes of China and the United States, the latter of which is said to have invested around USD 6 billion in 2021 alone[6] — in addition to raking in the lion's share of the world's private AI investment.[7]

If the EU is serious about even attempting to catch up with the dominant players, regulation of AI must encourage, not stifle innovation and, furthermore, needs to be accompanied with bold spending and Special Committee on Artificial Intelligence in a Digital Age (AIDA) gives a preview, whereby the majority of the near 1400 amendments submitted to the committee's draft final report concentrate on the risks instead of opportunities and ways to promote the technology.[9] The deliberations on the AI Act will be similar and even if the outcome is more favourable than feared, the negotiations will drag for years and risk resulting in the same situation that General Data Protection Regulation (GDPR) ended up creating.

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Namely, by the time it was adopted, it was already partly out of date with the emerging technologies and trends. Even the GDPR's "father", MEP Axel Voss, conceded to the Financial Times a year ago that the regulation needs "some type of surgery" and that "[t]he digital world is about innovation. We cannot stick with principles established in the 80s that do not reflect the new situation we are living in."[10]

In fact, the EU's approach to AI is more complicated still. For the technology affects strongly the future of work too. The future waves of automation and the replacing of tasks and workers by robots will be mostly achieved thanks to innovation — and successful application — of AI-based solutions. Europe badly needs this given the low productivity growth and the demographic challenges. Unfortunately, the long-term economic benefits are no easy sell to the voters — even if in the long term AI will not destroy more jobs than it creates, if past automation waves is something to go by. The microcosm of this can be witnessed with the EU's car industry where mild panic about job losses due to transition to electric vehicles is already slowing that transformation to the detriment of the EU's industrial competitiveness.[11]

Similarly, with its overly cautious and unambitious approach taken to date the EU will not only lose the AI race, but risks being increasingly shaped by the technologies developed elsewhere. It may end up having the "gold standard" AI legislation, but not the AI itself. Unless it changes course, the EU's competitiveness and sway over the world economy will further decrease.

It does not have to be that way. At the very least, investment not only needs to, but can be increased noticeably. Even and especially within this planning period, the EU and the Member States have an unprecedented opportunity to invest wisely and strategically in the right areas. Instead of focusing on "[open] strategic autonomy" in areas of semiconductors and other fields where the market forces will solve the problems anyway, the EU can, for instance, increasingly promote both studies and research into AI. To date, best AI studies are provided outside of the block, but it can be changed. Starting with the basics would be notable, as many EU Member States do not offer even one undergraduate AI course. It is not that the demand is missing. To the contrary, according to one estimate, introductory course enrollments or attempted enrollments in the EU increased by 165 percent through the past four academic years staring with 2016-17.[12] If lack of offer persists while demand for AI studies rises, many of the prospective students will graduate — and find jobs — outside of the EU.

Similarly, research funding must be increased and provided with less strings attached to stop the trend whereby brightest minds end up working for the tech giants in Silicon Valley. To promote understanding, acceptance and deployment of AI, general population also needs to be supported. Currently well over two thirds of Europeans lack even the most basic digital skills.[13] Indeed, skills shortage is one of the reasons why the AI uptake by many EU-based companies is already lagging.[14]

Furthermore, among other tasks, more work and ambition must be put into making a digital single market as well as a true capital markets union a reality. The ease of doing business across the Member States can still be vastly improved and not only when it comes to finance, but even labour mobility.

To sum up, there is a lot more that the EU can and must do in order to promote artificial intelligence, whatever one's view of the regulation. The economic and social benefits of developing, promoting and deploying the AI systems are big and growing. There is no time left to waste.

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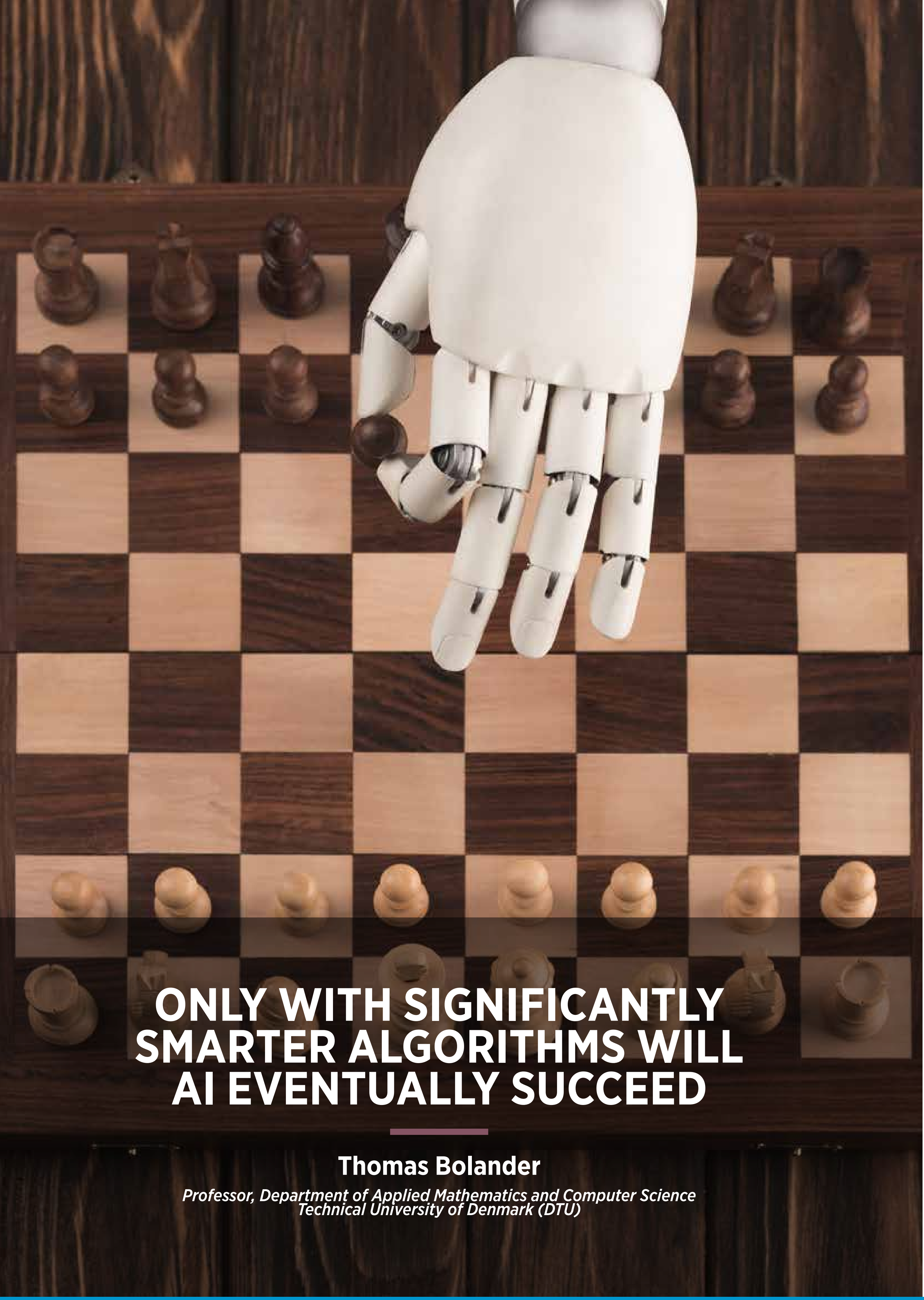

ONLY WITH SIGNIFICANTLY SMARTER ALGORITHMS WILL AI EVENTUALLY SUCCEED

Thomas Bolander

Professor, Department of Applied Mathematics and Computer Science
Technical University of Denmark (DTU)

EU has the twin objective of harvesting the opportunities of AI on the one side and avoid its potential risks and pitfalls on the other. The risks of AI include potential loss of transparency, explainability, trust and accountability. Achieving the twin objective is a difficult balancing act. One of the most crucial conditions for its fulfilment also happens to be one that is often underestimated or even overlooked: We need to develop new techniques and algorithms in AI with higher cognitive abilities. All the data and computing power in the universe is not in itself enough to get us there.

Good AI, bad AI

The last 10 years of AI development and adaptation has taught us two things. It has taught us that AI can be an exceptionally powerful technique with large-scale commercial impact and huge societal benefits. And it has taught us that AI can also conversely be a significant societal threat to fairness, transparency, explainability, trust and preservation of our cultural values. EU has the goal of being globally leading in "good AI" – AI that does not suffer from the mentioned threats. The goal is noble, though it might at first be perceived as an obstruction to the commercial development of AI to insist on "good AI" and regulate against "bad AI". However, the long-term winners of the AI race will certainly be those who develop good AI, as this is bound to become the global norm. Many of my non-European colleagues are impressed by how seriously the ethical issues of AI are taken in the EU, and how many initiatives are being made to regulate AI in order to ensure trustworthy AI grounded in our values and fundamental rights.

> ***"The 2020 EU white paper on AI talks about ensuring that AI systems are "trained on data sets that are sufficiently broad and cover all relevant scenarios needed to avoid dangerous situations". With our current methods and algorithms, I find it highly unlikely that we will ever have enough data for something like driverless cars to become safe. What is really needed is the general cognitive ability to correctly interpret traffic situations, including unfamiliar ones.***

The only problem is then how to achieve that noble goal. Do we need more data? Yes, probably. Do we need more computing power? Maybe also that, yes. But, in fact, what we need more than anything else is new algorithms with higher cognitive abilities.

Algorithms, data and computing power: the trinity of AI

The three components of any working AI system are computing power, data and algorithms. If we make a parallel to natural intelligence in humans and animals, then computing power roughly corresponds to the size of the brain, data corresponds to the experience that the brain is exposed to, and the algorithm is the specific structure or architecture of the brain (how it is wired, how it learns). To achieve a high level of intelligence, obviously all three are needed: a large brain, a lot of experience, and a brain that has been sensibly wired from the outset. It turns out that the wiring of the brain is probably the most important of these. Our higher cognitive abilities such as our social or linguistic skills are more a consequence of the exact architecture of our brain than its size or the amount of external stimuli we receive during our lifetime.

Elephant AI

The brain of an elephant has 3 times more neurons than a human brain, and some whales both have larger brains and live significantly longer than humans. Despite this, humans are far superior in cognitive abilities like problem-solving and learning new ways of acting. Elephants have 98% of their neurons in the cerebellum, the area of the brain linked to motor skills and sensory input (controlling movement). Their cerebral cortex, the area linked to higher intelligence, is relatively small and not very robust. In that area they only have one third of the number of neurons of a human. Hence, it is not too surprising that compared to humans, elephants have very limited abilities in problem-solving, reflecting on their own actions, learning new ways of thinking, etc. (Herculano-Houzel, 2014).

To take the parallel back to AI, if we don't have the right algorithms that can mimic the required cognitive abilities, then it doesn't matter how much data or computing power we can provide to those algorithms. We don't get trustworthy, explainable, and transparent AI that adheres to European values just by getting larger computers and more data. That would be like arguing that if we want trustworthy and dependable animals that know how to act in agreement with human values and norms, we just need to ensure that they have very large brains and get a lot of experience. But the existence of elephants and whales show that this isn't true.

From Shakey the Robot to Google Maps

The central importance of algorithmic development can also be illustrated by looking at some of the specific problems that AI has historically been trying to solve. A classic problem in AI is pathfinding: finding a route from A to B. It might sound as something too trivial to even be considered AI, but efficient algorithms for pathfinding come out of AI research, e.g. the famous A* (A-star) algorithm that was originally developed in the 1960s to allow the box-pushing robot Shakey of the Stanford Research Institute to plan its actions efficiently (Nilsson, 1984). Pathfinding algorithms are today for instance used for route and action planning in robots, in AI for video games, and in route planning applications like Google Maps. Finding a route from A to B is a problem that can normally be solved completely without data, except the obvious need for a map of the environment. So not all AI is necessarily data hungry. The data hungry AI is usually within machine learning, when we don't have a static, fixed algorithm to solve the problem, but need to learn to recognize patterns from experience.

Pathfinding however tends to be relatively power hungry, i.e., demanding a lot of computing power. But with the many improvements and refinements of the classic A* algorithm that have been invented since the 1960s, we now have algorithms that can easily scale up to very large maps and still find short routes in decent time. At least if we scale up the size of the computer running the algorithm, as Google Maps does to compute routes almost instantly for more than 50.000 users per second around the globe.

From Google Maps to Amazon warehouse robots

However, interestingly, sometimes we just need to change a problem only slightly for it to suddenly become very hard for computers, no matter how large. Amazon has a couple of hundred mobile robots in each of their warehouses, in total almost 200.000 worldwide. These robots are also just computing paths from A to B, but of course they must take each other into account when doing so. Otherwise they might bump into each other, or two robots might forever wait for the other one to get out of the way. This problem, known as multiagent pathfinding, has turned out to be significantly harder to solve. Ten years ago, it was impossible to solve for more than a very few robots, simply because we hadn't yet developed the required algorithmic sophistication. The problem, however, gradually started to attract attention from AI researchers, partly due to the obvious relevance to applications such as fleets of mobile warehouse robots. Its rising popularity led to the publication of more than a thousand research papers on the subject within the last ten years, with half of those throughout the past two years. These research papers all present more sophisticated algorithms for multiagent pathfinding, so that today we can easily solve the problem for hundreds or even thousands of robots.

From Amazon robots to driverless cars

As explained, going from a single robot (pathfinding) to many robots (multiagent pathfinding) turned out to be surprisingly tricky and required a lot of novel algorithmic research to be solved. The complication had to do with interaction, the fact that when a robot is not alone in its world, it can't always just act as it pleases. The problem of interaction and coordination is clearly even significantly more intricate in the case of navigating in traffic. This is the main reason why the development and deployment of fully autonomous cars is lagging. Markkula (2020) defines interaction in traffic as "a situation where the behavior of at least two road users can be interpreted as being influenced by the possibility that they are both intending to occupy the same region of space at the same time in the near future." For a driverless car to truly engage in interaction in traffic, it needs both to have the intention to use the same space as another road user as well as to know that the other road user potentially intends to use the same space. In other words, the car needs to reason about knowledge and intentions — not only its own, but also the knowledge and intentions of other road users. This requires algorithms that can simulate sophisticated cognitive abilities, including social intelligence. The development of such algorithms is still in its infancy.

> ***Currently, there seem to be a tendency in the EU to focus mainly on data and computing power. This might be a wise strategy in the short run but could be holding us back in the long run, especially if we don't sufficiently invest in developing smarter algorithms. We need more fundamental AI research to develop new methods and algorithms in AI, and a lot of it must be interdisciplinary.***

The 2020 EU white paper on AI talks about ensuring that AI systems are "trained on data sets that are sufficiently broad and cover all relevant scenarios needed to avoid dangerous situations". With our current methods and algorithms, I find it highly unlikely that we will ever have enough data for something like driverless cars to become safe. What is really needed for driverless cars is the general cognitive ability to correctly interpret traffic situations, including unfamiliar ones.

Trustworthy algorithms of the future

The limited sophistication of the AI algorithms that currently run on our computers is the reason why we even started to worry about things such as trust, explainability and transparency in the first place. When we talk about these issues in AI, it is all about getting the AI systems to adapt to how we humans conceive the world. We want to have an explanation that *we* can understand. We want a system that *we* can trust and that adheres to *our* values. So, for human-centric AI to become a reality, we need AI systems that can relate to humans – similarly to how we humans relate to each other – that is, AI systems with social intelligence.

Currently, there seem to be a tendency in the EU to focus mainly on data and computing power. This might be a wise strategy in the short run but could be holding us back in the long run, especially if we don't sufficiently invest in developing smarter algorithms. We need more fundamental AI research to develop new methods and algorithms in AI, and a lot of it must be interdisciplinary. There are still many aspects of human cognition that we need to understand better in order to be able to mimic them in algorithms.

> *Do we need more data? Yes, probably. Do we need more computing power? Maybe also that, yes. But, in fact, what we need more than anything else is new algorithms with higher cognitive abilities.*

As discussed above, many problems we want to solve with AI are not solvable with data and computer power alone, no matter how much data and computer power we can provide. Hence, the invention of new and more sophisticated algorithms still needs to be at the heart of AI development. This is not to diminish the importance of data and computer power, which are clearly crucial. Rather, we need to take all three dimensions seriously.

Unless the AI systems of the future are equipped with higher cognitive abilities like social intelligence or the ability to critically reflect on data and data sources, it is not likely that we humans will ever trust them – and probably we shouldn't in that case.

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THE POTENTIAL IMPACT OF ARTIFICIAL INTELLIGENCE ON ADULT LEARNING SYSTEMS

Annelore Verhagen

Economist, Organisation for Economic Co-operation and Development (OECD)

Artificial Intelligence (AI) has the potential to make significant improvements to adult learning systems. This is necessary, because the way we work is changing rapidly, and yet only four in ten adults across the OECD participate in education and training in any given year, and these numbers are even lower for vulnerable groups on the labour market (OECD, 2019a). Moreover, training quality remains an issue, and aligning training to labour market needs and individuals' career goals can be challenging.

Drawing on a review of the literature and insights provided by various experts in the fields of AI and training, the OECD finds that, while technological developments such as AI are one of the major forces behind the need for retraining, they might also be part of the solution. However, despite its potential to address some of the barriers that adults face when approaching training, the use of AI for training could in fact raise other existing barriers and generate new ones (Verhagen, 2021).

Potential improvements

AI has the potential to help address some of the key barriers to training participation, notably those related to time constraints. AI-based content and assessment can significantly shorten the learning process, particularly as compared to classroom-based training, because it allows learners to skip irrelevant training tasks and modules, and only focus on filling their knowledge and skill gaps. AI may add value to 'regular' (non-AI) online courses and asynchronous training where there is no live interaction between students and instructors (e.g. Massive Open Online Courses), by making sessions more tailored to the individual needs and interactive, for instance by incorporating chat-bot functions. Thanks to AI-powered augmented and virtual reality technologies (AR and VR) the advantages of distance learning can be extended to practice-oriented training.

AI can also help people find training programmes that are most relevant to their needs quickly and easily, which, in turn may increase individuals' motivation to participate in training. This could be advantageous compared to human career and training advisors because it can scale-up their exercise, and it is more tailored and interactive than non-AI digital solutions such as online training repositories. Tailored training recommendations, as well as AI-based assessments that are tailored to the learners' progress and entry level, may also reduce the risk of participating in less relevant training that could otherwise discourage people from participating in further training. Finally, using AI for training may increase motivation to train by expanding the provision of practice-oriented training through AR and VR, which often includes playful elements, and by providing instant feedback to the learner.

> ***AI-based content and assessment can significantly shorten the learning process, because it allows learners to skip irrelevant training tasks and modules, and only focus on filling their knowledge and skill gaps.***

Vulnerable groups – such as the low-skilled, disabled and non-native speakers – are significantly under-represented in training (OECD, 2021; OECD, 2019a). Using AI for training may be particularly attractive for them. The practice-oriented component of AR and VR may be more motivating for adults who have become disengaged with classroom-based education and for adults who have trouble understanding written materials and instructions (e.g. non-native speakers or people with low literacy skills). The focus of AR and VR on learning from mistakes in a safe environment may motivate people who suffer from fear of failure to participate in training. Moreover, AI-powered text-to-speech and speech-to-text technology facilitates the captioning or reading aloud of any spoken or written communication in real-time, as well as its translation in any language. This can broaden access to training for the visually or hearing impaired.

Employers also stand to benefit from the provision of training through AI. AI-powered AR and VR can be interesting for employers, due to their time and place flexibility, but also for the potential savings in raw materials and the avoidance of physical injuries relative to in-person training. Finally, AI may help make training participation more efficient by improving the matching between learning outcomes of training and the skill gaps of individuals.

Moreover, AI can enable personalised education at scale. It allows developing training that is adapted to specific reskilling needs, at a significantly smaller cost than private tutoring. As discussed above, the advantages can be multiple. Personalisation can be translated into time savings for some trainees while also helping vulnerable populations that need more time to learn. AI-driven personalisation is scalable at little cost as it does not require additional classrooms, teachers or tailored curricula. This scalability has the potential to benefit employers, training providers and policy makers.

may become more accurate. Moreover, timelier and more granular labour market information can be analysed through AI, which may improve the match between supply and demand for skills. With the increasing availability of large amounts of vacancy data from online job postings, it is becoming increasingly common to use AI to assess which skills employers are looking for and whether skill needs change over time within and across occupations. Using similar techniques, AI can also be leveraged to automatically categorise education and training programmes into skill categories, which helps policymakers and employers find the training programme(s) that teach the skills in need. AI-powered training suggestions may help people self-select into the training programmes that will teach them the skills they need in order to remain employable.

Finally, AI has the potential to increase diversity and inclusiveness in the workplace, by training humans in making fairer decisions and improving human interaction, for example when recruiting, assessing work performance or providing feedback. Due to its

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AI may also help make training more impactful by enabling a better alignment of training to skill needs, by enhancing human career and training advisors' skill assessment and training suggestions, and by guiding and empowering adults with limited access to human career counselling to find the most relevant training for them. Thanks to AI, skills profiling may become more widely available, and the profiling conducted by humans

immersive nature and the possibility to create full body ownership illusions, AI-powered augmented or virtual reality training provides the unique opportunity to experience situations through other people's eyes. Automating the assessment of students through AI-powered adaptive assessments or through augmented or virtual reality training may reduce bias in education and training.

Drawbacks and how to overcome them

Participating in training that is powered by AI requires a higher level of digital skills than participating in face-to-face instruction, and in some cases attending a non-AI online training course. Although the digital skills requirements may only be moderate, this still risks excluding groups with lower digital skills, such as older adults and the

low-skilled more generally. This may decrease the inclusiveness of adult learning systems instead of increasing it as suggested above. To get a sense of the size of the problem, in the OECD on average, 25% of adults lack even the most basic digital skills and another 14% can only perform basic functions on a computer or other digital device. The expansion of

training programmes for digital skills is already high on the policy agenda in most countries. The delivery of more training through AI technologies would increase the urgency.

High data requirements and costs can increase inequalities in access to AI tools for training between large and small enterprises. Most AI solutions, including the ones used for training, require vast amounts of data and data storage, as well as powerful computers and access to high-speed wireless internet

The use of AI for training raises similar ethical and transparency issues as in other domains. Many AI systems lack explainability and transparency for the final users. At best, this could reduce the value of using them in some aspects of the training process, for example to tailor training content. At worst, it could lead to bad training decisions, when used to identify skill gaps or assess training outcomes. In addition, the lack of explainability and transparency can discourage adults from

> *Another way to build trust in AI is to increase public understanding of what AI can and cannot do and to be transparent about when it is being used.*

networks. This may be particularly challenging for small and medium enterprises (SMEs), in low and middle-income countries and in rural areas. Moreover, the technical and data needs as well as the required human resources to implement AI solutions can make them quite costly. In order to ensure that AI improves access to training for all rather than for only a minority of larger companies, appropriate mechanisms for sharing AI knowledge and solutions may need to be put in place. These should include mechanisms for sharing data, algorithms and AI knowledge in general, while respecting privacy, intellectual property and other rights. Additionally, external funding initiatives could be targeted for enterprises that face more challenges when it comes to adoption.

Since AI can perform tasks that are traditionally human (e.g. designing tests or providing career guidance), its introduction in training could significantly change the skill requirements in jobs related to training – including teachers, trainers but also Human Resource managers – potentially leading to deskilling in these occupations. One way to address this challenge is by providing opportunities for people in these occupations to reskill in order to leverage their comparative advantage compared to AI systems, such as higher cognitive and social skills. For instance, trainers and career counsellors could use the time gained through AI tools for training to devote more attention to adults with more complex upskilling needs.

undertaking training that uses AI. People are unlikely to (want to) start using AI tools for training when they do not trust that the tools are easy to use, that they provide high quality unbiased output that is easy to interpret, and that data are well protected and used in an ethical and fair way.

Building trust in AI requires the development of trustworthy, human-centred AI. As set out in the OECD AI Principles, trustworthy AI systems benefit people and planet; uphold human rights, democratic values and fairness; are transparent and explainable; robust, secure and safe; and are operated by accountable entities (OECD, 2019b). Another way to build trust in AI is to increase public understanding of what AI can and cannot do and to be transparent about when it is being used. Explainability and transparency of AI are essential for people to challenge the outcomes when necessary. Nevertheless, transparency about AI should respect personal data protection obligations and intellectual property. Finally, AI systems should include the capacity for human intervention and oversight, meaning that AI tools for training are intended to empower humans, not to replace their decision-making altogether. Informing people about this empowering role of AI tools for training may help build their trust.

Conclusion

Using AI for training has the potential to make improvements to adult learning systems, by increasing training participation, including among currently underrepresented groups, by lowering some of the barriers to training that people experience and increasing training motivation. Certain AI solutions for training may also improve the alignment of training to labour market needs, and reduce bias and discrimination in the workplace. However, AI could also lead to increased inequality in training access and provision, it could reduce transparency and explicability in training decisions and assessments, and could lead to the deskilling of jobs in the training sector. Realising AI's full potential and ensuring that using AI for training has beneficial outcomes for all requires policies that address these drawbacks.

> ***AI-powered training suggestions may help people self-select into the training programmes that will teach them the skills they need in order to remain employable***

Moreover, expanding the use of AI tools for training is constrained by the supply of AI-specific digital skills needed to develop the tools (e.g. *Machine Learning, Data Structures* or *Natural Language Processing* skills). Even though the demand for AI skills on the labour market is still relatively small (around 2% of IT job postings currently require AI skills), shortages are already emerging. Countries with education systems that are relatively unresponsive to changing skill needs and with relatively few people willing to enrol in AI skills courses may struggle to find enough people to expand the use of AI tools for training. There are various ways in which countries can try to address this challenge, including: i) raising awareness of the demand for AI skills in the labour market and the positive employment prospects they open up through career guidance for youth and adults; and ii) making the development of AI skills more accessible, for instance through targeted financial incentives.

Finally, the potential benefits of AI tools for training notwithstanding, to date there is a lack of scientific evidence about the effectiveness of these tools compared to their non-AI or human alternatives. Without rigorous and robust evidence about the effectiveness of AI tools for training, policymakers and employers cannot weigh the costs of these tools against their benefits in their decisions to implement or expand the use of AI tools for training. Before resources are allocated to the expansion of the use of AI tools for training, further research is needed in order to improve our understanding of these tools, and whether the benefits of the different types of tools outweigh the costs, harms and challenges. Governments should therefore consider long-term public investment and encourage private investment in research and development in trustworthy AI tools for training that outperform non-AI and human alternatives.

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ARTIFICIAL INTELLIGENCE AND THE EU SKILLING CHALLENGE

Konstantinos Pouliakas
European Centre for the Development of Vocational Training (Cedefop)

Covid-19 and the resurfacing of automation concerns

Not long before the coronavirus outbreak, fears about artificial intelligence (AI) algorithms and smart machines resulting in a jobless society were widespread. A well-cited University of Oxford study cautioned that about half of all jobs in advanced economies could disappear due to advancing machine learning methods. Follow-up studies that deconstructed jobs using their task composition or focused on employers' incentives and human resource management practices (Cedefop, 2020a) provide a more nuanced picture and dispel such fears of massive job destruction. A 2018 research paper using Cedefop's 1st European skills and jobs survey (ESJS) found that about 14% of jobs in the EU labour market face a very high risk of automation (Pouliakas, 2018). With close to 4 in 10 jobs likely to experience marked task restructuring, most change refers to transformation of jobs from within.

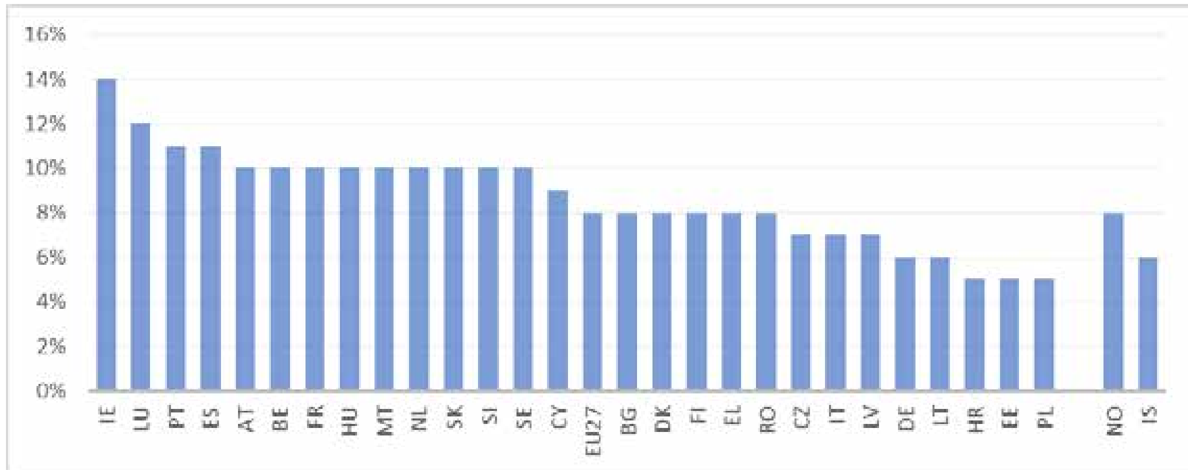
Despite such rebuttal, there are now once again concerns about the coronavirus crisis accentuating or accelerating automation of work. The pandemic and the social distancing measures implemented to fight it have influenced the incentives of companies and societies to adopt new digital and data-driven technologies. Recent analysis based on Cedefop's 2nd ESJS highlights that about 4 in 10 EU adult workers started using new digital programs or software, or new computerised machinery, not deployed before the coronavirus pandemic. About 8% of EU adult workers now use a computing device for programming or coding, that also involves using artificial intelligence (AI) methods, such as machine or deep learning, as part of their main job (figure 1).

Growing digitalisation has thus renewed fears that the post-Covid19 recovery may be a jobless one and has uncovered a marked upskilling and reskilling challenge that many displaced and low-skilled individuals will need to overcome. The 2nd ESJS data reveal, for instance, that about 1 in 10 EU workers strongly fear that new digital technologies in their organisation can or will do part of their job. A quarter fears that new technology will be able to do so to a moderate extent.

Answering an old question with new (big) data

To develop well-designed and forward-looking up- and reskilling policies, in-depth understanding of which skills and job tasks within occupations may be displaced by AI and other digital technologies is crucial. Due to data limitations in conventional labour market surveys, much of the current literature estimates however the underlying probability of some occupations being replaced by machine learning algorithms based on a limited set of broad job tasks. Up-to-date and detailed data on required occupational work activities is hence valuable.

FIGURE 1. Share of EU adult workers using computing devices to write programs or code (including using AI methods)



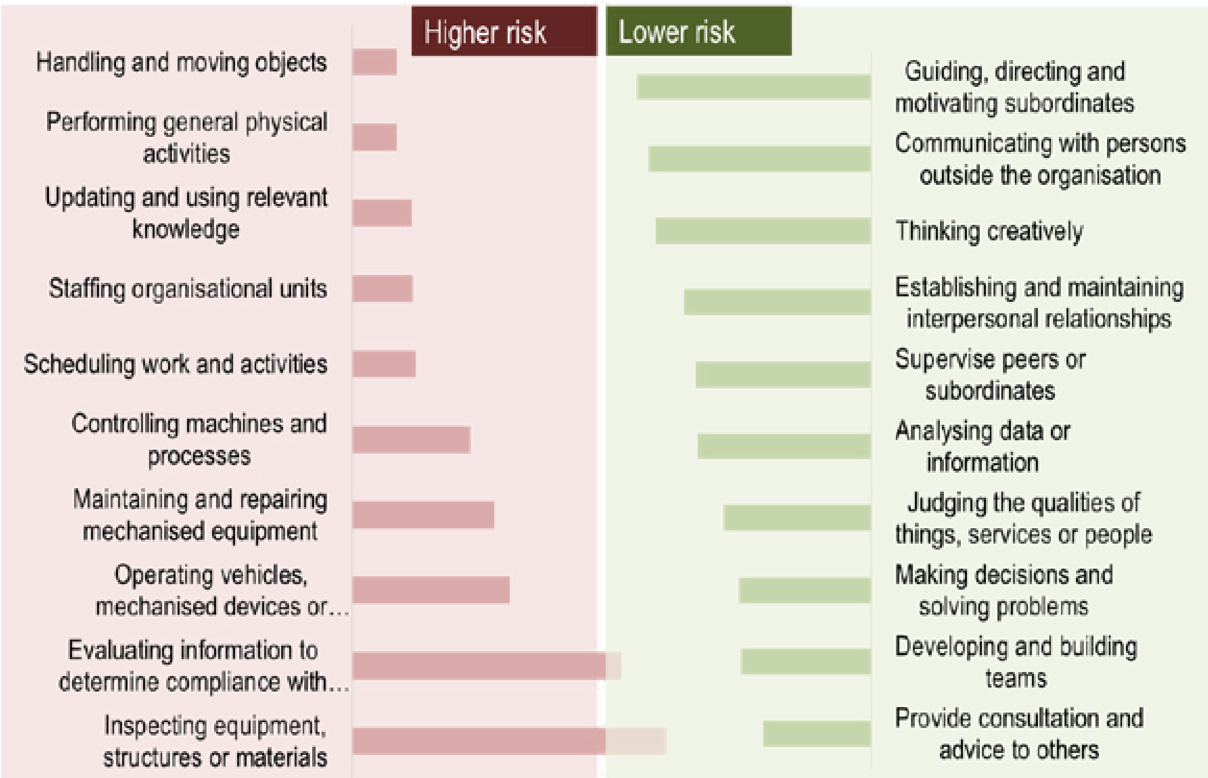
NB: Share of adult workers (aged 25-64) in EU27+NO+IS who replied positively to the following questions: 'Did you use any computing devices (desktop, laptop, notebook, tablet, smartphone) to do the following activity as part of your main job in the last month? Write programs or code using a computer language, for instance C++, Python, Java, Visual Basic etc. including using artificial intelligence methods, for instance machine-learning or deep-learning algorithms'. *Source:* Cedefop's 2nd European skills and jobs survey

> *Work activities that are relatively shielded from replacement by machine learning algorithms include interpersonal skills, managerial skills and problem-solving skills.*

A recent study has sought to overcome skills data challenges by using Cedefop's Skills-OVATE. This is a new EU database, developed by Cedefop in cooperation with Eurostat as part of the European Web Intelligence Hub, that utilises information from millions of online job advertisements (OJAs) posted by employers on thousands of private and public job portals. This new EU-wide big data collection and analysis system contains granular information on skills, work activities and technologies. The study exploits the wealth of job-related information available to identify job tasks that are prone to automation or are associated with the use of digital technologies at work (e.g. computer software, artificial intelligence, robots).

Core work activities susceptible to machine displacement are found to be those that rely on highly codifiable *information recording and retrieval skills* ('inspecting equipment, structures or materials', 'evaluating information to determine compliance with standards', 'updating and using relevant knowledge', 'recording or documenting information') as well as *routine, manual skills* ('operating vehicles, mechanised devices or equipment') (figure 2). Work activities that are relatively shielded from replacement by machine learning algorithms include those dependent on *socioemotional / interpersonal skills* ('coaching and developing others', 'communicating with persons outside the organisation'), *managerial skills* ('supervising peers or subordinates', 'guiding, directing or motivating subordinates', 'training and teaching others', 'judging the qualities of things, services or people') and *problem-solving skills* ('thinking creatively'). Occupations involving work alongside industrial robots are found to be in greater need of workers who can 'inspect equipment, structures or materials' and 'perform general physical activities'.

FIGURE 2. Tasks of eu jobs at high risk of automation



Source: Pouliakas (2021) using Cedefop online job advertisement data (Skills-OVATE)

Crucially, the findings demonstrate that associating AI technologies only with higher automation risk is not correct. Work activities associated with greater occupational automation risk or jobs dependent on robot-human interaction (e.g. 'inspecting equipment', 'performing physical activities'), which are typically concentrated in routine or manual jobs, differ from those prominent in occupations with higher AI exposure (e.g. 'thinking creatively', 'evaluating standards').

Upskilling and reskilling policies to accompany digitalisation

Insight into the skills and job tasks at risk of being displaced by AI and other digital technologies is crucial for shaping preventive upskilling and reskilling policies. Alongside proactive innovation, competition and employment policies, 'robot proof' upskilling and reskilling programmes are needed (Cedefop, 2019). Such efforts should focus on the development of next generation digital and technological literacies, systems thinking, skills related to the four C's (communication, collaboration, creativity and critical thinking) and human-machine interaction.

Increasing awareness of the need to expand the skills of individuals affected by digital technologies has not led however to a large expansion of targeted upskilling and reskilling initiatives in European countries. Few countries have recently adapted their national continuing vocational education and training (CVET) strategies to accompany and shape the digital transformation. Preventive and supportive VET programmes targeting adults who have been displaced by or are at risk of automation are commonly an integral part of such strategies (Table 1).

TABLE 1. examples of cvet programmes to mitigate automation impact

COUNTRY	NAME OF PROGRAMME	AIM
AT	Digi-Winner	Support programmes for qualification and continuous education and training of employed adults in the field of digitalisation. The aim is to develop their digital skills, ensure better job security, find new job opportunities and make better use of the opportunities offered by digital technologies.
DE	Arbeitswelt 4.0 – Fit fur Digitalisierung	Introduces the right to access CVET funding for the employed regardless of qualification, age or company size, if they need it because of automation and digital structural change.
LU	Qualification Opportunities Act	A pilot project aimed at employees whose jobs are changing or are at risk due to the digital transformation. This programme strives to anticipate the impact of technological developments on workers' skills and offers them the opportunity to invest in new business or digital and cross-functional skills.
SK	'Digital Skills Bridge' programme	Establishes, by 2023, a centralised management framework for increasing digital competences of workers and their certification. The aim is to unify labour market requirements and the potential of the workforce. The project foresees retraining and certification of 5000 unemployed or employed workers at risk of dismissal.
UK	'Get employed, be COMPetent'	The scheme aims to support people affected by the changing economy (in particular, automation) to reskill. It is led by a National Retraining Partnership made up by the Department for Education, the Confederation of British Industry and the Trades Union Congress. It targets individuals aged 24 and over, who do not hold a degree level qualification and earn 'low and medium wages' and offers them a 'Get Help to Retrain' digital service. The service helps people understand their current skills, explore alternative occupations and access support from a dedicated advisor.
	National retraining scheme	The scheme aims to support people affected by the changing economy (in particular, automation) to reskill. It is led by a National Retraining Partnership made up by the Department for Education, the Confederation of British Industry and the Trades Union Congress. It targets individuals aged 24 and over, who do not hold a degree level qualification and earn 'low and medium wages' and offers them a 'Get Help to Retrain' digital service. The service helps people understand their current skills, explore alternative occupations and access support from a dedicated advisor.

Source: Cedefop 'VET for the future of work' articles

Towards a new AI-managerial-skills paradigm

In addition to the need to design policies to encourage "formal" CVET that can accommodate the job displacing impact of AI, evidence using Cedefop's ESJS data shows there is a need to strengthen the provision of non-formal and informal continuous upskilling opportunities *within EU workplaces*. These will enable workers to cope with the skill mismatches and changing job-skill requirements linked to the introduction of new digital technologies. As shown by McGuinness et al. (2021), most technological change affecting EU workers implies greater task variety within jobs and drives up- or reskilling needs.

But ensuring that individuals have the skills to leverage AI technologies and harness the opportunities they provide is challenging. Integrating AI effectively in firms' "core business" requires a profound transformation in business and managerial strategy and training and skilling orientation. The high degree of complexity in adopting and implementing AI at technical, organisational and individual level distinguishes it from previous ICT breakthrough waves.

AI adoption entails marked implications for skill demands and human resource management within organisations, but these are poorly understood due to lacking research. Intelligent automation technologies require a new approach to managing employees and can affect within-firm skill requirements. This has an impact on recruiting processes, training (e.g. via the formulation of personalised training plans) and performance management. Changes in the skill composition of organisations (e.g. via replacement of middle-skill or incumbent workers and managers) could be accommodated by expanding AI technologies in organisations. Human-AI collaboration implies significant task and/or job reengineering.

AI adoption requires a broad spectrum of different specialists, roles and know-how for core business use, including an intermediary layer of business analysts. This raises the issue of whether organisations should rely on the skills available in the outside freelancing or platform economy ('buy') as a means of sourcing AI talent or choose to invest in within-firm employee upskilling ('make') (Cedefop, 2020b). Introducing AI also requires widespread upskilling efforts across the board so that every employee gains basic understanding of cognitive AI functions, and learns not only AI-related skills but acquires an AI-compatible interdisciplinary and problem-solving skillset.

> ***Integrating AI effectively in firms' "core business" requires a profound transformation in business and managerial strategy and in firms' skilling policies.***

As AI deployment relies on non-hierarchical and cross-functional collaborative efforts across different organisational layers, work organisation changes are also necessary. Such changes cannot be accommodated without shifting managerial paradigms. Successful AI adoption by organisations requires strategic alignment, manager's own AI domain know-how and commitment by top management to data-driven decision-making. It may also affect the division of decision-making authority between management and staff, as AI could entail greater decentralisation or centralisation of supervisory quality control depending on the task and required skill level.

AI and learning at work

Changes in skill requirements and in managerial and workplace practices induced by AI are likely to have marked implications for the types and extent of workplace or in-work learning in organisations. Innovative research is needed to develop fundamental understanding of the within-firm organisational and workplace dynamics linked to the adoption of cutting-edge AI technologies, as moderators of in-work learning. Better understanding the chain of causal relationships between firms' adoption of AI technologies and the provision / receipt of all forms of in-work learning (including non-formal and informal, structured or unstructured) by their workforce is key. It is also important to obtain more insight into the historical trajectories of firms to understand why firms decide to proceed to AI adoption or not. A critical issue to explore in the future is identifying conditions where AI adoption fosters a supportive in-work learning culture, skill development and job quality without the negative impacts of enhanced and non-transparent algorithmic management.

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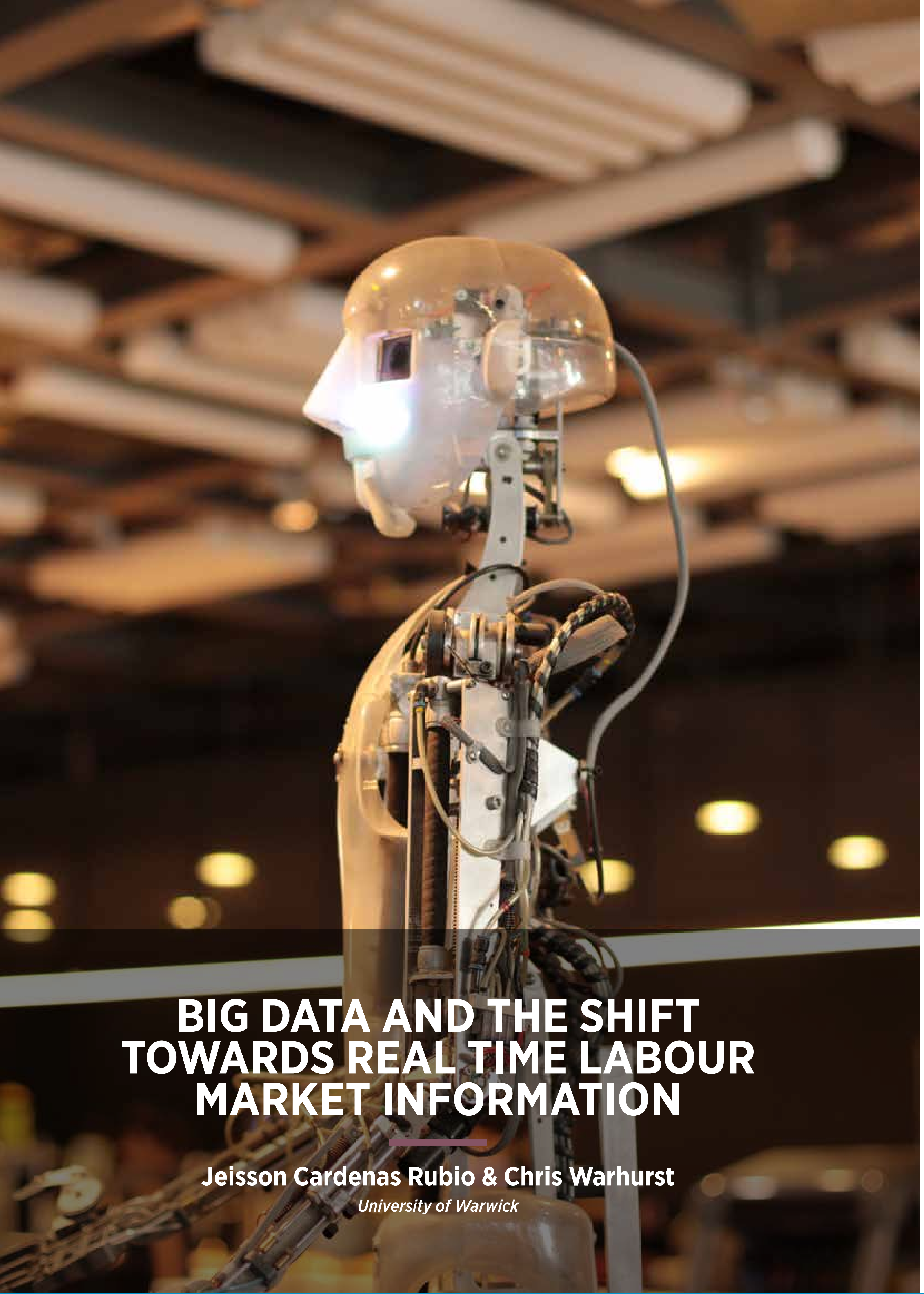
WEB SOURCES

Cedefop's *European skills and jobs survey*, available at: https://www.cedefop.europa.eu/en/projects/european-skills-and-jobs-survey-esjs

Cedefop's *Skills Online Vacancy Analysis Tool for Europe* (Skills-OVATE), available at: https://www.cedefop.europa.eu/en/tools/skills-online-vacancies

Cedefop's *VET for the future of work* thematic perspective articles, available at: https://www.cedefop.europa.eu/en/events-and-projects/projects/digitalisation-and-future-work/vet-future-work



BIG DATA AND THE SHIFT TOWARDS REAL TIME LABOUR MARKET INFORMATION

Jeisson Cardenas Rubio & Chris Warhurst
University of Warwick

The Covid pandemic showed how quickly labour markets can change. As national lockdowns kicked in, almost overnight businesses closed their doors and millions of workers lost their jobs. At the same time, other workers necessary to keep society functioning were in high demand. Governments desperately needed to know what was happening and fast.

In the background to this dynamic and dramatic situation was a debate about an emerging digital age in which artificial intelligence, big data, advanced automation and enhanced computing power might be used to improve business and government efficiency. Well before the pandemic many governments had been facing a squeeze on their public finances, meaning that government statistical offices, including those of the EU and its Member States, were being asked to explore this other development in the hope that that new, real-time data gathering could be achieved and could overcome existing problems with labour market information collection.

Attention has thus focused on online labour market data sources, in particular, collecting freely available web-based job vacancy. It seemingly offers the promise of better information and, with it, better understanding and policy development.

This article examines the case for change to traditional methods of labour market data collection, the benefits but also the challenges in using real time Big Data labour market information.

Traditional labour market information collection

Traditionally, labour market information has been collected through face-to-face, telephone or, more recently, online surveys. Collecting data this way involves statisticians, interviewers and a sample of companies or individuals willing and available to respond. There are three general problems with this data collection method.

First, it is costly in terms of resources and time. Surveys require time for design, validation and data collection, all which can create delay in database creation. When data does become available, statisticians need further time to process and analyse it. During this time the data might become outdated due to socio-economic changes, as the initial Covid crisis illustrated. As Reimsbach-Kounatze points out, many OECD countries only have access to labour supply information several weeks (at best) after the data was collected. Some countries, especially those with small government budgets, are simply discouraged from collecting accurate labour market data.

Second, surveys tend to have a fixed structure with a pre-designed questionnaire that collects information on set topics and which can lack short-term flexibility. The EU's Labour Force Survey (LFS) collects data on unemployment, education and training and income from work. Variables that are beyond this scope are not measured. Adding additional questions, besides being time consuming, increases survey costs and might also affect the structural logic, response rates and results of surveys. The rigidity of current data collection methods can therefore be a problem.

Third, there can be sample constraints. Even if a survey is conducted, a restricted sample size exists, in part again because of cost limitations. The hope always is that this sample is representative. However diminishing response rates with the current LFS means that more effort is required to secure a sufficient size of response to be representativeness. Nevertheless, the size of the database might not be detailed enough to enable disaggregated analysis, for instance, by the skills or occupations in demand by different sectors or regions. Analysis can thus be limited and blunt.

In addition to these general problems, the Covid crisis has raised specific challenges. Most obviously that face-to-face interviews had to be suspended in order to follow social distancing measures. The outcome was that Covid undermined the ability of some countries to collect and disseminate labour market statistics the UN's International Labour Office noted.

Alternative labour market data collection methods are required generally and in order for governments to be able to respond to moments of rapid change and crisis.

The promise of web-based vacancy data scraping

Freely available web-based job vacancy data offers the promise of addressing these problems. Even more so given that fact that this data reflects employer labour demand when supply-side information, usually drawn from individual workers, has been easier to collect in the past. Through posting job adverts, employers provide details of the number of vacancies and these vacancies' characteristics. Using this information has a number of benefits.

The first is the large volume of available data that can be captured. Employers and job seekers have increasingly used the internet to advertise or find job vacancies. By 2007, more than 110 million vacancies and 20 million unique resumes were stored in online US sources alone, according to Maurer and Liu. More recently, Kässi and Lehdonvirta suggest that the volume of online new vacancies grew by around 20% worldwide from 2016 to 2018. Likewise, the number of job seekers looking for jobs online has increased. In the US, the share of people who used the Internet to find a job increased from 26% in 2000 to 54% in 2015 Smith states. These sources of information are publicly available and can be digitally accessed and stored.

Second, this information is real time. Job vacancies are posted as and when employer need arises. Job portals connect employers with job seekers and vice versa and provide a source of immediate labour market information. These job adverts can be viewed by people – workers and, moreover, statisticians and researchers – external to the organisation as soon as they are posted.

Third, job vacancies are relatively inexpensive to post and collect. Accessing and collecting this information does not require an army of researchers. It can be done via the development of algorithms, colloquially called 'web scraping'. These algorithms simulate human web surfing to collect specified parts of job adverts from various websites and store them in a database to be further organised and analysed.

Fourth, postings provide detailed information. Employers typically list education level (by qualification type), types of skills needed, any experience needed, the level of pay and type of contract being offered as well as the occupation title, sector and the locality of the job (or now, as a consequence of the Covid pandemic, if homeworking is available). With this information, it is possible to map occupations onto the most disaggregated level of official occupational classifications such as the classification of European Skills, Competences, Qualifications and Occupations (ESCO) used by the European Commission and which contains nearly 3000 occupations. This fine-grained level of analytical disaggregation is difficult to obtain using other means.

> **"Alternative labour market data collection methods are required generally and in order for governments to be able to respond to moments of rapid change and crisis.**

Fifth, public policy development can be more rapid and responsive. Job vacancy information signals vacancy levels both overall and for specific occupations, sectors and regions. It can also identify changing job and skill requirements, occupational restructuring, and the emergence of new occupations over a relatively short time horizon. Emsi, a labour market analytics company, has started to build a skill taxonomy that incorporates growing demand for relatively new skills, such as 'Cloud computing', and does not need to wait for the ten-yearly updates undertaken by official occupational classifications. This detailed, real-time information creates an opportunity for governments to better monitor the labour market and change policies or guidance more quickly and responsively – or encourage others to act, for example by advising vocational education and training providers which skills workers need to maintain or increase their employability.

Given these benefits, some countries have started to create internet-derived job vacancy databases.

> **"Detailed, real-time information creates an opportunity for governments to better monitor the labour market and change policies or guidance more quickly and responsively – or encourage others to act, for example by advising vocational education and training providers which skills workers need to maintain or increase their employability.**

In the US, the Help Wanted Online data series has been created by the Conference Board. Australia has the Internet Vacancy Index developed by the Government's Department of Education, Employment and Workplace Relations. Both provide measures of labour demand (advertised vacancies) at national, state, regional and occupational levels. In the UK, NESTA now uses online vacancy data to develop a system for supporting job transitions by identifying the occupations at lower/high risk of being replaced by machine learning and artificial intelligence or severely affected by Covid. In the EU, the European Centre for the Development of Vocational Training (Cedefop) works with Eurostat and DG Employment to collect data on skills demand using online job portals. With this information, Cedefop monitors skills and other job requirements at an occupation level and can identify emerging skills and jobs in Europe to advise training providers on new curricula needs.

Problems with current vacancy data scraping

Despite the benefits of this type of Big Data, limitations also exist. The quality and interpretability of the data depends on what is posted, its availability and the methods used to collect and standardise the information.

First, in terms of data quality, it needs to be borne in mind that job portal information is not produced for the purpose of labour market analysis and employers do not follow a specific format when they advertise vacancies. Companies use their own language when describing jobs and required skills. As a consequence, different terms can be used to describe the same jobs. Employers also decide the extent of information to include and online vacancy data has a high level of missing values. For instance, employers might list the pay offered for low-skilled jobs but not high-skilled jobs. Such omissions can create biased analysis.

Second, what is posted might not always represent real jobs. As Emsi note, companies might post more job advertisements than available positions in order to receive more applications, and then hire the candidates who best fit their requirements. Alternatively some organisations, such as recruitment agencies, might advertise vacancies to collect resumes and store them. These organisations can then quickly start the applicant screening process when there is a job opening. Such practices create uncertainty about the exact number of real vacancies in any given period.

Third and relatedly, duplication can occur, of which there are two types. The first refers to a situation in which companies advertise the same job in the same job portal more than once. The second occurs when employers advertise the same vacancy on more than one website. Duplication can be a real problem in calculating the actual number of job vacancies. Data collection then over-estimates the number of job vacancies and any statistical inference can again be biased.

Even if the job vacancies represent real jobs, there is a fourth issue about the representativeness of data. Not every company posts job vacancies and some jobs are less likely to be advertised online. As Cardenas discovered, some sectors in some countries tend not to use online advertising – the agricultural sector in Colombia for instance.

Similarly, companies recognise that workers with low skills tend not to use the Internet in their job search. Instead, these workers are often recruited informally, through word of mouth for example. As a consequence, for some labour market segments it is not possible to make any statistical inference.

Finally and ironically, data availability can be a problem. Online job vacancy advertisements belong to job portals or to other platforms where employers have decided to make their vacancies public. The availability of information can sometimes change if changes occur to the portal or platform. Job portals can, for example, suddenly and unexpectedly change the kind of job characteristics listed on their websites such as pay or contract type. In addition, job portals can restrict the use of vacancy information. In most cases, job portals prohibit the storage and the usage of job adverts for commercial purposes. There is no legal requirement for these restrictions, for example to protect individuals' privacy. Restrictions tend to occur in order to prevent other companies financially exploiting the data.

> ***The emergence of a digital age has opened up the possibility of using freely available, real-time Big Data. In this respect, there is huge added value to be gained by web scraping job vacancy postings, potentially offering cheaper, more efficient data collection and providing more detailed information.***

Fifth and linked to the previous point, the usefulness of job portal information and, hence, its representativeness depends on internet penetration rate (the percentage of the total population that uses the internet). Although Internet usage has increased, this growth is not evenly spread by sector and region. In regions where internet access is low or has slow growth, the inferences that can be drawn from job portal information are limited.

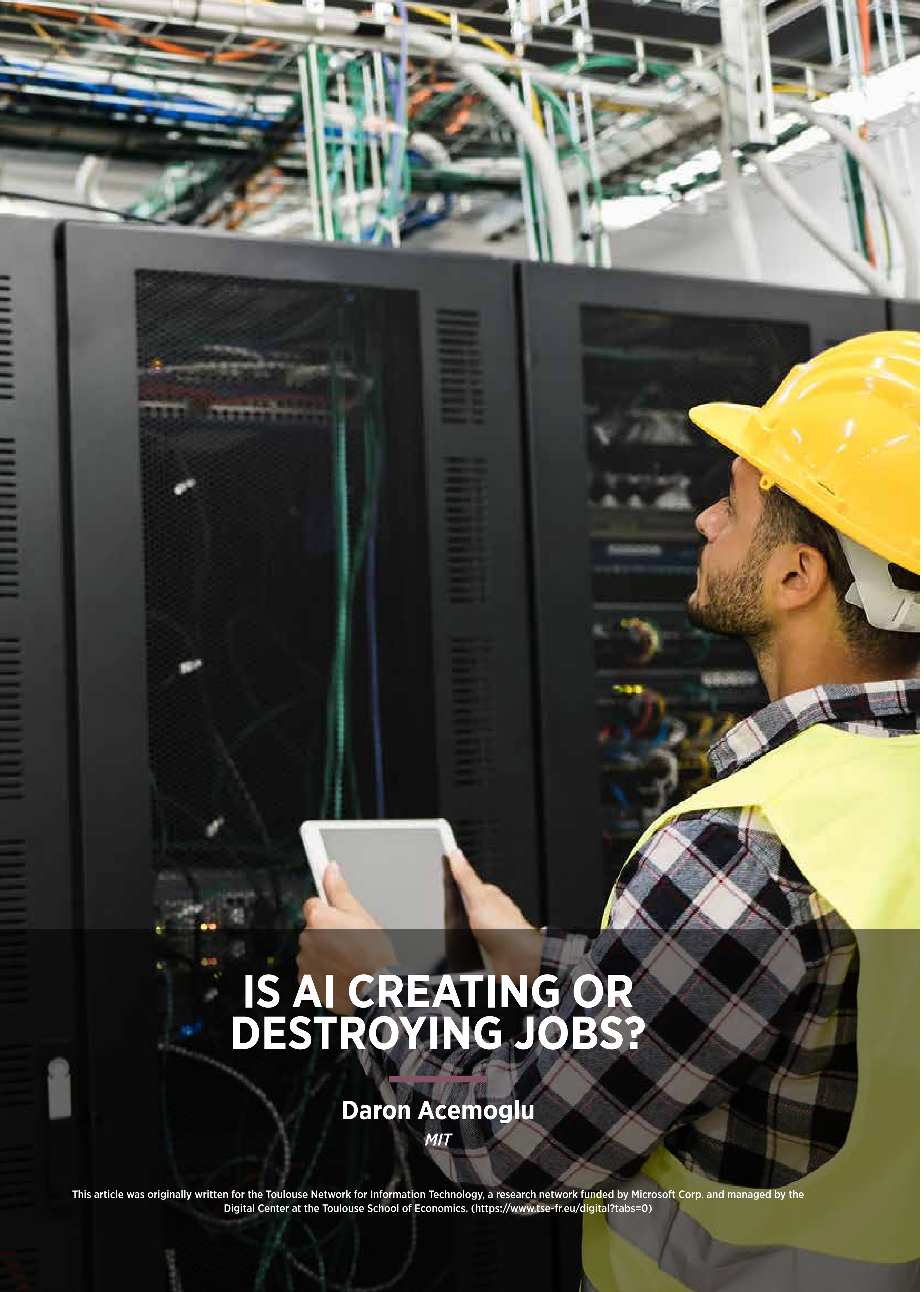
Conclusion

Governments want and need better labour market information from which to develop policy. Traditional methods of labour market data collection have problems and the Covid pandemic has compounded these problems. The emergence of a digital age has opened up the possibility of using freely available, real-time Big Data. In this respect, there is huge added value to be gained by web scraping job vacancy postings, potentially offering cheaper, more efficient data collection and providing more detailed information.

However web scraping job vacancy data is not without its own problems. The promise of bigger and better data still remains but, at present, too much 'dirty' data is being generated as a result of these problems. In particular, data representativeness is a crucial issue. It determines whether it is possible to better understand developments in the labour market and make better policy.

To maximise the benefits, more work on web scraping of vacancy data is needed. With funding from the UK Government's Department for Education, Warwick Institute for Employment Research is currently tackling these problems. It is developing and testing a new framework for collecting and analysing vacancy data from job portals that will provide more accurate data collection and interpretation. Its purpose is to support government policy development, not provide commercial gain. It is part of a wider public service project aiming to improve labour market information for all.[1] Delivery of this new framework will help the promise of Big Data be realised and enhance current labour market analysis.

1 https://warwick.ac.uk/fac/soc/ier/research/lmi_for_all/



IS AI CREATING OR DESTROYING JOBS?

Daron Acemoglu
MIT

This article was originally written for the Toulouse Network for Information Technology, a research network funded by Microsoft Corp. and managed by the Digital Center at the Toulouse School of Economics. (https://www.tse-fr.eu/digital?tabs=0)

Artificial intelligence (AI) is one of the most promising technologies currently being developed and deployed. There is a lot of excitement, some hype, and a fair bit of apprehension about what AI will mean for our security, society, and economy. Central to many of the debates is whether AI is creating or destroying jobs. Despite the huge and growing interest in this question, we know relatively little about the answers.

Some commentators are convinced that AI is the harbinger of a jobless future (e.g., Ford, 2015; West, 2018; Susskind, 2020). Yet others are equally adamant that AI will enrich work experiences and increase human productivity, contributing rather than detracting from job growth (e.g., McKinsey Global Institute, 2017). These contrasting visions persist in part because there is very little evidence on what AI is doing to work and workers. There are currently no representative data sets of AI, so we lack representative evidence on whether there has been a major increase in AI adoption (as opposed to just talk of AI). It is possible to find examples of AI technologies either replacing work or complementing workers, precisely because AI, as a broad technological platform, is capable of doing both. The level of job displacement that AI will create is thus partly a matter of societal and business choice (Acemoglu and Restrepo, 2019).

Tracking the rise of AI activity

In recent work, "AI and Jobs: Evidence from Online Vacancies", David Autor, Jonathon Hazel, Pascual Restrepo and I have studied AI adoption in the US and its labor market implications. AI adoption can be partially identified from the footprint it leaves at adopting establishments as they hire workers specializing in AI-related activities, such as supervised and unsupervised learning, natural language processing, machine translation, or image recognition. To put this idea into practice, we built an establishment-level data set of AI activity based on the near-universe of US online job vacancy postings from Burning Glass Technologies for the years 2007 and 2010 through 2018. This data set, which has been used in several recent papers, contains detailed information on occupations and the skills required for each posted vacancy.

> *"There are still relatively few vacancies in core AI areas, such as machine learning and natural language processing, though the rate of growth since 2015-2016 has been staggering.*

We then linked the adoption of AI and its possible implications to the task structure of an establishment. Put simply, the idea is to look for a set of "AI-suitable" tasks, which may be targeted by AI applications, then investigate whether establishments with a high fraction of such tasks are more likely to show rapid AI adoption, as measured by the hiring of AI workers. There is no consensus on which tasks are AI- suitable. Nevertheless, a number of recent studies have started developing systematic ways of measuring which tasks can be performed or augmented by current AI technologies.

For example, Felten, Raj and Seamans (2018) construct an index of the effect of AI on various occupations, meant to capture both the ability of AI algorithms to substitute for humans and their complementarity to humans. They build on experts' assessments of areas in which AI has made important advances then map these areas to the set of tasks performed by different occupations. Alternatively, Brynjolfsson, Mitchell and Rock (2018) build a measure of the suitability of an occupation's task to be performed by machine learning. Webb (2000), on the other hand, uses natural language processing on the text of patents to map them to specific tasks performed within various occupations. Each of these measures captures a different aspect of AI suitability (and we show they are quite distinct). There is information in each of them and our work uses all three of them.

The data paint a clear picture about AI activity, regardless of which specific measure one looks at. There is a notable takeoff in AI vacancy postings starting in 2010, but these postings remain very low until around 2015-2016, then undergo an inflection, trending up strongly thereafter. There are still relatively few vacancies in core AI areas (such as machine learning, natural language processing, etc.), though the rate of growth since 2015-2016 has been staggering.

We also find that AI-adopting establishments start demanding different skills than before, and in fact there is some evidence of increased "skills churn" associated with AI. This bolsters the case that there are significant changes in the organization of production and thus the skills demanded by businesses at the forefront of AI adoption.

> *The fact that AI is a broad technological platform suggests there are important decisions for both corporations and public policymakers. What type of AI do we want? Can we create more jobs than we destroy?*

Where does this growth come from?

We show that there is a strong association between the baseline task structure of an establishment and AI activity. This relationship is present with all of the measures mentioned above. As important, it remains even when we focus on establishments within a narrow industry or, more notably, when we compare two establishments belonging to the same multi-establishment firm that still differ in terms of their baseline task structure. This is evidence that AI adoption is being at least partially targeted to a specific set of AI-suitable tasks. This correlation, however, does not answer the key question we started with...

Is AI creating or destroying jobs?

The answer seems to be: Mostly, it's too soon to tell. Despite a remarkable takeoff, there is still very little AI activity at the moment, and AI-impacted job changes may be a small drop in a big bucket. The number of AI-suitable tasks may grow and lead to the hiring of more workers than before because of the rollout of AI technologies. Or, conversely, the workers who previously performed these tasks may be replaced by AI algorithms.

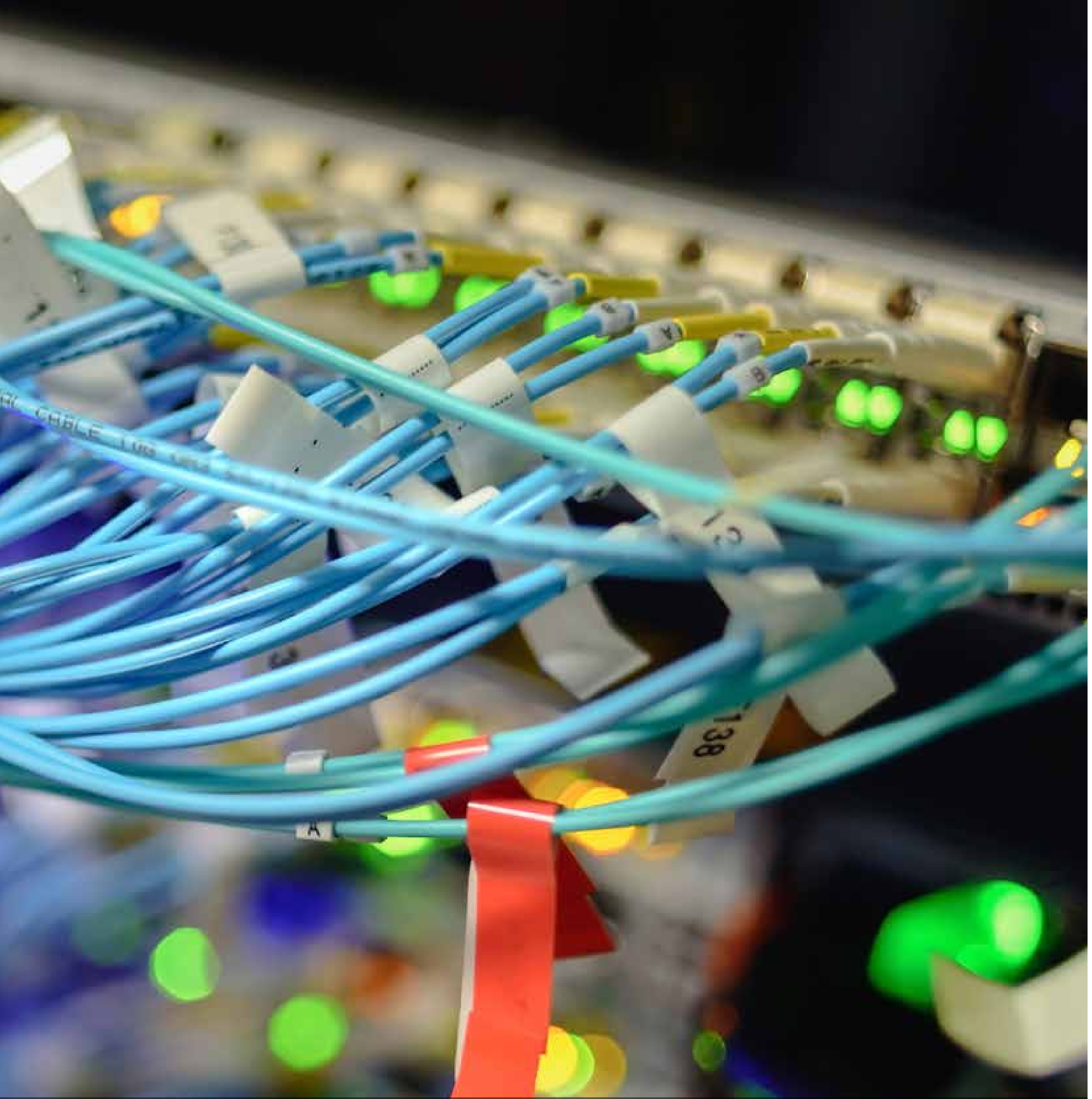
Nevertheless, we see some evidence of fewer vacancies for non-AI positions in the more heavily impacted establishments (those with a high fraction of AI-suitable tasks). For example, establishments with a high share of AI-suitable tasks in 2010 subsequently show significantly slower growth in vacancies. Yet, confirming our conclusion that AI activity is still too small, this establishment-level result does not translate into slower growth in the more AI-exposed occupations or industries.

So where do we go from here?

The evidence we gathered – coupled with advances in machine learning, big data and other areas of AI – suggests that the rapid takeoff in AI activity will continue in the years to come. This may imply more displacement (similar to the negative hiring effects we may be seeing already at some establishments), but AI is a broad technological platform and can be used in many different ways. The fact that early AI is targeted to specific tasks does not mean that, as the technology matures, it will not have other applications. There is already evidence that AI technologies are being used for new product development and reorganization (Bresnahan, 2019), and these uses may intensify in the years to come.

The fact that AI is a broad technological platform also suggests that there are important decisions for both corporations and public policymakers. What type of AI do we want? If AI can create and destroy jobs at the same time, can we make sure that we create more jobs than we destroy?

We sometimes hear a narrative suggesting that there is a clear path of future technology. For AI, a broad technological platform with many applications, this may be particularly untrue. The disagreement about the effects of AI for workers is rooted in the fact that AI can destroy as well as create jobs. But this also implies there is a lot of room for public policy and corporate strategies in shepherding AI in a direction that is more beneficial for society.



UNLESS THE EU CHANGES ITS COURSE, ITS APPROACH TO AI WILL ULTIMATELY HURT US ALL

Elmārs Kehris
Economist, PhD candidate, Riga Technical University

Artificial Intelligence is one of the most important technologies that is shaping our century. From safer vehicles and more accurate weather forecasts to modernised medicine and education, the benefits for the society and economy are noticeable and expanding. The potential and significance of AI are understood by tech companies as well as nation-states, with China and the United States being at the forefront of the race.

To date, the European Union is choosing a different regulatory path — one that all but ensures that the region will likely be behind in AI innovation and technological development. These legal extensions will reduce tech-sector productivity and job creation, therefore reducing the overall economic growth of the EU.

To understand the EU's stance towards AI, we need to look no further than the legislative and other proposals by the European institutions.

The Commission's white paper on AI,[1] communicated in early 2020, already outlined the priorities of the "Union that strives for more." The rhetoric about the need to promote "excellence" and "leadership", the paper hardly included any tangible vision for the Union to even attempt to catch up with the rivals in the field of AI. Instead, regulation to promote "human-centric" AI is touted as the solution. As the Financial Times commentator correctly summarised the Commission's outdated take on AI: there is "fear of a high-tech digital future; the need to protect oneself against it; and the complacency inherent in the belief that regulation is the solution."[2]

The following Artificial Intelligence Act,[3] proposed by the Commission earlier in 2021, goes down the same route. Prior to the Act's announcement, a number of Eastern, Northern and Southern EU countries[4] in their position paper on AI stressed the need to creative incentives for companies through a soft-law approach to AI regulation.[5] Yet, the European Parliament, fuelled by demands of privacy and other lobby groups which have publicly voiced their strong criticism, will likely argue for even more safeguards and limits to deployment of AI systems.

> ***Whilst the Commission's classification of AI according to risk levels is a reasonable approach, the overall emphasis on preventing any possible risk will inevitably further stifle what little innovation and growth in the field there is.***

Whilst the Commission's classification of AI according to risk levels is a reasonable approach, the overall emphasis on preventing any possible risk will inevitably further stifle what little innovation and growth in the field there is. The high compliance costs and paperwork will predominately hit homegrown startups and SMEs, not the foreign tech giants. Meanwhile, private investment will be further alienated.

According to the European Investment Bank additional EUR 10 billion annually are needed to keep the EU in the global AI and blockchain race.[6]

1 European Commission (2020) WHITE PAPER On Artificial Intelligence - A European approach to excellence and trust, European Commission February 19. Available at: https://ec.europa.eu/info/sites/default/files/commission-white-paper-artificial-intelligence-feb2020_en.pdf

2 Munchau, W. (2020) Europe is still in thrall to the analogue mindset, Financial Times. February 23. Available at: https://www.ft.com/content/0f62fd52-54a8-11ea-8841-482eed0038b1

3 European Commission (2021) Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL LAYING DOWN HARMONISED RULES ON ARTIFICIAL INTELLIGENCE (ARTIFICIAL INTELLIGENCE ACT) AND AMENDING CERTAIN UNION LEGISLATIVE ACTS. April 21. Available at: https://eur-lex.europa.eu/resource.html?uri=cellar:e0649735-a372-11eb-9585-01aa75ed71a1.0001.02/DOC_1&format=PDF

4 Denmark, Belgium, the Czech Republic, Finland, France, Estonia, Ireland, Latvia, Luxembourg, the Netherlands, Poland, Portugal, Spain and Sweden

5 Innovative and Trustworthy AI: Two Sides of the Same Coin: Position paper on behalf of Denmark, Belgium, the Czech Republic, Finland, France, Estonia, Ireland, Latvia, Luxembourg, the Netherlands, Poland, Portugal, Spain and Sweden (2020). Available at: https://em.dk/media/13914/non-paper-innovative-and-trustworthy-ai-two-side-of-the-same-coin.pdf

6 EIB (2021) New EIB report: €10 billion investment gap in artificial intelligence and blockchain technologies is holding back the European Union. June 1.

Even though the EU has adopted its most ambitious multi-year budget, combined with a recovery package, worth over EUR 1.8 trillion, Digital Europe programme allocates a little over EUR 2 billion to AI. Horizon Europe — EUR 15.3 billion that will be devoted to "digital, industry and space" (Cluster 4). Much less of that will trickle down for AI research and development and even so will be divided between 27 countries. In fact, the Commission is already managing expectations and officially notes that through the above two programmes "at least" EUR 1 billion per year should be invested in AI.[7]

Yet even with limited financial resources, the EU could do more in areas related to human capital in which it is considered to be performing well such as the promotion of higher education. There are currently fewer undergraduate AI study programmes in the whole of the EU than in the UK alone. Yet the AI is scarcely mentioned in either the Commission's much prioritised European Education Area or in the Digital Education Action Plan.

Artificial intelligence should not be seen as just another race that the EU must be in. The region must consider the advantages that its companies and societies could gain by embracing the technology.

Within the context of the technical unemployment due to AI applications, there is a high-risk that low-skilled people could become segregated due to the rapid technological developments of the fourth industrial revolution. The shift has accelerated the need for upskilling and reskilling as well as redeployment at a global scale. Around half of employees will require reskilling and 40% of workers' core skills are expected to change in the next 5 years[8]. The ILO estimates that 50% of work related duties could be automated.[9] The EU has to expand its AI, human capital and technical education programmes as without proper skillset and modernised tech-sectors our digital economies are at risk of being controlled by foreign technologies.

AI is vital in the region which is ageing rapidly and for the economies that are increasingly characterised by low productivity and slow economic growth. Mechanical automation that helped improve living standards throughout the 20th Century has reached its limits. AI, through its many applications in multiple industries, has shown tremendous breakthroughs which could increase industrial competitiveness, living standards and the overall economic growth. It is for these reasons why the EU must embrace, not stifle the technology.

The EU can and must be willing to innovate more rapidly. AI innovation and adoption must be embraced to full extent. The risks, even though limited and mostly unfounded, will inevitably be sorted out in the longer term, primarily by the industry and companies themselves. The benefits, however, are measurable and growing. In fact, the single biggest AI-related risk facing the EU is too little of the technology which will also indirectly result in the region being shaped by applications developed elsewhere. It is high time we change that and let the AI do its work.

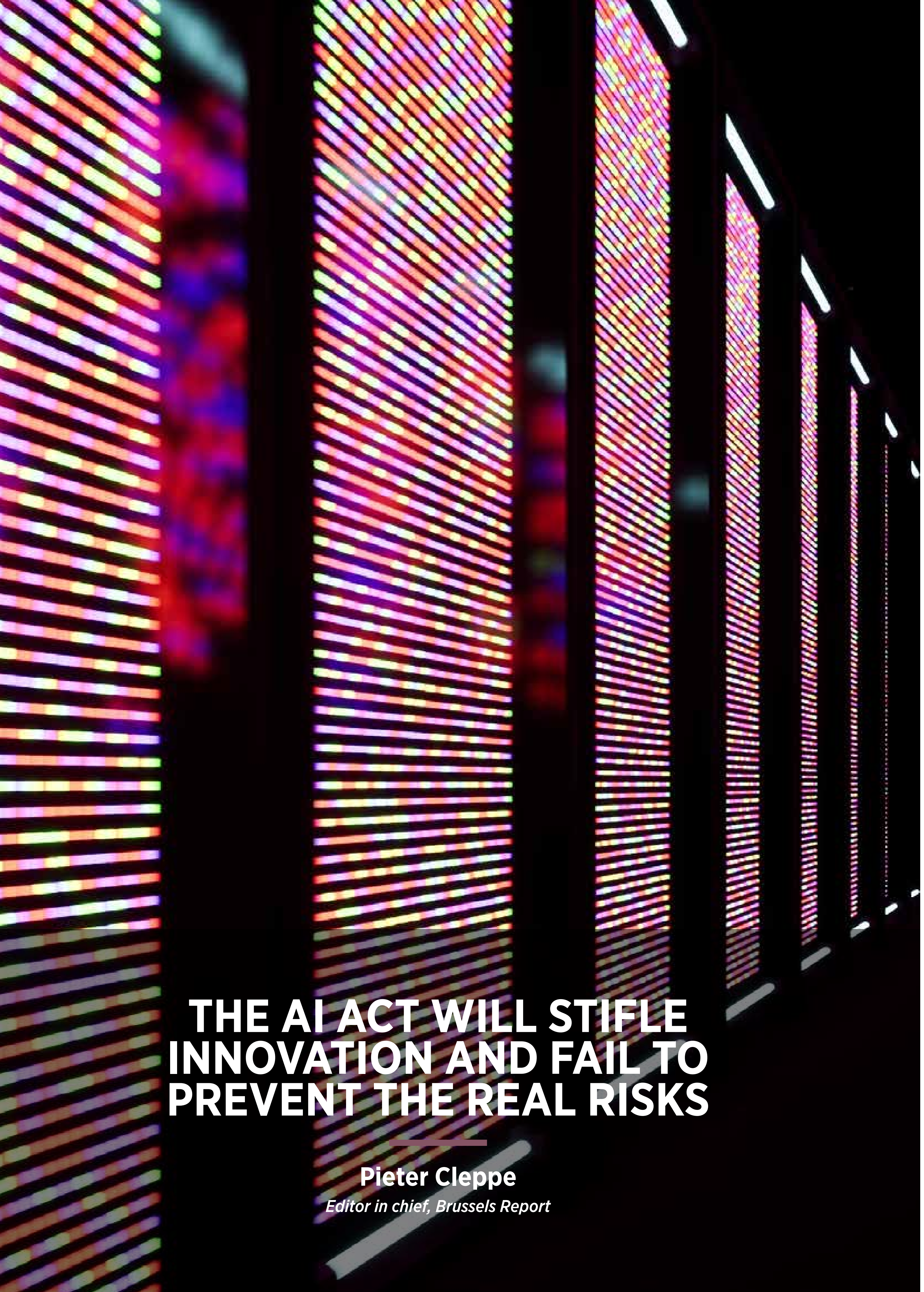
> ***"Mechanical automation that helped improve living standards throughout the 20th Century has reached its limits. AI, through its many applications in multiple industries, has shown tremendous breakthroughs which could increase industrial competitiveness, living standards and the overall economic growth.***

Available at: https://www.eib.org/en/press/all/2021-181-new-eib-report-eur10-billion-investment-gap-in-artificial-intelligence-and-blockchain-technologies-is-holding-back-the-european-union

7 European Commission (2021) ANNEXES to the Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, Fostering a European approach to Artificial Intelligence, COM(2021) 205 final, April 21. Available at: https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=75787

8 The World Economic Forum, "Building a Common Language for Skills at Work: A Global Taxonomy," 2021. Accessed: Jun. 01, 2021. [Online]. Available: http://www3.weforum.org/docs/WEF_Skills_Taxonomy_2021.pdf

9 International Labour Organization (2019) Work for a brighter future: Global Comission on the future of work. January 22. Available at: https://www.ilo.org/wcmsp5/groups/public/---dgreports/---cabinet/documents/publication/wcms_662410.pdf



THE AI ACT WILL STIFLE INNOVATION AND FAIL TO PREVENT THE REAL RISKS

Pieter Cleppe
Editor in chief, Brussels Report

According to study by the Information Technology and Innovation Foundation, the European Union is lagging the United States and China when it comes to the development and use of "artificial intelligence", which can be loosely translated as "machine learning", or perhaps "advanced automation". The most futuristic prospect here is "artificial general intelligence (AGI)", described as "the hypothetical ability of an intelligent agent to understand or learn any intellectual task that a human being can undertake".

The study comparing the EU with the U.S. and China comes to its conclusion after having taken into account 30 separate metrics, including human talent, research activity, commercial development and investment in hardware and software. Whereas the U.S. is leading overall, as well as in key areas such as investment in startups and research and development funding, China is leading when it comes to the number of "supercomputers", as it has 500 of them, which is more than the 113 based in the States and the 91 in the EU.

It notes that "the United States has maintained or expanded its lead over the European Union in nearly 75 percent of the updated metrics." A key problem for the EU here is access to venture capital and private equity funding, even if the EU was doing better when it comes to the number of research papers published. Still, "China has surpassed the EU as the world leader in AI publications".

The leading author of the report, Daniel Castro, commented that "The Chinese government has made AI a top priority and the results are showing".

For a number of years now, "AI" has been grabbing the attention. In 2017, already five years ago, Russian President Vladimir Putin claimed that whoever reaches a breakthrough in developing artificial intelligence will come to dominate the world, as it raises "colossal opportunities and threats that are difficult to predict now." He thereby predicted that future wars would be fought by drones, and "when one party's drones are destroyed by drones of another, it will have no other choice but to surrender." Commenting on this, Tesla founder Elon Musk tweeted that "China, Russia [will] soon all [be] countries with strong computer science. Competition for AI superiority at [the] national level [will] most likely [be the] cause of World War III, in my opinion." Unsurprisingly, China is also very active when it comes to AI applications for defense, as in 2020, nearly 350 artificial intelligence-related equipment contracts were awarded by the People's Liberation Army and state-owned defense enterprises.

In sum, Artificial Intelligence is likely to have both great economic but also great geostrategic consequences. It's not a pretty sight to witness the European Union and its member states falling behind.

> *"Artificial Intelligence is likely to have both great economic but also great geostrategic consequences. It's not a pretty sight to witness the European Union and its member states falling behind.*

How is the EU tackling AI?

Again according to the report, "the biggest challenge for the EU and member states is that many in Europe do not trust AI and see it as technology to be feared and constrained, rather than welcomed and promoted."

To illustrate this, it recalls how the 2020 European Commission's white paper on AI, which provides a roadmap for its anticipated legislation, highlights these fears about AI citing "potential risks, such as opaque decision-making, gender-based or other kinds of discrimination, intrusion in our private lives or being used for criminal purposes."

The same distrust is at the root of the EU's infamous General Data Protection Regulation (GDPR), which also limits the collection and use of data that can foster developments in AI. In March, German CDU MEP Axel Voss criticized this piece of EU legislation, arguing that "Europe's obsession with data protection is getting in the way of digital innovation" as "[GDPR] implementation has been a huge headache for the average business, organization and citizen. But most importantly, the GDPR is seriously hampering the EU's capacity to develop new technology and desperately needed digital solutions, for instance in the realm of e-governance and health." He added: "Many of the important technologies of the future — such as artificial intelligence, blockchain or single sign-on solutions — were already widely known in 2016, when the GDPR was finalized. And yet, provisions in the legislation — which many argue was supposed to be

The Commission's proposal foresees a ban on AI applications that are considered to have unacceptable risks, including Chinese-style "social scoring". Slovenia's EU Council Presidency has pushed to extend this from public authorities to private entities, while also extending the definition of prohibited use to include exploiting a "social or economic situation." This means that banks would for example not be able to use such arrangements to assess the likelihood of loans being repaid.

Furthermore, biometric identification systems are also being regulated by the EU's AI Act, even if these are already used in at least 11 EU member states. The idea is to only permit them for certain purposes, like protecting critical infrastructure, and to only allow them to be used subject to the prior approval of judicial authorities, or ex post, in cases of urgency, while also restricting their use to law enforcement or their collaborators.

> ***Wherever one stands on AI, it seems very complex to get it right, as even well-intended regulation mindful of not throwing up unnecessary hurdles for innovation may easily end up tolerating loopholes for actual risks to materialise.***

"technology neutral" — make it impossible to properly use or even develop them."

At the moment, the EU's so-called AI Act is going through the EU regulatory machine. The latest version submitted by the rotating EU Council Presidency foresees to take out provisions related to AI systems developed exclusively for military purposes from the scope of the regulation, given how national security is an exclusive national competence. It also pushes to exempt AI systems developed for the sole purpose of scientific research and development.

The EU's planned regulation also includes a classification of AI-related activities that are considered to be either "Unacceptable risk", "High-risk", "Limited Risk" or "Minimal Risk", whereby each category also comes with corresponding regulatory obligations. The use of AI systems to estimate insurance premiums, is for example classified as "High-risk". EU member states are tinkering with this, for example by removing the subcategory of crime analytics from the "High-risk" category. Last but not least, the European Parliament is likely to toughen up all of this.

Question marks surrounding the EU's approach

Despite EU leaders discussing the excessive administrative burden for SMEs at the October Summit, thereby calling for 'innovation friendliness' in digital policy, not everyone seems convinced that the EU is already there, to put it mildly.

In an assessment of the EU's proposed AI act, Jared Brown, director of US and international policy at the Boston-based Future of Life Institute, argues that there are potential loopholes in the EU's AI Act, as it regulates or outright bans specific uses of AI, but doesn't dig deeper into the foundation models underlying these applications. According to him, if a foundation model does not have a declared intended purpose, it could avoid being covered by the act.

One example is that if "the act would for example ban "social scoring" AI applications, or those that "exploit the vulnerabilities of specific group of persons", such activities may still escape a ban, given that foundation models – termed "general purpose AI systems" by the act – "have many different uses, so one bias or flaw in the system could affect different sectors of society" according to Brown. He provides the example of an anti-Muslim bias, which "could affect media articles, educational materials, chatbots, and other uses of this system that will likely be discovered in the near future."

Foundation models are acknowledged in the amendments to the act proposed by the Slovenian Council presidency, but will not automatically be covered by the act. They will only be covered by the act if the "intended purpose" falls within its scope. This is contrast to the U.S. regulatory treatment of AI, according to the Future of Life Institute.

A consequence of this is also that the burden of regulation would be shifted away from the big US and Chinese tech giants who own foundation models, and on to the European SMEs and startups that use the models to create AI applications, something which "could harm the relative competitiveness of the European tech sector" according to Brown, in an interview with Science Business. He would prefer to see EU regulation of AI focusing on the general qualities of the entire AI system, like whether or not it is biased, or whether it can tell a user it isn't that sure of its answer.

Another AI expert, Stanford University researcher Sébastien Krier, agrees with this, take, arguing that "If you've got a bad foundation model [...] everything downstream will be bad too", adding that he considers foundation models to be essentially "centralising" AI, thereby making it potentially more vulnerable, through data poisoning, for example, as "you have one point of attack".

One conclusion from all of this seems clear: wherever one stands on AI, it seems very complex to get it right, as even well-intended regulation mindful of not throwing up unnecessary hurdles for innovation may easily end up tolerating loopholes for actual risks to materialise.

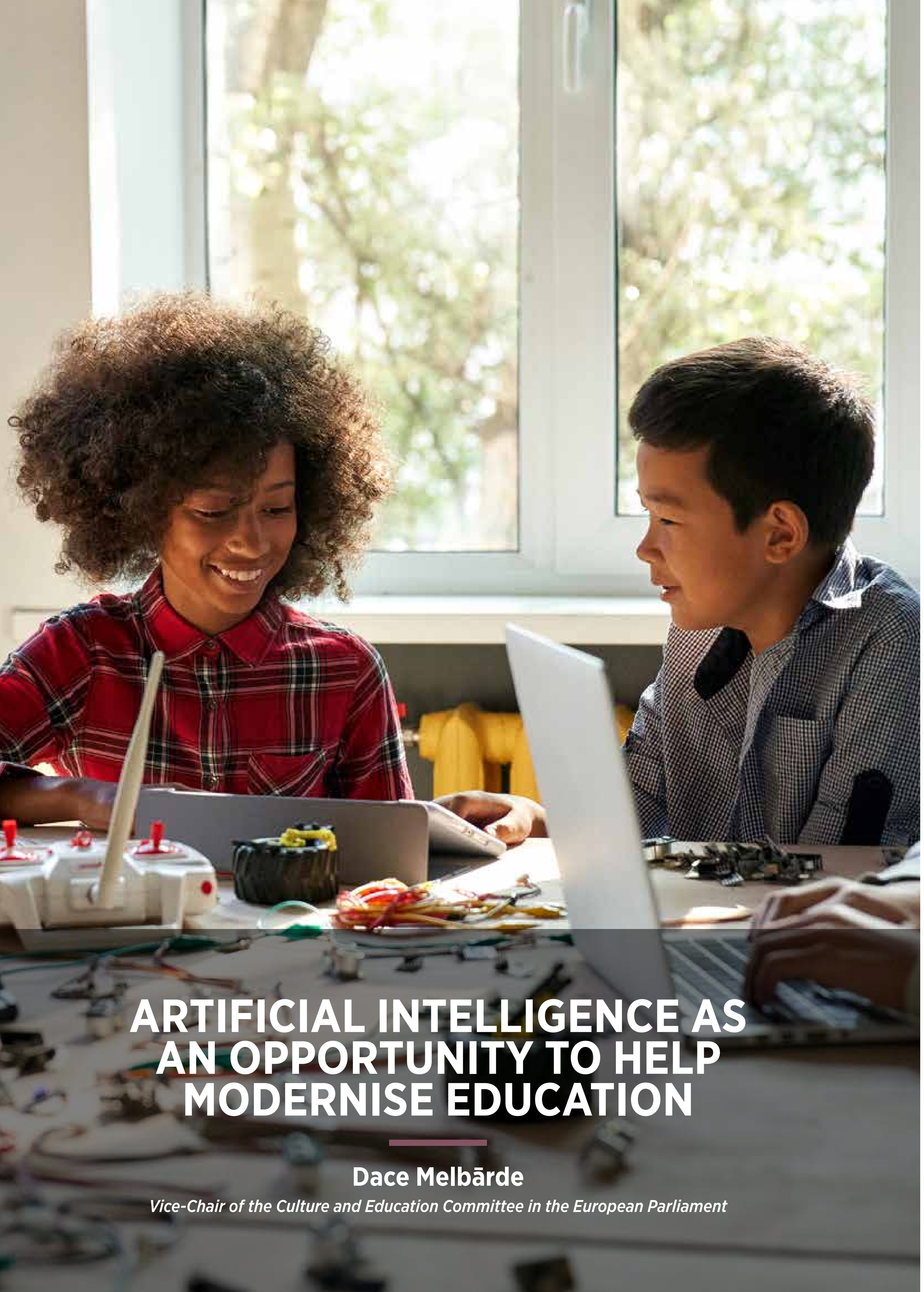
Brussels types tend to play up the importance of the so-called "Brussels effect", which involves the EU being able to set out regulations that are taken over by much of the rest of the world, due to the EU's market size. This is what's recalled in a 2020 Carnegie paper on "Europe and AI", as it notes that "Central to the EU's efforts is the notion of AI that is "made in Europe," that pays attention to ethical and human-centric considerations, and that is in line with core human rights values and democratic principles."

At least judging from what U.S. academic critics are saying, the EU's regulatory approach is inspired by a fear of the technological development, while it may fail to tackle the actual risks resulting from AI.

In fairness, given the great uncertainty about how this technology will evolve, it's better to reserve judgement for now.

In any case, the Carnegie researchers make a great suggestion that will enable for the EU to get it right however its regulatory treatment of AI packs out in the end. They write that for its AI ecosystem to thrive, the EU "needs to catch up on digitizing its economies and complete the establishment of the digital single market once and for all."

If there is a scarce positive outcome from the Covid crisis, it may be that many Europeans have become more comfortable with the digital world. In a way, this is a massive opportunity. A priority for the EU and its Member States should therefore now be to embark on a large-scale programme to first detail the many regulatory hurdles for digital businesses within the EU and to then scrap them one by one, ideally not by harmonizing at the EU level but by member states simply mutually recognising each other's regulations. Given how difficult it is to get regulation of AI right, that may be the most useful thing to do at this very moment. It may also be the necessary thing to do right now, for there to be a thriving AI industry in the EU.



ARTIFICIAL INTELLIGENCE AS AN OPPORTUNITY TO HELP MODERNISE EDUCATION

Dace Melbārde

Vice-Chair of the Culture and Education Committee in the European Parliament

Education is key for personal growth and fundamental for informed societies. It is also one of the most important investments for both individuals and countries. In a World Bank study that draws from 1,120 estimates in 139 countries, authors George Psacharopoulos and Harry Antony Patrinos show that the private average global rate of return remains high and stable over the decades, with one extra year of schooling constituting 9 percent. Even though AI robots are not arriving imminently to take over a large portion of the existing jobs, the future is far from certain. Good and continuous education is therefore more important than ever.

In order to stay relevant, education needs to change with the time. The Covid-19 pandemic and the related school closures have highlighted the inability of schools to ensure quality distance and online learning. Yet even before the pandemic the situation was far from perfect, with education systems failing to embrace change to the detriment of not only the students, but also teachers. AI-enabled solutions are well placed to improve both teaching and learning.

Individualised and differentiated learning are one the major examples where AI can play an increased role. Meeting the needs of each student's pace as well as approach to learning is difficult, if not impossible, especially in a classroom of 30 or even more students. AI systems can target each student's strengthens and weaknesses and so not only help improve the outcomes, but also learning as a process. Among other applications, Edtech (education technology) companies are deploying AI to provide tailored feedback to students, track progress achieved and identify each student's knowledge gaps and areas of strength as well as to increase learner engagement. AI has even been successfully used to lower high school dropout rates.

Teachers, too, can benefit from innovative solutions in education. News articles and studies about high stress levels, long working hours, burnout, mental problems and, as a consequence, increasing share of teachers considering leaving the profession were not hard to come across even before the Covid-19 outbreak. The associated lockdowns have become a tipping point for many professionals. Unfortunately, it is not only teachers that suffer the consequences. An education scholar quoted by the *New York Times* sums the situation well: "If we keep this up, you're going to lose an entire generation of not only students but also teachers."

While no panacea, various AI-enabled solutions can help ease the workload for teachers. Grading is one example. Whereas it can take hours for a teacher to grade homework and tests one at a time, mostly a repetitive and boring process, AI-powered software can often do it immediately for everyone.

> ***With AI-enabled automation and other software fully embraced and utilised, teachers could devote more time to what they enjoy doing most — teaching — as well as shorten their workweek. According to one study, embracing the automation and AI solutions to the fullest, teachers could in total gain 13 extra hours per week.***

Furthermore, preparation for class, which takes around a fifth of the teacher's time per week, could be eased by making use of the software that helps with working out better study plans and pre-assessment of the student's skills. That way the teacher would either have to spend less time on preparation or could prepare even better using the same time. Other administrative and routine tasks that can be delegated to machines include taking attendance and generating test questions.

With AI-enabled automation and other software fully embraced and utilised, teachers could devote more time to what they enjoy doing most — teaching — as well as shorten their workweek. Currently teachers spend only around half of their time in direct interaction with students, while much of the rest is allocated to tasks that can be partially or fully automated, including the aforementioned preparation for the class, evaluation and feedback and administrational tasks.

According to one study, embracing the automation and AI solutions to the fullest, teachers could in total gain 13 extra hours per week.

AI can also help make education more involving and interesting. Student engagement can now be successfully measured and fed back to the instructor. That way the teacher can understand not only in which area a student is struggling, but also where the class as a whole is failing or slow to understand a concept. Similarly, such solutions can also help the teacher restructure parts of the course or even drop certain approaches to teaching altogether. To quote a teacher who already uses AI in teaching, "Students are excited to be in my room, they're telling me they love math, and those are things that I don't normally hear."

Within the context of teachers and AI, the oft-cited concerns including about the need to ensure "human-centric approach…for the use of AI [in education]" to those about robots on path to replacing teachers entirely are unfounded. Just as the arrival of computers and ATMs did not make office administrators and bank tellers redundant, digital tools can help teachers' profession evolve. According to one study, not only are teachers not threatened by automation trends, but their profession will grow between 5 and 24 percent in the United States in a 15-year period until 2030. The central mission of the teacher, schools and in-person learning will not lose their relevance. If anything, the pandemic-induced school closures and the associated shift to online and distance learning have reinforced the case for both teachers and schools. As parents were struggling or even refusing to stand in as the de facto teacher assistants, the case for the invaluable role of teachers is cemented. As one commentator put it at the time, "I'm not going to recreate school for them [the kids]. … And when it's over, the schoolwork will be there."

Even though AI robots are not arriving imminently to take over a large portion of the existing jobs, the future is far from certain. Good and continuous education is therefore more important than ever.

Promotion of digital education could be especially beneficial for making it more accessible to people in need for skills upgrade living in rural areas or otherwise unable to attend in-person classes and training such as professionals working long hours. While distance education and e-learning are not novel concepts, much remains to be done for improving their delivery as well as to broaden the reach. Recorded university lectures and coursework in PDF format is hardly the best way to foster engagement. The rise of massive open online courses (MOOCs) is slowly transforming the field with platforms like Coursera already making use of AI in various forms. Yet more can be done as reliance on platforms alone is not sufficient. Vocational education institutions, too, must embrace e-learning so that it is accessible without impediments to wherever one is.

Looking more broadly, education on all levels stands to benefit from an overhaul that puts e-learning on an equal footing to in-person schooling. While the hasty transition to distance learning during the 2020 lockdowns is often portrayed as a proof that e-learning is a subpar solution, it is the wrong conclusion. The difficulties experienced by the students, teachers and schools — from lack of computers to teachers struggling to effectively modify and present their teaching material to an online domain — rather reinforce the argument that introduction of e-learning should have happened earlier.

Those countries and schools that already had online learning ingrained in the system were not struggling much. Estonia, a long proponent of all things digital, was embracing e-education long before the Covid-19 outbreak. Already in the 1990s Estonia was beefing up schools' IT infrastructure nationwide and throughout the 2000s was developing educational content suitable for online teaching and learning. E-schoolbag, the country's online library consisting of over 20 thousand educational resources, was already developed by 2016. Homework is submitted and graded online. In parallel, promotion of digital literacy among teachers was also among the priorities. As one official put it, "Estonia has been preparing for [this] kind of crisis for already 25 years."[1]

As the schools were closing across Europe during the first lockdowns of 2020, the students in Estonia were already used to e-learning. "For us this transformation to distance learning was not something new," admits another official.[2] Estonia's success speaks for itself, with the country being ranked fifth in the PISA 2018 Worldwide Ranking for students' performance in reading, mathematics and science.[3] Whereas the high results are not due to digital education alone, it is acknowledged that it plays its part.[4] What is more, the fact that Estonia — still an emerging economy with limited resources — could afford and successfully implement e-learning solutions proves there is no justification for equally or even more resourceful countries to follow suit. Estonia's spending on education was 6 percent of GDP in 2019. Albeit higher than the EU-27 average, it is lower than for countries like Sweden, Denmark and Belgium, all of which performed worse in the above-mentioned aptitude test.[5]

Edtech (education technology) companies are deploying AI to provide tailored feedback to students, track progress achieved and identify each student's knowledge gaps and areas of strength as well as to increase learner engagement. AI has even been successfully used to lower high school dropout rates.

Looking more broadly, the AI-powered Edtech industry is gaining prominence — and funding. In the United States alone, the latter increased by nearly a third in 2020, reaching 2.2 billion dollars.[6] Countries that take advantage of such solutions and make use of other AI tools to improve quality and accessibility of education will be winners in the long term.

To address some of the above challenges and take advantage of the latest solutions, the European Commission's updated Digital Education Action Plan and the broader aim for a European Education Area are steps in the right direction. Among other objectives, the attempt to vastly improve both digital skills and digital literacy are a necessary precondition for enabling not only quality education, but also helping Europe stay relevant on the world map in the forthcoming decades. And whereas educational content is and must remain the prerogative of the Member States, an EU-led approach for promoting open standards and interoperability as well as sharing of best practices should be encouraged.

The EUR 800 billion recovery package to overcome the effects of the pandemic can help the EU to update the education systems and drive investment in AI. Yet ultimately it must be Member States that put modernisation of education as one of the priorities.

The world is changing, with artificial intelligence being one of the major technologies driving that change and offering vast opportunities. Adopting AI-powered solutions in learning and teaching is not merely an option, but a necessity in order to future-proof the education systems and maximise the benefits that the technology can bring to students, teachers and the society as a whole.

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WORKERS CAN UNLOCK THE ARTIFICIAL INTELLIGENCE REVOLUTION

Employers and artificial intelligence developers should ensure new technologies work for workers by making them trustworthy, easy to use and valuable in day-to-day work.

Mia Hoffmann & Laura Nurski

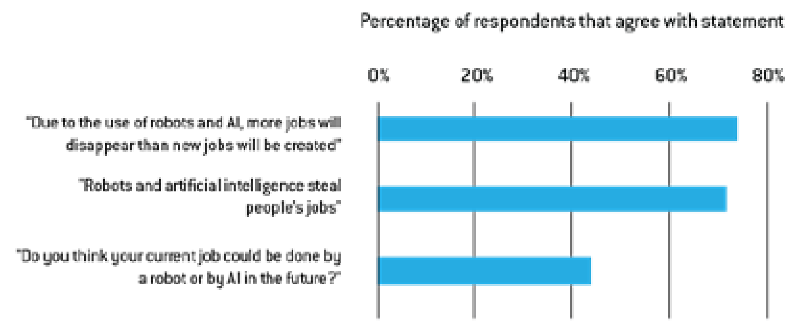
Bruegel

This article originally appeared on Bruegel: https://www.bruegel.org/2021/06/workers-can-unlock-the-artificial-intelligence-revolution/

Artificial intelligence (AI) has the potential to boost firm-level labour productivity by three to four per cent, and therefore significantly impact economic growth in Europe (Alderucci et al. 2020; Damioli et al 2021). However, only four in ten European businesses have so far adopted an AI technology, most commonly in areas such as fraud detection or warehouse management (European Commission 2020).

One reason why AI take-up in European firms might be slower than it could be is hesitance among workers to accept AI and other smart technologies at work. The underutilisation of technology by employees is considered a crucial factor in explaining the '*productivity paradox*', or the phenomenon of productivity stagnation despite hugely increased technology uptake (Landauer 1995; Devaraj and Kohli 2003), because simply providing a new technology does not necessarily lead to its adoption by workers (Atkin et al. 2017). The percentage of Europeans comfortable with having a robot assist them at work decreased from 47% in 2014 to 35% in 2017, a statistic that seems partly driven by employment concerns: 74% of Europeans expect that AI will destroy more jobs than it creates, and 44% of workers think their current job could at least partly be done by a robot or AI (Figure 1). This worry is greatest among low-skilled manual workers and white-collar workers, confirming research that people in professions at risk of automation are more fearful about the future (Dries 2021).

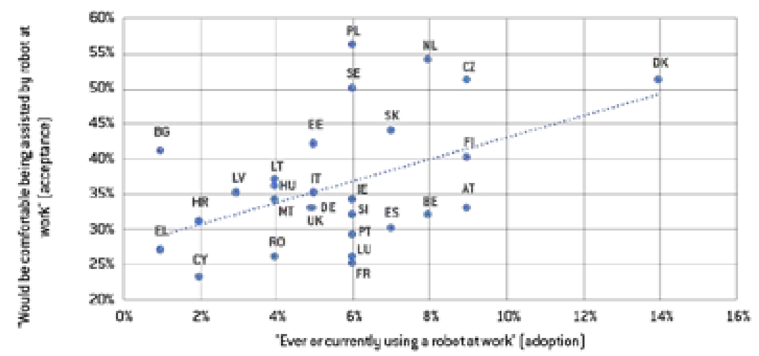
Figure 1: Europeans worry about the employment impact of AI and robots



Source: European Commission (2017) Special Eurobarometer 460.

European data linking firm-level AI adoption and worker-level AI acceptance is scarce, but Eurobarometer provides some evidence about worker acceptance and adoption of new technologies at work. Workers in countries with greater acceptance of robots at work also report greater exposure to the adoption of workplace robots (Figure 2). Causality probably runs both ways (as exposure to robots also increases acceptance through learning effects over time), but this data indicates that worker acceptance and adoption by firms of new technologies are intricately linked (with a correlation of 0.47).

Figure 2: Worker acceptance and firm adoption of robots at work are intricately linked



Source: European Commission (2017) Special Eurobarometer 460 - dataset volume A

To make the most of AI, both employers and workers need to be able to see its potential. The literature on technology acceptance in the workplace can guide policymakers and businesses to help workers accept AI and other smart technologies in the workplace.

Accepting technology at work: what do I have to gain and how much will it cost me?

A worker's decision on whether and how to use a new technology depends on two factors: the technology's perceived usefulness and its perceived ease of use. Perceived usefulness is defined as *"the degree to which a person believes that using a particular system would enhance his or her job performance"* and perceived ease-of-use is defined as *"the degree to which a person believes that using a particular system would be free from effort"* (Davis 1989). If a worker believes the technology offers a lot for little effort, they will be more inclined to use it. Early studies showed that usefulness is a stronger predictor of uptake than ease-of-use: *"Users are often willing to cope with some difficulty of use in a system that provides critically needed functionality"* (Davis 1989). However, no amount of ease-of-use can compensate for a useless system.

A worker's decision on whether and how to use a new technology depends on two factors: the technology's perceived usefulness and its perceived ease of use.

Workers judge the first factor, perceived usefulness, by comparing the system's capabilities to their duties in the workplace (Venkatesh and Davis 2000). A worker values a technology more when it is relevant for their tasks, produces quality outputs and its results can be easily demonstrated. Social processes also influence the perceived usefulness. If the technology appears to enhance one's status or if co-workers or supervisors expect a person to use the new technology, the worker's perception of the system's usefulness will increase.

The second factor, perceived ease-of-use, depends on the worker's pre-conceived beliefs about a technology, and the adjustments to those beliefs over time as a result of gaining direct experience with the system (Venkatesh 2000). A worker anchors their beliefs based on their computer literacy, existing organisational support resources, intrinsic motivation to use computers and any computer anxiety. Once the worker experiences the actual technology, they adjust their beliefs based on the actual enjoyment of using the technology (aside from any performance consequences) and its objective usability (the actual level, rather than perception, of effort required to complete specific tasks).

The importance of organisational support for technology uptake increases over time, as more of the available support infrastructure gets used and assistance for concrete, on-the-job use becomes more relevant. Gender, age, experience and willingness to use have moderating effects on the above-mentioned factors (Venkatesh et al. 2003).

Accepting robots and AI in the workplace

Algorithms in the workplace are not new. They have been used for optimisation (such as scheduling and inventory management) and prediction (such as demand forecasting, credit-risk analysis and personalised marketing) for several decades. The main differences between these old-school algorithms and current AI applications at work are: *who* is interacting with the algorithm, and *how* and *when*.

In the past, algorithms were mostly handled by statisticians or computer engineers in back-office departments. The outputs of algorithms had an impact on front-line workers (for example, by determining their monthly schedule), but those workers were usually unaware of the system's existence. Now, many AI applications involve front-line workers interacting daily with algorithms on computers, smartphones and wearable devices (Wilson and Daugherty 2018; Golembiewski 2019). Also, in the past, algorithms acted over longer periods: scheduling and forecasting was done in advance and provided some form of stability for workers. Now, fast and accessible algorithms can make minute-to-minute adjustments and react to the workers' environment in real time (for example Uber's surge pricing algorithm (Lee et al. 2015)).

Research on the acceptance of robots and AI is still in its infancy and is characterised by small-sample studies. Workers' perspectives are underrepresented. A few critical factors emerge nonetheless. For one, workers have been found to avoid using AI systems that are burdensome, for example, by increasing workloads or by sending excessive amounts of recommendations and alerts (Varonen et al. 2008; Moxey et al. 2010).

The underutilisation of technology by employees is considered a crucial factor in explaining the 'productivity paradox', or the phenomenon of productivity stagnation despite hugely increased technology uptake, because simply providing a new technology does not necessarily lead to its adoption by workers.

Similarly, the impenetrable nature of algorithms can be a barrier to adoption by workers. In the healthcare sector, not understanding why an AI's recommendation differs from one's own assessment prevents integration of its use into daily routines (Jauk et al. 2021). The inability to judge the correctness of the system's decision leads to mistrust and reduces its perceived usefulness. Obscure accountability for medical decisions makes workers uncomfortable about relying on a system with low levels of transparency. This accountability issue is just as important when workers themselves are data sources, for example, with algorithmic management (Nurski 2021). In this case, the scepticism caused by the system's lack of transparency is reinforced by privacy concerns and doubts about data security, which can make workers less willing to adopt the technology (Park et al. 2021).

When robots are involved, additional concerns about physical wellbeing arise. In workspaces with active human-robot collaboration, as in manufacturing, even minor robot malfunctions can lead to severe human injuries. Therefore, safety considerations are crucial determinants of industrial workers' attitudes towards robotics in their workplace (Brähl et al. 2019).

Individual job security concerns and overall adverse labour market effects are important factors in people's attitude towards robots at work (Bröhl et al. 2019). At the same time, workers base their attitudes on the robots' impact on their day-to-day jobs. For example, human-robot interaction may replace human-human interaction, reducing communication and collaboration between co-workers. Or workers may need to reallocate time from job-specific tasks to monitoring the robot at work, leading to deskilling and depreciation of operational knowledge.

How to increase technology acceptance

Employers can ensure technologies work *for* workers, not against them, by making them easier to use and making them more useful in employees' day-to-day work. Interventions to increase user acceptance can occur before and after implementing a new technology (Venkatesh and Bala 2008).

Pre-implementation interventions focus on enabling accurate perceptions of usefulness and ease of use by providing a realistic preview of the system. This involves identifying and communicating specific use cases, such as operational problems or business opportunities that can be addressed by AI. It also includes explaining the specific choice of technology with a transparent assessment of its benefits over other technical solutions (Jöhnk et al. 2021). Enhancing the interpretability of models, for example by visualising which data influences the model's output, can reduce user uncertainty and increase trust (Jauk et al. 2021). In addition to management buy-in and high software engineering standards, two further factors increase technology acceptance pre-implementation: user participation and incentive alignment.

User participation, or involvement in the design, development and implementation of the system, helps users form judgments about the system's eventual relevance to their jobs, the output quality and demonstrability of results. This can be achieved through hands-on activities including system evaluation and customisation, prototype testing and business process change initiatives. In the specific case of AI, workers from different backgrounds could be involved in establishing anti-discrimination protocols that ensure the system has no underlying bias.

Incentive alignment ensures that the effective use of the system, as envisioned by the employer, aligns with workers' own interests and incentives (Xu and Zhu 2021). These incentives should be regarded more broadly than just monetary rewards, but extend to the fit between a technology and a worker's job requirements and value system. For example, if using the technology does not benefit a worker or her direct co-workers but instead benefits members from other work units, the user will perceive a lack of incentive alignment that may lead to low use of the system.

Post-implementation interventions, in turn, focus on supporting the transition and adaptation to the new system. Training is the most critical intervention for greater user acceptance and system success. To reduce the perceived impenetrability of AI systems, organisations should invest in the data literacy of their workers. Firms can further support workers by providing the necessary infrastructure for using the technology, creating dedicated helpdesks and providing business process experts. Finally, worker's peers can provide support as well: they can assist with formal or informal training and can help with direct modification of the system or work processes.

Employers can step in to ease worker worries about AI's specific employment effects. While replacing workers is not the main objective of most AI adopting businesses, employers can focus more on augmenting workers' value through enhanced insights or learning (Deloitte Insights 2020). When job losses are unavoidable, employers can invest in retraining their workers for other opportunities within the firm.

Policy interventions to address concerns over loss of employment can include: creating safety nets with reskilling and transitioning programmes, individual learning accounts, unemployment benefits and universal basic income. To increase worker trust in AI systems, the regulation of AI itself and a focus on increasing worker data literacy are both essential to make sure they are ready to accept, adopt and allow AI to reach its full economic potential.

> *Algorithms in the workplace are not new. They have been used for optimisation (such as scheduling and inventory management) and prediction (such as demand forecasting, credit-risk analysis and personalised marketing) for several decades.*

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Voice AI: AT THE ROOT OF A COMING AI-POWERED MACRO-ECONOMIC CHANGE

Elise Pinto
CEO, Vocads

When Karen Kaushansky, the Senior Conversation Designer at Google, talked about voice technologies back in 1996, people listened without much consideration. However, like any technology, we only realise its potential when it reaches the market.

Nowadays, around 50% of households in the UK and the US own a voice assistant, according to consumer research from Ampere Analysis. This extraordinary development happened thanks to both amazing progress in research communities and companies building products from state-of-the-art models.

Voice technologies include every system that deals with a human voice: from text-to-speech to Natural Language Processing (NLP) passing by voice synthesis and much more. The introduction of more and more performant AI models such as the very famous BERT took NLP to a whole new level, opening almost limitless opportunities. Existing models are very good at turning one's voice into text, analyzing this text to understand the user's intent, generating a text answer and turning this text into a realistic audio answer. These technologies now have the entire toolkit to build conversations with human users.

AI-based voice technologies are at the root of a coming macro-economic change by including more people in the digital world. Indeed, in times where online platforms are emerging everywhere, it is essential not to leave behind members of our community like elderly and disabled people who have more difficulty engaging with computers and technology. Having the ability to interact with online platforms by speaking to them could make the online experience better.

Institutions are already pushing towards obliging major websites to include accessibility features. Act III of the American Disability Act in the US and the EU Web Accessibility Directive (Directive 2016/2102) require public sector websites to include those features, while the European Accessibility Act (Directive 2019/882) extends those requirements to essential goods and services related websites, showing a clear trend towards the need for more online accessibility solutions.

On a broader note, accessibility solutions very often convert into widely used products and voice technologies are no exception to this principle: they also benefit the general public and companies on a vast scale. Indeed, with the soar of e-commerce in the last few years that is projected to continue in the upcoming years (Statista forecasts online retail revenue to increase by 100 billion USD in the EU by 2025, with a similar trend in the US), companies are looking for ever more natural online user experiences, and humans' natural medium of communication is voice. Guiding users through a website, searching specific products in a database, enabling secure authentication as well as satisfaction estimation are just some of the examples already supported by voice-tech startups ready to take the online user experience to the next level.

It is a well-known principle that the easier it is for someone to do something, the more likely they are to do it. Voice technologies make online interactions much easier, therefore boosting sales through increased conversion rates. Not to mention how user-generated voice data, at the core of their true will, can help companies tailor their business to their customer's true needs and preferences. This edge is confirmed by market research company Juniper who in its 2021 report forecasted that voice commerce (transactions handled by voice assistants) will rise to $19.4 billion by 2023. This represents a 320% growth from the figure in 2021, mainly due to more and more people having access to voice technologies. Those are the reasons why, in a nutshell, voice technologies are at the root of a macro-economic impact.

Artificial Intelligence is at the core of the gigantic power of voice technologies. While integrating voice tech solutions in existing businesses used to be costly, rigid and time-consuming, rising startups like Vocads now make it easy, flexible and fast. In a paradigm where they answer a rising demand for website accessibility and open a new perspective for more natural user experiences, voice technologies are about to change our relationship to software for the better. Like we say at Vocads, "it is by talking to each other that we understand each other."

"Artificial Intelligence is at the core of the gigantic power of voice technologies. While integrating voice tech solutions in existing businesses used to be costly, rigid and time-consuming, rising startups like Vocads now make it easy, flexible and fast.

AI CAN HELP SHAPE THE FUTURE OF MEDICINE

Vida Groznik

CEO, NEUS Diagnostics, Assistant Professor, University of Primorska

Artificial intelligence (AI) has become one of the most disruptive technologies of the last decade, and we might as well call it the next industrial revolution. AI is increasingly permeating our lives and most of us are not even aware that it is embedded in the devices we use on a daily basis (e.g. mobile phones, smartwatches, cars, etc.). However, because AI came into media focus only in the recent years, most people believe that AI is a new technology, which is far from the truth.

A GLIMPSE INTO THE PAST

The beginnings of artificial intelligence date back to 1956, when a small group of researchers came together for the Dartmouth Summer Research Project on Artificial Intelligence [McCarthy et al., 1955]. This event is considered to be the birth of AI as a research discipline.

First applications of AI in medicine were expert systems where experts provided their knowledge in the form of general rules which were then encoded into the system. The first medical expert system using this approach, MYCIN, was developed in 1975 [Shortliffe & Buchanan, 1975]. The system identified bacteria that caused infections, recommended the antibiotics treatment and the dosage taking into consideration the patient's body weight. There were several other medical decision support systems developed throughout the years applied to different medical domains [e.g. Miller et al., 1982; Aikins et al., 1983; Shortliffe, 1986; Miller, 1994, Groznik et al., 2013].

> ***AI is being applied to several medical domains to help medical practitioners with their tasks including but not limited to diagnosis, monitoring, prognosis, treatment, and prevention of different diseases.***

THE FUTURE IS BRIGHT

Fast forward to 2010s and 2020s. AI is being applied to several medical domains to help medical practitioners with their tasks including but not limited to diagnosis, monitoring, prognosis, treatment, and prevention of different diseases. But the big breakthrough happened in 2015 when the AlphaGo computer programme beat a human professional Go player for the first time. This was made possible also by the use of multi-layer neural networks which are more commonly known as deep learning [LeCun et al., 2015] and a large amount of available data that has previously not been around. Since then deep learning approaches have been in the centre of attention of many researches and have been used for analysing big amounts of data. It proved to be especially useful in the field of computer vision for analysing ultrasounds, MRI, EMT, and PET scans.

There are several opportunities where healthcare can greatly benefit from the use of AI, but we will focus only on a few of them that are in the author's opinion among the most interesting ones.

PERSONALISED MEDICINE

Personalised medicine has been at the forefront of medical diagnostics and treatment for the past decade. The aim of the personalised medicine is to be able to offer tailored treatment for each individual patient based on their specific health characteristics. By analysing all available data about a given person (e.g. omics, clinical and diagnostic data, patient and family history, ...) we can identify different patterns that allow for a better and possibly earlier diagnosis, targeted therapies, theranostics, and even more efficient drug development. AI with its abilities to analyse big amounts of data will play a crucial role in the field of personalised medicine.

DIGITAL TWINS

The digital twin technology has been used in different industry sectors in the past and is only now starting to emerge in the field of medicine. What exactly are the digital twins? Basically they are a digital representation of a human body that allow modelling different aspects or functions, such as the bio-physical systems or protein structures [Kamel Boulos & Zhang, 2021]. By combining AI and the digital twins we could produce personalised care recommendations for the individual, observe effectiveness of the planned treatment, and drug interactions. And most of all, to cite Kamel Boulos & Zhang, "by harnessing electronic medical records of individual patients and patient-generated data, digital twin technology can also empower personalised medicine research."

The average cost of developing a new drug is estimated at USD 1,335.9 million and it can take somewhere between 11 and 18 years of research and trials before getting the regulatory approval. Narrowing down the number of candidate drugs could save a lot of money and speed up the process of finding a successful drug. AI can be applied to several stages of drug development.

DRUG DISCOVERY AND DRUG INTERACTIONS

One of the most challenging tasks in drug development is actually finding successful new drugs from several thousand candidate drugs or even billions of different chemical compounds. The average cost of developing a new drug is estimated at USD 1,335.9 million [Wouters et al., 2020] and it can take somewhere between 11 and 18 years of research and trials before getting the regulatory approval. With this in mind, narrowing down the number of candidate drugs could save a lot of money and speed up the process of finding a successful drug. AI can be applied to several stages of drug development including identification and validation of drug targets, drug design and repurposing, aggregating and analysing biomedical information, and even selecting most appropriate patients for clinical trials [Mak & Pichika, 2019].

BIOMARKER DISCOVERY

Biomarkers play a vital role in disease diagnosis as they are normally used as an indicator of a presence of a certain disease, disease prognosis and as predictive factors to treatment response. Normally when we think about biomarkers we are thinking of biological biomarkers we obtain by analysing blood, urine, and other body fluids, tissue samples, different types of imaging (MRI, PET, EMT) etc. Of course AI can help us identify hidden patterns in the data that would otherwise remain unnoticed by a human and that could be important in the disease diagnostic and monitoring. The deep learning approach is, for example, particularly suitable for the analysis of imaging data, as for it to work well it needs a lot of data for training the underlying neural network.

With the wide spread and use of the technology, biomarkers are not necessary derived from biological samples as we have been used to in the past. The way we walk can be a biomarker for different neurological diseases such as Parkinson's disease and multiple sclerosis. Automatic analysis of a video recording of a person walking or from sensors placed on a person's body can detect early signs or progression of those diseases. Another example is the analysis of eye-movements. At NEUS Diagnostics we combine eye-tracking technology that records eye movements of a person when looking at the computer screen and performing some tasks, e.g. reading. Based on this data, our AI diagnostic model can differentiate between cognitively impaired and healthy people by deriving different biomarkers and using them within predictive models [Groznik et al., 2021; Gerbasi et al., 2021].

OTHER APPLICATIONS OF AI IN HEALTHCARE

In this paper we have focused mainly on the use of AI for medical purposes and patients' health benefits. But this is not the only possible application of AI in healthcare. We should not forget the benefits it can bring to managing hospitals in terms of reducing costs, optimising staff workload, automating repetitive processes, robotisation, predicting outbreaks of infections, risk assessment, telemonitoring and virtual assistants, advances in tele-surgeries, population screening, and much, much more.

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