

EVIDENCE BASED POLICY REPORT

IMPERIAL COLLEGE LONDON

**Future polarised labour markets,
robots, and economic policy reforms**

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1 Executive summary

The workshop on “Future polarised labour markets, robots, and economic policy reforms” brought together academics, industry leaders and policymakers from economics and robotics to discuss how the recent advents in robotics impact specific industries and the labour market outcomes across the earnings distribution, and what are the appropriate policy reforms that should be considered. The main findings from the workshop can be summarised as follows:

1. Automation has had a labour-replacing effect across OECD countries in the last four decades, and this affected lower skilled workers disproportionately.
2. This effect manifested itself due to the institutional framework: lower taxes on capital relative to labour incentivized companies (especially big-tech) to prefer labour-replacing technologies to labour enhancing ones.
3. Going forward, we need an improved role for governments and more international cooperation on automation related issues to ensure equitable effects and sharing of the gains brought about by technology.

The rest of the report discusses these findings, which we have divided into general and industry-specific components. This is accompanied by a series of interviews conducted on academics working on relevant issues.

2 Advent of robotisation and labour market impacts: workshop findings and discussions

2.1 General trends and challenges

The advances seen in the last decades in robotics and artificial intelligence popularised an age-old question: will robots take our jobs? This question inevitably formed the backbone of the discussions in the workshop. Experts in both economics and robotics agree that while the threat seems more imminent than before, humankind can rest assured: this is not a likely scenario in the short run. For the most part, automation remains in a controlled environment. However, there are still discerning features of how and when this new technological wave came about. Hence, many concur that there is cause for concern – but this is not inherent to the technologies, rather to the institutional framework.

Academics agree that automation is likely to have had a role in the recent trends seen across the globe of declining labour share and wage polarisation. The effect of automation on labour between 1947 and 1987 was neutral. This is because its job displacement effect (substituting human workers) was compensated by its job reinstatement effect (i.e., technology increasing human productivity and demand for

labour). The job displacement effect has instead been strongly prevailing between 1987 and 2017. This has been shown to be the case for industrial robots and it seems it will be the same from now on with AI.

In principle, AI might just be a platform, a technology complementary to labour. Nevertheless, it can also be used as a replacing technology and up to now the latter has been the choice of companies, following the big tech firms' business model. This model exploits AI to produce algorithms that replace human work as much as possible.

This trend of excessive automation does not derive from technology as such, and thus it is not inevitable. It is instead the result of the choice that our society made on how to deal with technological progress. Three main elements contributed to this: global competition, business models and tax code.

Global competition, especially from low-income countries, has pushed companies in US and Europe towards an aggressive cost reduction strategy. In the attempt to reduce costs as much as possible, companies automated. Moreover, the business model of big tech companies was adopted across virtually all industries and sectors. This model focuses almost exclusively on producing algorithms to automate and replace human labour. However, participants from MAXON motor company noted that for every robotic intervention, roughly 2 vacancies for human workers opens up due to the elastic demand curves in many products (disproportionate expansion of sales as a result of a unit cost reduction). Finally, another element that is relevant for understanding how this automation trend came to be is the evolution of the tax code. In the US tax rate on labour stayed constant at around 25% in the last thirty years, while the tax rate on capital (structure, equipment, software) has strikingly and continuously declined from 20% in the 80s to about 5% nowadays (similar evidence can be found for many other OECD countries). This created a huge incentive for firms to automate, at the expenses of labour.

Whether increased use of robots created efficiency gains remain unclear. Total factor productivity, a traditional measure of such gains, is growing at annual rate of 0.5%, while thirty years ago this rate was almost 3%. While macro evidence points to a stagnating growth in total factor productivity, new studies using firm-level micro data point to productivity gains at firms that adopt robot use. However, these gains are not equal across firms – smaller firms might not be able to keep up with larger, “superstar” firms in the adoption of new technologies. This might be an impediment to innovation.

The effect on the workforce is, similarly, heterogenous. In the last thirty years, real wage growth became stagnating and labour share (the share of national income paid to workers) has declined. The worsening of workers' conditions has not been uniform: it has disproportionately affected the least educated ones. On the contrary, the highest educated workers have seen their real wages increase significantly. Such a widening in the education pay gap produced a polarised compensation scheme, with high paid and low paid workers, while the middle of the earnings distribution has progressively hollowed out. Some groups, such as middle-educated women, are

among the most affected. Academics point out that these effects are sustained in the long-term.

2.2 Industry specific challenges and opportunities

From the perspective of employers and business leaders, adopting new technologies is one of the most important factors to consider when planning for the future of the companies. The discourse in the business world is slowly shifting from one of substitution of humans by robots to the idea of collaboration between the two, and this shift needs to continue down the road for sustainable implementation of automation.

Considering the impact of automation on employment trends in the hospitality sector, the human-centric characterization of this industry must be taken into account. Experts comment on the increased use of service robots, mostly in the back of the house tasks such as cleaning and disinfection, but also in some customer-facing tasks such as bartending. The usage of service robots aims at supporting employees during their routine tasks and allows them to focus on more complex situations. This way, they can train themselves and get ready for more skilled roles. Although the labour-replacing effect is seen in the hospitality industry, academics believe automation and robotics can serve those employers to have better working conditions and become empowered.

Academics agree that technological developments in healthcare have an accelerating effect on business and there are several new technological improvements on the horizon such as software-hardware power developments, smarter, cheaper, smaller devices, and robotic visualization. On the other hand, there are some challenging issues that needs to be considered such as certifications, patents, and private/public healthcare. Besides, it is highlighted that there is a need for better cohesion between humans and smart robots to empower end-users.

After the establishment of the self-driving start-up ecosystem, the development of Autonomous Vehicles (AVs) gained great momentum. Current R&D efforts focus on safety assurance and the ability to react to situations that have not been previously encountered by the vehicles during trial runs or past trips. AVs sector is developing with many diverse challenges such as the problem of having two different regulation frameworks at the same time for humans and robots on the roads, which could cause opposite incentives. AVs robotic systems may take certain jobs humans do, but robots can also empower them to flourish in self-employment in an economy driven by robotics.

3 Policy proposals

The way technology affects the labour market is the result of a series of decisions and events in a deregulated market environment. Academics across the board agree

that there is a need for a robust institutional framework to regulate technology development and adoption. This way, it might be possible to switch from the current equilibrium to another one where technology thrives together with less inequality and more relevance for labour.

Experts agree that a new and improved role for the state in a Welfare 3.0 reality is the perspective which best conforms with this necessity of regulating technology. This could be obtained through the reinforcement of the state power, which will have to combat inequality, climate change, pandemics, ensure security and develop a new approach to technology regulation. Governments need to work on appropriate legal framework that can accommodate human-autonomous machine interaction.

Another point that arose is international cooperation. Together with technology development and increase in trade and globalization, there is a need for increasingly common global standards to communicate and collaborate between different countries and realities. This is also true for regulatory standards.

More discussions need to happen around the ethical use of robots, using robots to empower communities and ensuring “tech for good”. Since increased automation brings about increased data creation, the protection and use of this data should be at the forefront of policy discussion.

4 Appendix

4.1 Breakout Session

For the breakout session, we asked participants the following questions in their breakout room and talk about any other important trends or factors that they think might be relevant for a given industry group.

1. Think about the automation trends, labour challenges and business opportunities presented by our speakers - as well as your own experiences. Which specific tasks or entire jobs do you think will have to be automatized/robotized in next 5-10 years and why? (E.g., lack of qualified labour; robots can do the job much better (fewer human errors, higher efficiency, etc); cost reasons).
2. Do you think such automation/robotization will lead to labour-replacement or labour-reinstatement (i.e., more tasks/jobs will be generated)? If your job was to be replaced or significantly changed as a result of robotization – what would you do about it?
3. What are the biggest risks and challenges for society as a whole (jobs, vulnerabilities, wellbeing, potential for cyberattacks), and what could be the best societal responses to those risks and challenges? A short summary of the answers to the question and the feedbacks that we received from the participants are given below in summary.

4.1.1 Breakout Room 1: Infrastructure

Most participants in this breakout room were from the automotive and transport industry. The conversation mainly focused on the risks and challenges that robotization is currently introducing. It started from a technical point of view, focusing on ways to accurately estimate the impact of new trends in the short and long term. Then, the discussion shifted to a more philosophical perspective on the definition of capital and labour under these new frameworks, and the moral responsibility of developed countries to share safely technologies with other countries.

4.1.2 Breakout Room 2: Home and Hospitality

The discussions in this session focused on the hospitality and hotel industries. Participants discussed two key points. The first one about the role of robots in hospitality: analytical roles (software based automated kiosks), social roles (humanoid concierge), and mechanical roles, through robots that have the ability of cleaning and tidying the rooms. The second point concerns the opportunities in the entertainment industry. The idea of an hotel with robots in place of usual employees can be interesting in the short term, but in the long term, it is hard to predict people's preferences.

4.1.3 Breakout Room 3: Health

In the healthcare section, the focus was on the assistive role of robots. Thanks to robots, there may be autonomous interventions carried out with minimally invasive procedures in the future. Robots will be more intelligent, multi-modelled, and collect more data to have tactile information. Besides, concept of robotic patients can play assistive role in training medical students and technicians. In this context, issues around ownership or data and privacy concerns arise. To alleviate these, we need a multidisciplinary approach from economists, public policy makers alongside robotics experts so that we can prevent the jeopardizing effects.

4.2 Interviews with academics

4.2.1 Academics from Economics and Business Departments

This section is dedicated to the interviews with the Economics and Business faculties. The interview consisted of a set of four questions. Below we report each of them with the main points that emerged overall from the talks. Next, we report specific perspectives emerging from each interview.

Report on the general perspectives

Question 1

Whether technology is a labour-replacing or a labour-enhancing factor is a widely discussed topic in economics. Different technological waves might belong to the one or the other category. At the same time, within the same technological wave, low and high-skilled workers might be affected in different ways. For example, when computers started to be introduced, clerical workers saw a strong decrease in the labour demand, while data scientists went through the opposite trend.

Thinking of the technological wave we are currently in, how would you sketch the main impacts that technology is going to have on low and high-skilled workers in the foreseeable future?

- Majority of academics think that the technological wave we are currently in has some similarities with previous ones: it will have a substitution effect on some workers categories, but we will not end up in a jobless world. Probably, low-skilled workers (or in any case those at the bottom of the earnings distribution) will be those most affected. At the same time, it is plausible that for the first time also workers at the top of the earnings distribution will see parts of their job automated.
- To understand the impact of technology on the different worker's categories we should not think of high and low-skilled workers. Technology affects workers on the basis of many more variables, such as age, experience, but especially on the basis of the task content of their jobs. The task contents of workers are very heterogenous within the low and high-skilled groups. But the task content is the key variable to understand who will be affected more.

Question 2

“Collaborative robots (co-bots) are complex machines which work hand in hand with human beings. In a shared work process, they support and relieve the human operator” (source: IFA). These robots are thus by definition complements to workers. They might have a role not only inside the firm but also outside, given their increasingly lower prices. This makes them affordable to individual workers, who might this way enter the labour market as self-employed. For example, powered exoskeletons make workers resilient to tough manual tasks. Robotic arms make it easier to perform “pick-and-place” jobs. One further example is represented by what happened with 3D printers in Italy during the start of the covid pandemic, when individuals were autonomously printing relevant parts of ventilators, hugely requested because of the hospital shortages.

Do you think co-bots will have a relevant role in shaping the future of labour market? Are they going to swell the ranks GIG-economy or are they more likely to become one extra device inside the traditional firm structure?

- General agreement on the role of co-bots as useful devices for some workers, for example workers with disabilities, but also for GIG economy workers (e.g. the riders using google maps when travelling across the city).
- No consensus on whether co-bots will be incorporated into the traditional firm structure. There might be a change in the firm structure, but the labour market power is likely to remain in the hand of the firms, with workers keeping a subordinated role.

Question 3

To the extent that technology may cause a reduction in labour demand and consequent wage and employment losses, government policies might be necessary to mitigate such a phenomenon. One proposed scenario is a tax on robot owners, through which a subsidy for affected workers could be financed.

Do you think this is a viable option? If not, what alternative policy would you propose to compensate for possible income/employment losses?

- The majority thinks some form of redistribution is deeply needed and that governments need to take strong actions. There are also disagreements on what such actions should imply.
- Consensus on the fact that any tax causes distortions and can reduce incentives to innovation. There is a trade-off between the necessity to create some form of redistribution and innovation/international competition (if one country has higher taxes, firms might move away).
- Some academics think a tax on capital (not necessarily on robots) is needed in order to reduce the power of the few big firms which produce and/or apply high technologies and accumulate rents.
- Other academics think governments should intervene, through financial incentive or through other forms, to ensure technology adoption is spread in the economy and adopted evenly by firms. This would avoid rents accumulation in the hands of few firms.

Question 4

One of the leading academic perspectives on technology is the task-based one by Acemoglu and Restrepo. Technology can be labour-replacing (substitutes humans in certain tasks) or labour-reinstating (creates new labour-intensive tasks or increases the demand for already existing labour-intensive tasks). According to these authors, the productivity gains of a technology determine which element prevails. If a technology can replace humans without an effective productivity gain, then it is a bad technology (as automatic check-outs) and can only have a labour-replacing effect.

Do you think this kind of “bad” technologies and their labour-replacing effect will become dominant and overshadow “good” technologies?

- Some academics think that a transitional traumatic phase with some degree of job disruption is unavoidable and physiological, not worrying.
- Other academics think that the incentives structure of our economy (coming from international competition, tax code, etc) might favour an excessive automation trend at the expenses of the labour component of production.
- Those who think that the current automation trend might be excessive and favour too much technology inside the firm, also agree that it should be the government to intervene redistributing technology gains in some form (for example taxing profits of big tech firms or reducing labour taxes).

4.3 Findings from individual interviews

Dr Julio Amador Diaz Lopez - Imperial College London

It is important to distinguish between different waves of innovations. The one we had at the beginning of the 2000s was characterized by robots automating tasks of middle-class workers (clerks, secretaries). That portion of employment was displaced. Few entered high-paid jobs while the majority had to move to lower-paid services jobs (polarization). This is the wave Frey and Osborne (2013) are talking about.

The wave we are currently in is instead mainly characterized by AI. This type of technology is likely to affect also higher-paid workers (white collars), even if they will on average be more shielded than lower-skilled. At the same time, we are still very far from a jobless world. All new technologies will still need some human control (for example, self-driving cars are not likely to drive entirely autonomously). Nevertheless, it is likely that we are going to experience some traumatic phase in the labour market because of the impact of technology. A reorganization of human labour around the new production processes is probably going to happen. Then, we are likely to end up in a stable second phase where people will work with the new technologies and will have more leisure time.

The idea of being able to “tax a robot” as a form of capital with an individual owner implies a Marxist approach which is not reliable anymore. We do not have a capitalist who owns the robots, but a complex chain of production with many stakeholders owning the various means of production in different proportions. Taxes are likely to translate into a loss of efficiency, even if some forms of redistributions are certainly needed, especially given the polarization trend.

Professor Michele Battisti - University of Glasgow

Distinguishing workers based on their education level might be a narrow perspective if we want to understand the impact of technology on the labour market. Other characteristics need to be considered, such as age, experience and training.

It is difficult to make a forecast on how collaborative robots (co-bots) might impact workers' position in the labour market. In some manual jobs, they can make workers more resistant and increase the supply of labour especially by individuals who are older or affected by disabilities. We see that some co-bots are already used by gig economy workers. Riders could not move so efficiently from one corner to another of any city without the support of a smartphone and google maps in it.

Some form of redistribution through taxes on capital is welcome. We have been taxing capital less and less across last decades, so now it could be the time to reverse this trend, irrespectively if the capital is in form of robots or not. To effectively act in this sense, governments will need to take strong actions. It could be that the covid pandemic and the current empowered role of governments on the economy and society might speed up the cultural process of acceptance of a stronger intervention power of the state. This is necessary if we want to substantially impact on the inequality issue. Taxes can be a way, an informed decision of which technology to subsidise for the common good of society can be another way.

Professor Tim Lee - Queen Mary University of London

Thinking of high and low-skilled workers is a simplification of reality which is not very useful for understanding the impact of technology on the labour market. High and low-skilled workers are very heterogenous groups, especially in the former case. The mean wage of the "high-skill" is unlikely to be representative of the whole category but rather is driven by top-income recipients.

We should rather think of the task content of workers occupations. What is new of the current technological wave is that it is sensible to expect that categories in higher ranks of the income distribution will be affected more with respect to previous decades. This is because certain machines and software are more and more able to reproduce tasks which were, up to now, performed by high skilled workers (such as data analysis) while they are unlikely to substitute certain low wage occupations (such as cleaners).

For what concerns the specific impact of co-bots, it is unlikely they will empower workers in a broad sense. Empowering workers means subtracting some powers from firms as production centers. But co-bots themselves will come from some firms. At the end, even in the case of very efficient and ready to use co-bots, firms will maintain their leading power position in the economy. Maybe not the same firm of today, maybe it will be the turn of those firms producing co-bots.

Taxes on robots will reduce incentives for innovation. Still, some firms today are making huge rents thanks to technology and to the way the technology ownership

is protected (e.g., patents). The size of these rents is strikingly larger than in the past, and it keeps growing, accumulating income and wealth in few hands. At the same time, in the past, innovation was not absent, even if this rent creation process was more bounded. We are facing a political choice. Partially depressing innovation by reducing the possibility of creating big rents is an option to reach higher levels of redistribution and lower inequality. We should not disincentivize people from adopting new technologies, we should rather aim at reducing the power of big tech firms that produce them.

Even in the case, we should have technologies replacing human labour without any productivity gains, this is not bad per se. In a purely theoretical utopia, machines and robots can entirely replace labour, and only those that want to work will work. This is socially compatible with a strong and efficient redistribution process usually identified in the presence of Universal Basic Income subsidized through the rents and profits of technology owners. We are extremely far away from something resembling that situation.

Dr Cornelia Metzger - Imperial College London

The idea that robots will take our jobs is not novel – it has been around for a long time. It is unlikely that this will materialize. What we will see is a massive shift on the type of existing jobs. Technology will replace certain jobs while creating others, exacerbating the trends we see today in delivery services and car sector. Low skilled jobs are likely to be replaced more, and education will become more important as time passes. The adoption of new technologies can also bring about huge improvements in working conditions. An example is seasonal workers who work on farms, and usually have poor working condition. Farm droids, a type of robot used in organic farming replacing some of the weeding tasks done by the workers, is hugely helpful for them in this case.

It is likely that humans will increasingly become unimportant in manufacturing and more important in service. Even if we can use robots in certain sectors (care and hospitality), it is likely we will not choose to. This will change our spending habits and our willingness to spend on certain things – for example, we are likely to spend a larger proportion on healthcare and hospitality and less on goods.

A government intervention in terms of a tax levied on robots is unnecessary – what government needs to think about is whether enough new jobs are being created, and to make sure there is not a high degree of monopolization in terms of robot owners.

Job destruction is a part of the economy, and if the economy is diverse and the effects of this destruction can be absorbed, it is nothing to worry about.

Dr Joseba Martinez - London Business School

There's no reason to expect that the current technological wave will be any different than the previous ones. For some groups of workers, new technologies are highly

complementary while for others they have a substitution effect. The coming technologies are likely to accelerate the trends we have been seeing. Some technologies (such as an exoskeleton that can help humans perform some physical tasks) will change how we compensate labour, taking physical form out of the equation in this case.

A robot tax is a losing game, partly because of international competition (a tax levied in a country will just lead to the migration of these technologies to a country that does not implement them). One way to mitigate the effect is to make sure technology is adopted widely in the economy – new technologies should be diffused evenly. Another important policy should be the retraining of workers to move them up the value chain, to higher-value tasks and to make sure their skills do not become irrelevant. Implementing these policies at firm level should be considered.

Professor Evgenia Passari - Université Paris Dauphine - PSL

Given that people live and work for longer periods, the importance of re-skilling is one thing we have to consider for both low and high-skilled workers. The acceleration of technology means everyone's skills are at risk of becoming redundant.

When considering the optimal government policy on robotisation, one thing to bear in mind is the current trend of putting more burden on labour rather than capital, which is seen in numerous countries. This might favour automation beyond what is socially optimal, by making it more favourable to displace workers. These trends can be reversed by national or international policies to realign these financial incentives – but it is unlikely it will be decided at the firm level. Governments should be playing an active role.

4.3.1 Academics from Robotics Community

This section is dedicated to the interviews with the robotics faculty. The interview consisted of a set of 5 questions. Below we report each of them with the main points that emerged overall from the talks. Next, we report specific perspectives emerging from each interview.

Report on the general perspectives

Question 1

Please describe 2-3 main technological developments and trends in your field/industry that are currently impacting human labour in the short term and the long term.

- There are many technological trends that are impacting human labour. Most seem to aim to replace human tasks in various fields such as transport, domestic, manufacturing and even healthcare. An interesting trend are co-bots (col-

laborative robots), which collaborate with humans instead of replacing them. A common trend is the application of Artificial Intelligence technologies in robotics.

Question 2

Technology is usually classified as either labour re-instating or labour replacing. How would you classify the previous mentioned trends and why?

- Robotics seem to be labour-replacing, but it is not really the case. It depends more on supply and demand; robots fill gaps in the labour market.
- Some robots will definitely replace human tasks, but it does not necessarily mean that they will completely replace the humans. They can take over human tasks that do not generate much value, so experts can focus on generating more value.

Question 3

Do you think we need more (or new) human roles for the technologies you mentioned above? (e.g. data scientists, robotics technicians, etc.)

- The consensus is that new human roles will be required to develop and train incoming technologies.
- In the short term, people with technical skills such as mathematics, software and hardware are being increasingly in demanded for robot training and development. In the long term, the goal is that non-experts can train and maintain robots with only basic intuition and knowledge.

Question 4

Are there any “bad-technologies” (e.g. larger carbon footprint, more dangerous, higher cost, etc.) examples in your field?

- New technologies always come with challenges and trade-offs.
- Machine learning and deep networks could potentially have a counter-intuitively negative effect on the broad clinical field.
- The constant monitoring required by robots is generate an increasing concern in ethics and privacy, which requires new regulation.
- Robots in manufacturing may pose safety problems, and usually come with a higher carbon footprint.

Question 5

From a technical point of view, how do you think the government could incentivise/disincentivise these new trends, and what would be the caveats of these policies?

- To address most of the new challenges, technological alternatives or improvements will be required. They will most likely come from academic research, which requires funding.
- The government can intervene in the cost of technologies by providing financial incentives to reduce the high costs of technology. This could be in the form of subsidies or taxes, depending on the objective. A mortgage program for buying and owning robots could be introduced.

4.4 Findings from individual interviews

Professor Ferdinando Rodriguez - Imperial College London

Surgical systems tend to help clinicians to perform more complicated procedures or procedures that could not be done before. Especially training systems for the surgeries are very labour intensive, surgical robotics can be used to solve the need of a person who can train the young generations with hand-eye coordination and functional skills. These technologies offer a great complimentary service within the surgical community and surgical tools enable to have better surgery. What we do is certainly labour reinstating to extend that they won't necessarily increase the number and demand of human beings to do this kind of jobs, but they will complement human operator doing the job better, faster or more efficiently. They certainly would not reduce the number of human beings to perform the procedure.

The clinicians of tomorrow will need to know more math's and physics than clinicians of today. A surgical specialist needs to evolve, and they are already evolving because they are using complicated instruments that require a better grasp of triangulation, coordinate system, imaging so on so forth. With regards to systems, they need much more maintenance and there is a need for several divisions for this purpose and they must be more subspecialized for the technological complexities.

Machine learning and deep networks potentially having a counter-intuitively negative effect on the broad clinical field. The risk there these algorithms are not intelligent, they are only addressing and identifying complex, nonlinear patterns even more complicated data. So, this type of learning algorithms can very quickly start to produce conjectures which seem correct but have nothing to do with underlying science or medicine.

The classical way in medicine to measure the effectiveness of the technology is through a unit called quality-adjusted life-year (QALY), one very basic way in which we can measure the outcome of deployment of this technology on patients, just to

see patients are significantly better off by some metric qual measure. Efficiency from an economic point of view is that robots require capital investment, and they require consumable costs but as a result, you get fewer side effects, shorter hospitalization, better scaring, then of course what you spent on the machine and the consumable is that offset what you gain.

Dr Riccardo Secoli - Imperial College London

Surgical and rehabilitation robotics have a little market that requires doctors or technicians highly specialized. Long term goals are to try to replace surgeons or try to replicate physiotherapist in terms of care to a person. Also, collaboration with AI technologies become important for human labour.

Robotic technologies will be labour replacing because of the demands on highly specialized people. This need is high because the ageing of the population one of the biggest causes. We need highly specialized people who know how to design robotics and different fields like medicine for example. Robotics technologies are trying to replace those labour to facilitate their job. All the field of medical robotics is to work for that ultimate goal. The trend to these technologies is going quite well these days.

All the medical technologies are generally high cost and if we are looking where these technologies can make any improvement are in specifically western countries. But developing countries don't have access to these technologies. This inequality and higher cost some of the challenges for medical robotics. Robotics applied to the military is something that we need to look at more in details.

Dr Thrishantha Nanayakkara – Imperial College London

Soft robotics and collaborative robots can work with humans and be used in factories: they have pros and cons. AI and co-bots used in parallel are changing the domestic and health sectors. In 1980's, robots were introduced for heavy tasks but were separated from human interaction. The transition involves new interactions with humans. Robotics seem to be labour-replacing, but it is not really the case. It depends more on supply and demand. For example, in agriculture or manufacturing plants robots fill gaps with lack of labour supply. There will be a need for designers, maintenance crew, software engineers, sensor manufacturers. Robotics is piggybacking on other industries and manufacturers. For example, GPS and pressure sensors are already produced on a large scale and are being used by robots. The biggest job market will be the software programming one. In the longer term there will be more need for teachers and trainers for robots.

Robot ethics can be a big problem. E.g., IoT devices that record and monitor humans for all kinds of services that use your data in the background. Robots can be used to monitor people and thus as a proxy to influence them if not properly regulated, but overregulation is also bad and limiting. This is a big dilemma. Governments can reg-

ulate intrusive practices and protect privacy, data and human rights. Governments can empower people through robots. Robots can be rented or bought cheap, and people can add value to their robots by training and upgrading them – a mortgage program could be an incentive.

Dr Edward Johns – Imperial College London

The work in the Robot Learning Lab focusses on robot manipulation and object interaction. The applications are tasks that are easy for humans and therefore will have a labour impact, e.g. domestic robots and manufacturing robots. Robots will also replace some tasks that humans already do in their own home, similar to the role of a washing machine, so in some cases this might not directly impact labour, but will instead create more free time for humans. On the manufacturing side, there could be a large economic impact by completely replacing some humans, but it may also make existing automated manufacturing even cheaper. If the task is simple and technology is mature enough, any human could train these robots. If the task is more complex, then experts and specialists might be needed to train the robots.

In the longer term, the role of the research done in the Robot Learning Lab is to avoid needing any human expertise when deploying robots, so this is successful if a non-expert can train them. In the shorter term, there will be human roles to train the robots to perform new tasks, especially in manufacturing. But the more successful the research is, then the more labour problems will arise, because the need for a human in the loop is reduced. There will be intermediate stages that will require intermediate skills from humans. Robots are probably more dangerous than humans because humans can assess their own abilities quite well.

In terms of carbon footprint, robots are less efficient than humans in achieving power output – there is nothing like humans for energy efficiency. Military robots are also causing a dilemma. On the industrial side, the government needs to make it cheaper to use green technologies by giving financial incentives. This could be in the form of subsidies or lower taxes. There must be a technological alternative that will most likely come from academic research, which also requires government funding.