OXFORD ECONOMICS

How robots change the world:

Their impact on regional inequalities

January 2020

Edward Cone, Richard Holt, Michael Zielenziger

Oxford Economics

Abstract

The spread of robots across the workplace, and especially within manufacturing, is widely known. This paper reports on how robots have impacted directly on manufacturing jobs, and indirectly on national GDP growth via productivity gains, across a range of advanced economies. By the use of econometric modelling, our team have shown that there are overall gains despite significant job losses within industries. Crucially, however, we find that those regions whose residents have lower income levels have tended to lose twice the number of jobs, per robot, compared with those regions with higher average income levels. The consequence is a significant risk that in countries such as the United Kingdom, regional inequalities will increase—a challenge potentially made even greater as robots spread to occupations that have traditionally provided the destination for displaced factory workers. This creates a challenge for policy makers, who are likely to face political pressures to spread the dividends of robotization more evenly. Recent political developments across a range of advanced economy nations suggest that the pressures on policy makers are already mounting.

I. Introduction

The 2019 general election in the UK served to increase policy-makers' focus on regional disparities. Having secured victory by gaining seats in the economically under-achieving north of England, Prime Minister Boris Johnson announced a new focus on improving economic performance and life-chances in that part of the country. The Chancellor of the Exchequer Sajid Javid instructed Treasury officials to revise their investment appraisal rules, with a view to refocusing government spending away from the affluent south east of England. Officials have been told to take into account criteria such as narrowing the regional productivity gap and improving the well-being of people in low-income areas. Meanwhile, many in the opposition Labour Party argued that their defeat was partly caused by a neglect of their traditional northern heartlands.

In truth, of course, there is nothing new about regional inequalities, nor is this a phenomenon confined to the UK. Furthermore, experience suggests that under-performance by certain regions tends to be very persistent and hard to change. Reasons for that include the related phenomena of deindustrialization and globalization. These have for example impacted on the US mid-west and France's north-west, just as much as they have affected the north of England.

A controversial issue is the extent to which new technology increases inequalities, both between regions and between higher- and lower-skilled workers (with the two of these clearly being related to one another). An increasing aspect of that over recent decades has been the spread of robots, in and beyond manufacturing. Factories in which almost all the work is done by robots and almost none by people, are becoming commonplace. And as the capabilities and hence the likely uptake of robots increases, so too does the apparent threat to jobs, and hence the challenge that policy-makers face if they are to reduce regional disparities.

II. Modelling the spread & impact of industrial robots

In the light of this, a team at Oxford Economics has been looking at the issue of the impact of robots on economic performance, and how the impact varies across nations and in particular, how it varies across regions within nations. The full results are presented in *How Robots Change the World*, published by Oxford Economics in the summer of 2019.

We undertook econometric analysis of the link between robot installations and manufacturing job losses.

As part of our work we undertook econometric analysis of the link between robot installations and manufacturing job losses at both the national level and for regions within specific countries. Drawing on data from the International Federation of Robotics (IFR), an industry trade group, we investigated the ways in which the installation of additional industrial robots has affected local manufacturing employment in a range of manufacturing-intensive countries, drawn from the European Union plus Australia, Japan, South Korea and the United States.[1]

This data, combined with labour market indicators over an 11-year timeframe, has allowed us to isolate empirically the impact of robotization versus other influences on regional labour market outcomes. These include changes in real wages and shifts in global trade patterns.

We have also used the Oxford Economics' Global Economic Model (GEM) to generate projections of the likely employment impact of robots, utilising IFR benchmark robot investment trajectories. We have employed GEM's modelling capabilities to explore three robot-related economic "shocks":

[1] Despite its prominence in global manufacturing, China was omitted from our econometric modelling exercise due to a lack of data in other important modelling variables.

- **An increase/decrease in total factor productivity** as a result of adopting more/fewer robots into industrial practices;
- **A rise/fall in business investment,** capturing different levels of expenditure on industrial robots;
- **A shock to employment**, expressing the proposition that, to generate a given level of output, fewer/more workers may be required under the high/low scenarios.

Our modelling shows how the impact of robots compares between lower- and higher-income regions within countries.

By using GEM we have been able to examine the overall macroeconomic impact of robots on economies, nationally and regionally, rather than simply the first-round effects. For example, our modelling incorporates the impact of robots on productivity, and hence on firms' incentives to invest, influencing in turn the international competitiveness of countries, and hence the profitability of businesses. And it simultaneously takes into account the impact on household consumption of higher/lower wages and dividend payments; and the boost to public finances from stronger economic growth.

Crucially, in addition to providing absolute figures, we have calculated the marginal impact of each additional robot installation on manufacturing jobs across the countries studied. Our modelling establishes how this impact compares between lower- and higher-income regions within each country, defined as regions with average household income levels above and below the national average.

III. The results: economic gains, but also rising challenges

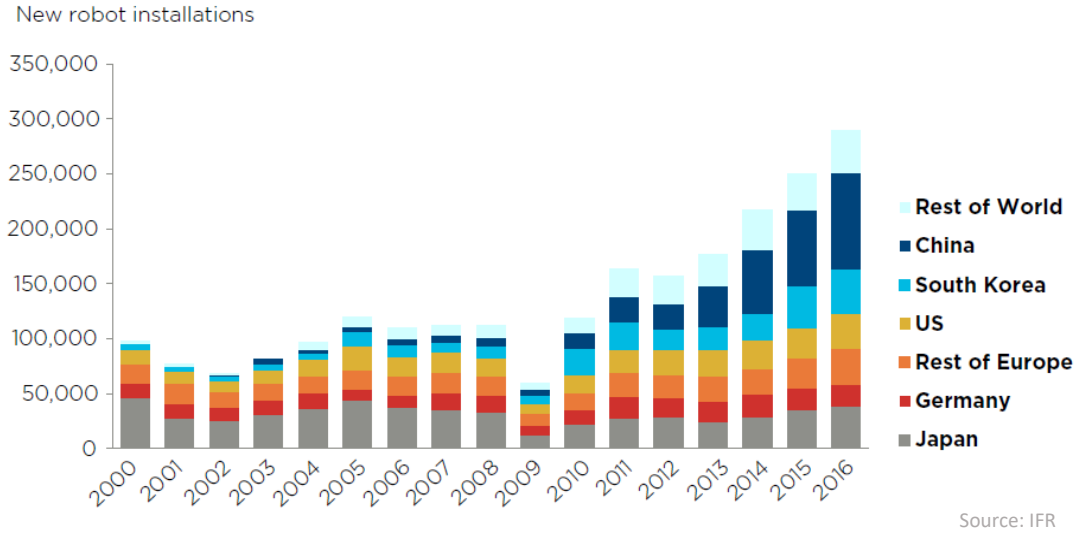
Since 2010, the global stock of industrial robots has more than doubled, to 2.25 million. The IFR projections mentioned above suggest that it will multiply even faster in the next 10 years, reaching as many as 20 million by 2030, with 14 million robots operating in China alone.

The current wave of robotization is tending to boost productivity and economic growth, generating new employment opportunities.

Nevertheless, our modelling also suggests that at the national level, and for the economies that we have examined, fears about overall job-destruction generated by this growth in robots are probably not justified, once full macroeconomic effects are taken into account. The evidence is clear: the current wave of robotization is tending to boost productivity and economic growth, generating new employment opportunities at a rate comparable to the pace of job destruction. We estimate that a 1% increase in the stock of robots per worker in the manufacturing sector leads to 0.1% boost to output per worker across the wider workforce.

Figure 1. Robot installations by country, 2000 to 2016

Note: US data included immaterial robot installation numbers for Mexico and Canada prior to 2010.



These increases are large enough to drive meaningful growth. A faster adoption of robots has a positive impact on both short- and medium-term growth. For example, boosting robot installations to 30% above the baseline forecast by 2030 would lead to an estimated 5.3% boost to global GDP in that year. This equates to adding an extra $4.9 trillion per year (in today's prices) to the global economy by 2030—equivalent to an economy greater than the projected size of Germany's.

Some 8.5% of global manufacturing jobs will disappear by 2030, amounting to 20 million jobs.

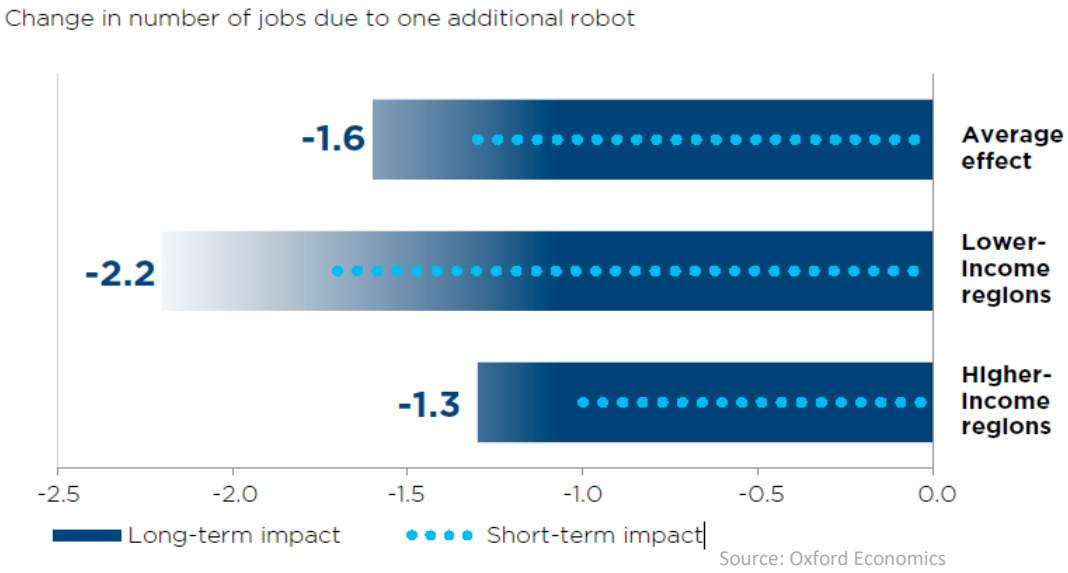
That said, there will be losses—large ones. We have calculated that each new industrial robot eliminates 1.6 manufacturing jobs on average, and that since the turn of the Millennium, newly-installed industrial robots have eliminated around 1.7 million jobs from the factory floor, world-wide. Looking forward, the pace of change and the numbers are both set to be much greater. We project that some 8.5 percent of global manufacturing employment will disappear by 2030, amounting to 20 million jobs.

IV. Regional impacts: the UK, France and Germany

A major concern has to be that the negative effects of industrial robotization will be felt disproportionately in regions of the globe's major economies that are already disadvantaged by lower average incomes and poorer life-chances. And this is not just because those regions have more manufacturing jobs to lose. We identify three factors to take into account, and have estimated the combined impact of all three:

- **Local dependence on manufacturing employment**—defined as the manufacturing share of total employment in the region.
- **Future readiness of local industry**—characterized by a region's current intensity of robot use in manufacturing, controlling for the type of manufacturing activity undertaken, and measured relative to international competitors.
- **Productivity of the local manufacturing workforce**—measured relative to the national average.

Figure 2. Manufacturing job losses skew towards lower-income regions

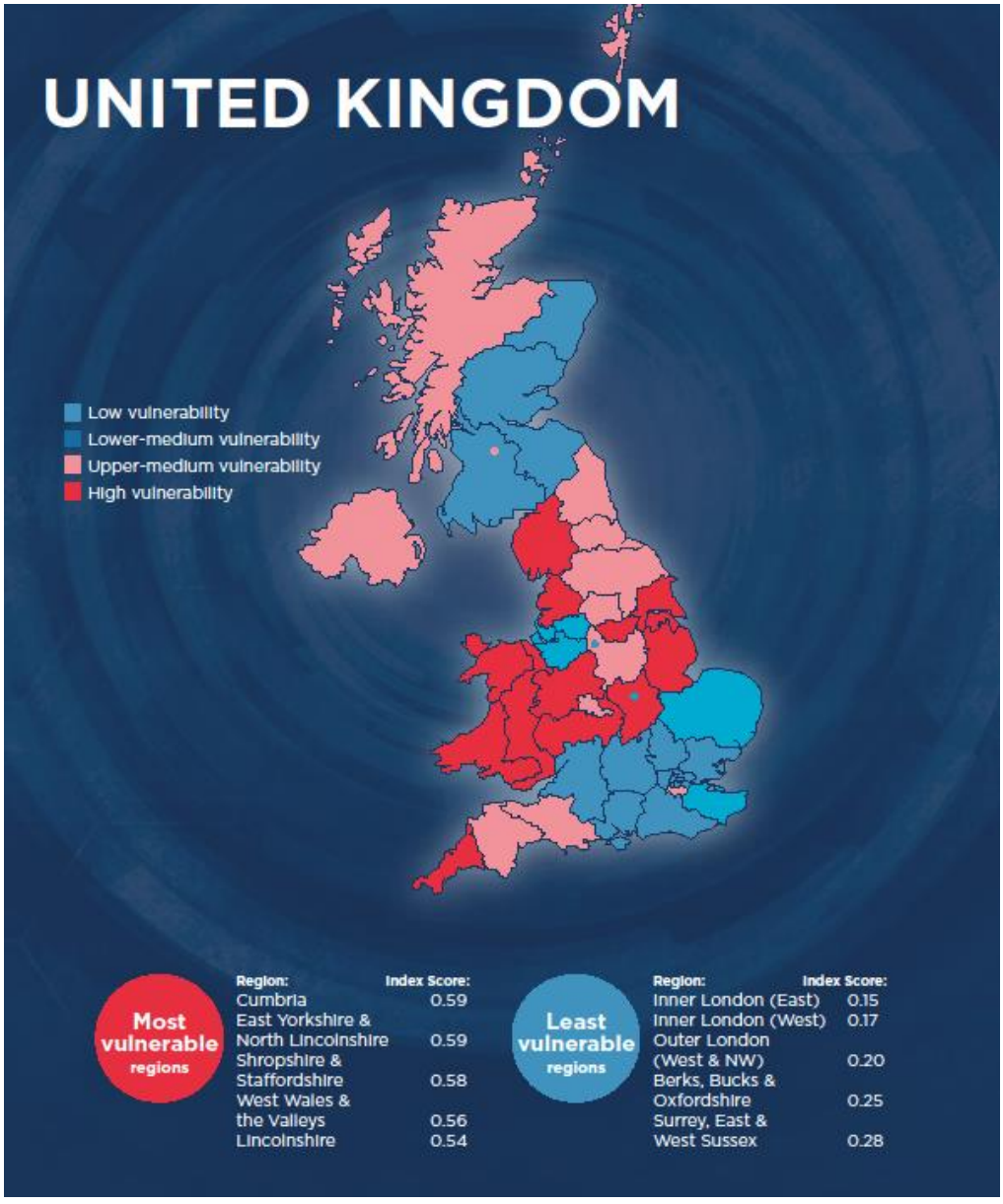


On average, a new robot displaces nearly twice as many jobs in a lower-income region compared with a higher-income region in the same country.

The effect of incorporating all three of these factors into the modelling is stark. We estimate that on average, a new robot displaces nearly twice as many jobs in a lower-income region compared with a higher-income region in the same country.

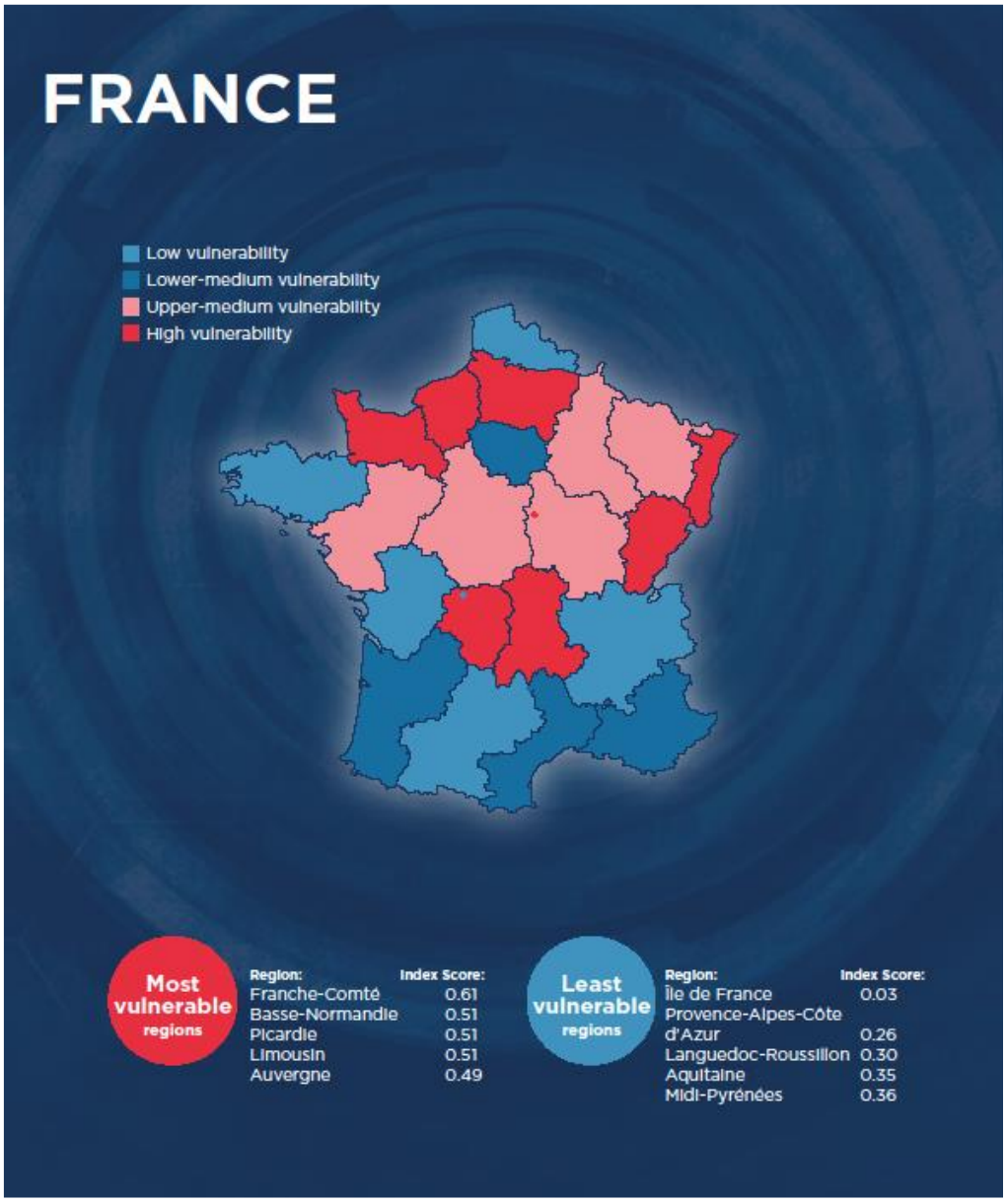
This signals a real danger, that the regional inequalities that exist within countries will be further exacerbated as robots become increasingly widespread. We have incorporated this notion into a Robot Vulnerability Index (RVI) which has allowed us to assess how different regions within several industrialized nations are likely to fare, in the years to come.

So, in the **UK** for example, there is a risk that the north-south divide will worsen. Inner London is (unsurprisingly) the least vulnerable part of the country to the rise of industrial robots, thanks to its service-based economy. But the South East region is similarly well-placed for the next phase of industrial automation, because manufacturing operations there tend to be more advanced and more automated than in other parts of the country, partly reflecting the higher cost of labour. By contrast, East Yorkshire and Northern Lincolnshire, Shropshire and Staffordshire, Cumbria, and West Wales and the Valleys exhibit the highest vulnerability scores in the UK. These regions are not just relatively dependent on manufacturing for employment: they also have a higher prevalence of lower-skilled labour.



And as we noted in the introduction, this is far from being a story just for the UK. For example, Île-de-France, centred on Paris, is **France**'s least-vulnerable region. It is least dependent on manufacturing jobs, and what manufacturing activity it does have is highly productive and already the most robot-intensive in the country, alongside Midi-Pyrénées. This means that it has already taken steps to introduce significant levels of automation in its bid to remain globally competitive.

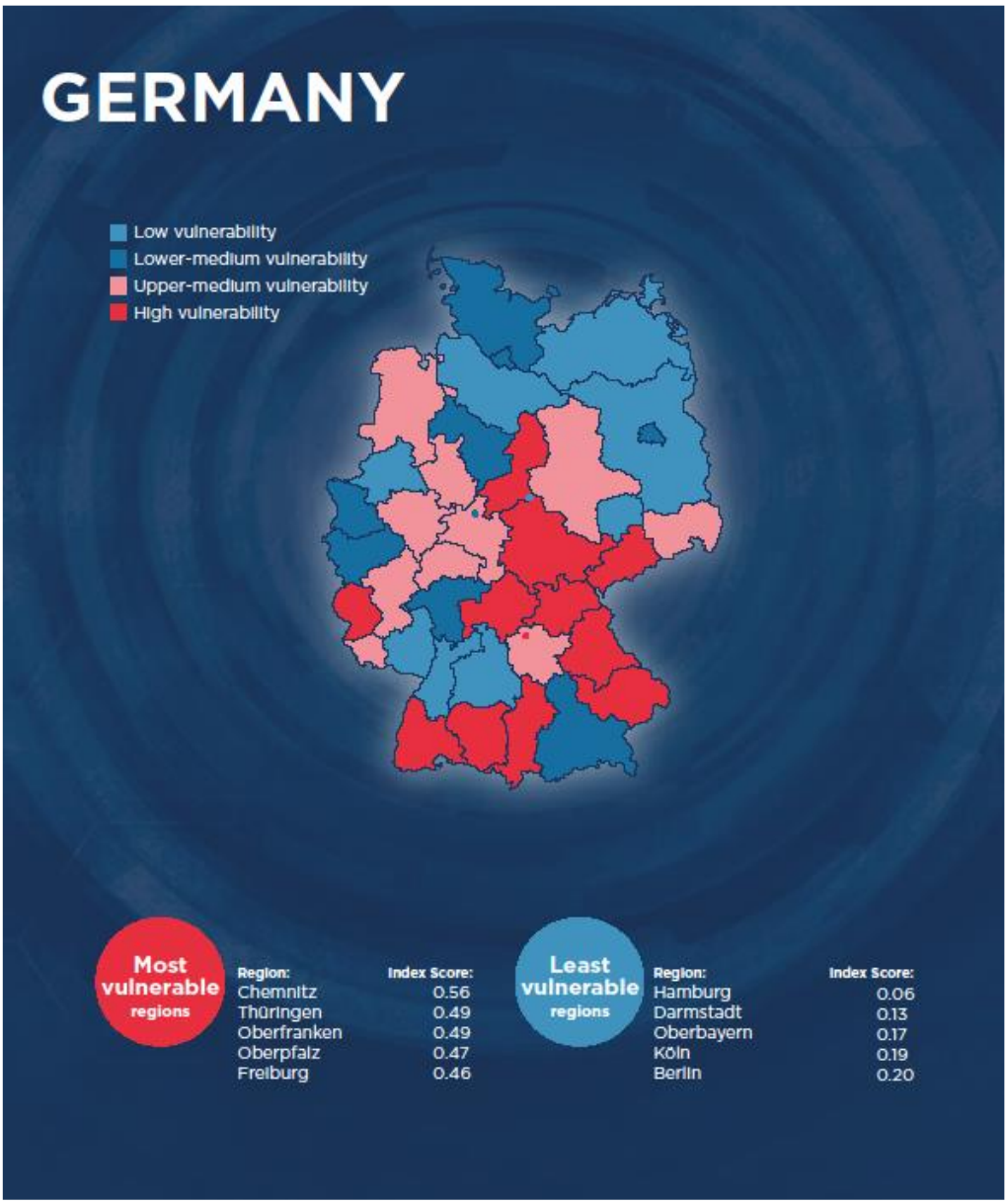
France's most southerly regions, plus Rhône-Alpes, are collectively the "runners-up" behind Paris in terms of their low vulnerability to displacement by robots. These regions are home to advanced high-tech manufacturing companies, notably in leading cities such



Franche-Comté is the French region most vulnerable to robotization. In Germany, it is a cluster of four eastern regions along the Czech border.

as Toulouse (home to Airbus, among others) and Grenoble. As a result, they already benefit from a future-ready and highly skilled workforce.

In contrast, the part of France that seems most vulnerable to robotization is Franche-Comté. This is France's most manufacturing-intensive region—an example of a globally under-recognized phenomenon in which relatively rural and sparsely populated places are often quite manufacturing intensive, essentially because the large service sectors associated with cities are much less prevalent there. In addition, Franche-Comté currently has a low rate of robotization. That means that high levels of automation could soon be introduced, making the region's workers particularly vulnerable to displacement.



Germany does not escape the same fate. Its least vulnerable region is Hamburg. The city has low dependency on manufacturing jobs, and what manufacturing it does have is typically advanced and highly productive, with cutting-edge levels of automation. (Again, Airbus is important, locally.) And the home regions of BMW and Mercedes—Bavaria and Stuttgart, respectively—are also examples of future-ready production ecosystems, featuring highly skilled, highly productive workforces. However, a cluster of four eastern regions close to the Czech border—Chemnitz, Thüringen, Oberfranken, and Oberpfalz—all look to be vulnerable to robotization. They have high concentrations of manufacturing employment, and low levels of productivity—particularly Chemnitz and Thüringen.

Regional patterns apparent across a broad range of nations

We could continue: similar stories apply in the United States and the other nations we have studied. Broadly speaking, three patterns tend to be present across diverse nations:

- **Existing inequalities are likely to intensify.** As discussed above, successful economic performance at the regional level in advanced economies is usually inversely correlated with robot vulnerability. Those regions that have performed best in recent years (in terms of overall GDP growth) are the least exposed to future robot automation, and vice versa. This means the regional inequalities that exist within countries could be further exacerbated as robots continue to expand within the workplace.

- **Many major cities are safe (for now).** Major cities are—so far—safe havens from robot-led job displacement. Diversified urban economies with abundant, high-paying service opportunities depend less heavily on manufacturing jobs, and higher labour costs mean manufacturers located there are already highly productive and tend to employ more highly skilled workers. London, Paris and New York typify these sorts of cities. But manufacturing-intensive cities face a less secure future: those with large populations that are more dependent on the manufacturing sector for employment but lag industry peers in robot intensity and labour productivity are quite vulnerable to disruption. Fierce competition will ultimately lead these city-based industries to pursue further automation or risk losing out to more productive competitors elsewhere. Either way, additional job displacement of current manufacturing workers is likely.

- **Rural regions mask hidden vulnerabilities.** The pockets of workers most vulnerable to automation can often be found in rural areas. Despite relatively sparse populations, these regional economies tend to be heavily linked to isolated towns with more manufacturing-intensive industrial structures on which the wider region depends. This is especially problematic when manufacturing in these towns is characterized by traditional, labour-intensive techniques, low levels of productivity, and dated manufacturing processes.

V. "Safety valve" jobs are likely to become less available

There is also the possibility that the challenge is greater than we are projecting. The analysis described above relates specifically to the use of industrial robots in the manufacturing sector—a focus that reflects the availability of robust, consistent, data across different economies. Within it, there is a more detailed story in which robots spread within manufacturing, from sub-sectors where they started out such as automotives to others such as food-processing.

But what of the spread to the service sector? Robots are already widespread in logistics, but innovations in engineering and machine-learning, and the shift towards digital delivery of services, means that jobs in transport, health care, legal services and many other parts of the service sector may also be under threat. Indeed, some pundits suggest that artificial intelligence (AI) represents an existential threat to mankind.

To get a handle on this, we analysed the job-moves of more than 35,000 individuals across the US, over the past two decades. The data suggests that more than half of the workers who left production jobs in that period were absorbed into just three occupational categories: transport, such as driving trucks or taxis; construction and maintenance; and office and administrative work.

The three "safety-valve" occupations of transport, construction & maintenance and office & administrative work are among the most vulnerable.

But our vocational analysis finds, alarmingly, that these three "safety valve" occupations are among the most vulnerable to automation over the next decade. So, in the future, a worker laid off from a processing plant might not find it possible to become a taxi driver or a trucker, if autonomous vehicles, powered by next generation AI and robotics, take over that sort of labour.

This is an area where research today involves as much speculation as evidence. But what does seem likely is that, among displaced manufacturing workers, a significant gap will exist between those whose skills are primarily technical or vocational, and those with stronger "human skills", with the latter possessing distinct advantages over robots. These

skills are typically thought to include negotiation, persuasion, social intelligence and empathy. This is not necessarily a "high" versus "low" skill distinction: jobs such as defense attorney will probably escape robotization, but so too may such occupations as social worker or even concierge. But whether those jobs will be easily accessible to displaced workers, and also to young people entering the labour market, is a moot point. Here too, geography may well be decisive—and with big social but also political implications.

VI. How policy makers might respond

Going forward, the spread of robots may be just one of several factors aggravating social and economic stresses that are already generating political turmoil and upheaval in a number of nations around the world, and adding to resentment against globalization and long-established political orders.

Citizens increasingly perceive gaps in outcomes, opportunities and fairness. Robotization threatens to make the gaps worse.

In that context the 2019 election results in the UK can easily be seen as part of a larger international phenomenon, that extends from Brexit to Donald Trump's rallying cry to "make America great again", and to that country's trade dispute with China. Other instances are the gilet jeune movement in France and the rise of parties such as Five Star in Italy. Citizens perceive widening gaps in outcomes, opportunities and fairness. And they also perceive a neglect of that problem, by their political leaders. Robotization threatens to make these gaps worse.

However, electoral pressures mean that it is realistic to think that politicians will seek to respond. The recent announcements by the new UK government, mentioned in the introduction, are an obvious example. But the question of what policy makers can actually do is a hard one. The possibility that the challenge will not be fully met is therefore real.

We return to our basic point: that although on average, a new robot displaces nearly twice as many jobs in a lower-income region compared with a higher-income region in the same country, robots nevertheless increase incomes overall. It would therefore be unfortunate if policy-makers and others sought to frustrate the adoption of robot technology—not least because, as with trade wars, such efforts are highly likely to be self-defeating.

If instead the challenge is to distribute the robotics dividend more evenly, then a politically obvious approach (although not necessarily an economically appropriate one) would involve some combination of **taxes and subsidies**. In 2016 a draft regulation presented to the European Parliament by its committee on legal affairs proposed that robot workers be classified as "electronic persons" and their owners be liable to pay social security for

If the challenge is to distribute the robotics dividend more evenly, then a politically obvious approach (although not necessarily an economically appropriate one) would involve some combination of taxes and subsidies.

them. A similar tax idea was proposed by a socialist candidate Benoit Harmon in France's last presidential election, who said the additional value created when a robot replaces a human should be taxed. Likewise, ideas of a Universal Basic Income (UBI), or negative tax policies to support those dislocated by robotization, have gained support in a number of countries.

A different approach is to **tax, not the users of the new technology, but its producers**. The argument for that is more powerful if, as is likely, those companies are earning monopoly rents. The problems here are familiar: the threat that innovations will be suppressed, and the difficulty of levying such taxes at the national rather than international level. Nevertheless, there must be a good chance that this becomes a policy option that gains (rightly or wrongly) increasing popular and political support—instead of or alongside measures to more tightly regulate, or even break-up, the companies concerned.

A softer variation on that might be to expect technology companies to develop **industry-wide initiatives to invest in human capital**, for example, by committing to share a portion of their profits to fund community-wide training programmes. As part of that they could partner with government and educational institutions, to take more responsibility for worker retraining and coaching.

Governments should help vulnerable workers, and perhaps regions, prepare for the upheaval that the spread of robots is likely to bring.

More generally, it seems appropriate that **governments should help vulnerable workers prepare** for, and adapt to, the upheaval that the spread of robots is likely to bring. There are different routes to this. Most countries load their spending on education and skills very heavily towards the young. But some shift towards greater spending on lifetime learning might radically ease the transition to more robot-intensive economies. That is true both for the state and the individual, with retraining and upskilling perhaps becoming a more normal part of the employment landscape. Serious econometric analysis of the benefits of reallocating an element of expenditure in this way might be helpful to policy-makers—but only if it takes a forward-looking rather than retrospective perspective.

On a similar theme, the European Union has a long history of providing support to regions that have been hit by past de-industrialisation. There is a certain logic to offering such **support to regions vulnerable to similar pressures in the future**. By using the kind of analysis that we have summarized here, it is possible that governments will be able to identify regions most vulnerable to dislocation from the rise of robots. And they can then develop aggressive, forward-thinking, programmes to counteract those effects.

As robots seem certain to become more a part of our daily lives, recognizing and counteracting at least some of the displacement effects that we expect to witness will be critical, if the dividends of the growth that they generate are to be more equally shared.