Introduction

The potential for disruption to labour markets due to advances in technology is not a new phenomenon. Most famously, the Luddite protest movement of the early 19th century was a backlash by skilled handloom weavers against the mechanisation of the British textile industry that emerged as part of the Industrial Revolution (including the Jacquard loom, which with its punch card system was in some respects a forerunner of the modern computer). But, in the long run, not only were there still many (if, on average, less skilled) jobs in the new textile factories but, more important, the productivity gains from mechanisation created huge new wealth. This in turn generated many more jobs across the UK economy in the long run than were initially lost in the traditional handloom weaving industry.

The standard economic view for most of the last two centuries has therefore been that the Luddites were wrong about the long-term benefits of the new technologies, even if they were right about the short-term impact on their personal livelihoods. Anyone putting such arguments against new technologies has generally been dismissed as believing in the 'Luddite fallacy'.

However, over the past few years, fears of technology-driven job losses have re-emerged with advances in 'smart automation' – the combination of AI, robotics and other digital technologies that is already producing innovations like driverless cars and trucks, intelligent virtual assistants like Siri, Alexa and Cortana, and Japanese healthcare robots.

While traditional machines, including fixed location industrial robots, replaced our muscles (and those of other animals like horses and oxen), these new smart machines have the potential to replace our minds and to move around freely in the world driven by a combination of advanced sensors, GPS tracking systems and deep learning – if not now, then probably within the next decade or two. Will this just have the same effects as past technological leaps – short term disruption more than offset by long term economic gains? Or is this something more fundamental in terms of taking humans out of the loop not just in manufacturing and routine service sector jobs, but more broadly across the economy? What exactly will humans have to offer employers if smart machines can perform all or most of their essential tasks better in the future11? In short, has the 'Luddite fallacy' finally come true?

This debate was given added urgency in 2013 when researchers at Oxford University (Frey and Osborne, 2013) estimated that around 47% of total US employment had a 'high risk of computerisation' over the next couple of decades – i.e. by the early 2030s.

However, there are also dissenting voices. Notably, Arntz, Gregory and Zierahn (OECD, 2016) re-examined the research by Frey and Osborne and, using an extensive new OECD data set, came up with a much lower estimate that only around 10% of jobs were under a 'high risk of computerisation'. This is based on the reasoning that any predictions of job automation should consider the specific tasks that are involved in each job rather than the occupation as a whole.

In an earlier article in March 2017 we produced our own analysis of the potential effect of automation on jobs with a focus on the UK. Using a more refined version of the OECD methodology, we concluded that up to 30% of UK jobs could be impacted by automation by the 2030s. We also produced high level comparisons suggesting somewhat lower potential automation rates in Japan and somewhat higher rates in Germany and the US.

At the same time, we also emphasised that various economic, legal and regulatory and organisational factors mean that these potential risks may not lead to actual job displacement. In some cases, it would alter the nature of jobs significantly, but not displace humans entirely.

Furthermore, we emphasised that there were likely to be broadly offsetting job gains from the new technologies, provided that the income and wealth gains from these advances were recycled into the economy. This qualitative judgement was backed up by later detailed quantitative modelling that concluded that the net long term job impact of automation would be likely to be neutral or even slightly positive. This will, however, require both business and governments to provide support to workers affected by these technological advances to retrain and start new careers.

In this paper, we extend our March 2017 analysis of jobs at potential risk of automation to a much wider set of countries, using the OECD's PIAAC database for 29 countries (27 from the OECD, plus Singapore and Russia). In total, this covers the jobs of over 200,000 workers and so provides a much larger dataset to explore potential impacts of automation by country, sector and type of worker. The additional data also allows us to provide a more robust analysis of the factors causing automation risk to vary across countries and sectors.

We also identify how this process might unfold over the period to the 2030s in three overlapping waves:

1. **Algorithm wave**: focused on automation of simple computational tasks and analysis of structured data in areas like finance, information and communications – this is already well underway.
2. **Augmentation wave**: focused on automation of repeatable tasks such as filling in forms, communicating and exchanging information through dynamic technological support, and statistical analysis of unstructured data in semi-controlled environments such as aerial drones and robots in warehouses – this is also underway, but is likely to come to full maturity in the 2020s.
3. **Autonomy wave**: focused on automation of physical labour and manual dexterity, and problem solving in dynamic real-world situations that require responsive actions, such as in manufacturing and transport (e.g. driverless vehicles) – these technologies are under development already, but may only come to full maturity on an economy-wide scale in the 2030s.

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