

The third great wave

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Technology isn't working. The digital revolution has yet to fulfil its promise of higher productivity and better jobs

IF THERE IS a technological revolution in progress, rich economies could be forgiven for wishing it would go away. Workers in America, Europe and Japan have been through a difficult few decades. In the 1970s the blistering growth after the second world war vanished in both Europe and America. In the early 1990s Japan joined the slump, entering a prolonged period of economic stagnation. Brief spells of faster growth in intervening years quickly petered out. The rich world is still trying to shake off the effects of the 2008 financial crisis. And now the digital economy, far from pushing up wages across the board in response to higher productivity, is keeping them flat for the mass of workers while extravagantly rewarding the most talented ones.

Between 1991 and 2012 the average annual increase in real wages in Britain was 1.5% and in America 1%, according to the Organisation for Economic Co-operation and Development, a club of mostly rich countries. That was less than the rate of economic growth over the period and far less than in earlier decades. Other countries fared even worse. Real wage growth in Germany from 1992 to 2012 was just 0.6%; Italy and Japan saw hardly any increase at all. And, critically, those averages conceal plenty of variation. Real pay for most workers remained flat or even fell, whereas for the highest earners it soared.

It seems difficult to square this unhappy experience with the extraordinary technological progress during that period, but the same thing has happened before. Most economic historians reckon there was very little improvement in living standards in Britain in the century after the first Industrial Revolution. And in the early 20th century, as Victorian inventions such as electric lighting came into their own, productivity growth was every bit as slow as it has been in recent decades.

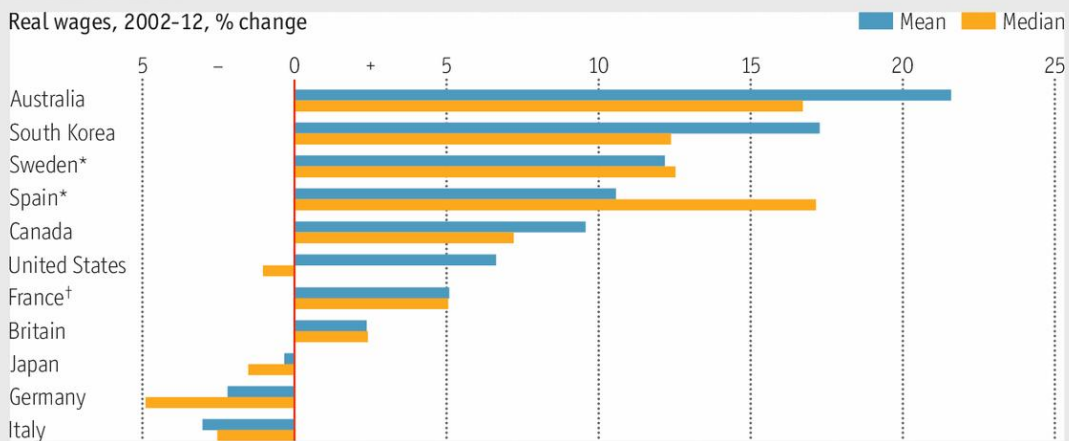
In July 1987 Robert Solow, an economist who went on to win the Nobel prize for economics just a few months later, wrote a book review for the *New York Times*. The book in question, "The Myth of the Post-Industrial Economy", by Stephen Cohen and John Zysman, lamented the shift of the American workforce into the service sector and explored the reasons why American manufacturing seemed to be losing out to competition from abroad. One problem, the authors reckoned, was that America was failing to take full advantage of the magnificent new technologies of the computing age, such as increasingly sophisticated automation and much-improved robots. Mr Solow commented that the authors, "like everyone else, are somewhat embarrassed by the fact that what everyone feels to have been a technological revolution...has been accompanied everywhere...by a slowdown in productivity growth".

This failure of new technology to boost productivity (apart from a brief period between 1996 and 2004) became known as the Solow paradox. Economists disagree on its causes. Robert Gordon of Northwestern University suggests that recent innovation is simply less impressive than it seems, and certainly not powerful enough to offset the effects of demographic change, inequality and sovereign indebtedness. Progress in ICT, he argues, is less transformative than any of the three major technologies of the second Industrial Revolution (electrification, cars and wireless communications).

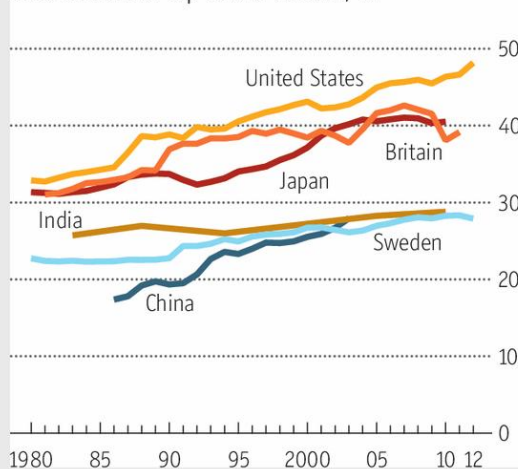
Get used to it

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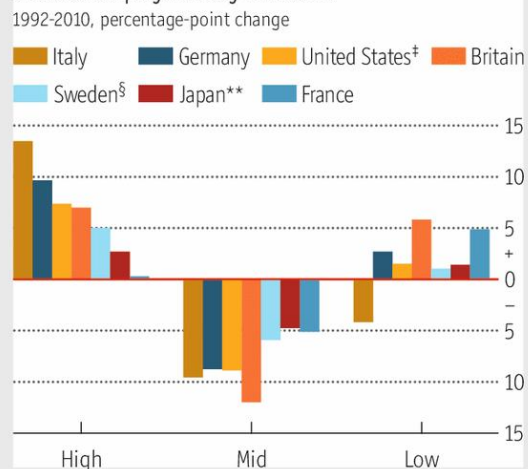
Real wages, 2002-12, % change



Income share of top 10% of earners, %



Share of employment by skill level



Sources: OECD; World Top Incomes Database; World Bank; ILO; BLS; *The Economist*

*2004-12 †2002-10 ‡Estimate based on two series §1997-2010 **1990-2008

Yet the timing does not seem to support Mr Gordon's argument. The big leap in American economic growth took place between 1939 and 2000, when average output per person grew at 2.7% a year. Both before and after that period the rate was a lot lower: 1.5% from 1891 to 1939 and 0.9% from 2000 to 2013. And the dramatic dip in productivity growth after 2000 seems to have coincided with an apparent acceleration in technological advances as the web and smartphones spread everywhere and machine intelligence and robotics made rapid progress.

Have patience

A second explanation for the Solow paradox, put forward by Erik Brynjolfsson and Andrew McAfee (as well as plenty of techno-optimists in Silicon Valley), is that technological advances increase productivity only after a long lag. The past four decades have been a period of gestation for ICT during which processing power exploded and costs tumbled, setting the stage for a truly transformational phase that is only just beginning (signalling the start of the second half of the chessboard).

That sounds plausible, but for now the productivity statistics do not bear it out. John Fernald, an economist at the Federal Reserve Bank of San Francisco and perhaps the foremost authority on American productivity figures, earlier this year published a study of productivity growth over the past decade. He found that its slowness had nothing to do with the housing boom and bust, the financial crisis or the recession. Instead, it was concentrated in ICT industries and those that use ICT intensively.

That may be the wrong place to look for improvements in productivity. The service sector might be more promising. In higher education, for example, the development of online courses could yield a productivity bonanza, allowing one professor to do the work previously done by legions of lecturers. Once an online course has been developed, it can be offered to unlimited numbers of extra students at little extra cost.

Similar opportunities to make service-sector workers more productive may be found in other fields. For example, new techniques and technologies in medical care appear to be slowing the rise in health-care costs in America. Machine intelligence could aid diagnosis, allowing a given doctor or nurse to diagnose more patients more effectively at lower cost. The use of mobile technology to monitor chronically ill patients at home could also produce huge savings.

Such advances should boost both productivity and pay for those who continue to work in the industries concerned, using the new technologies. At the same time those services should become cheaper for consumers. Health care and education are expensive, in large part, because expansion involves putting up new buildings and filling them with costly employees. Rising productivity in those sectors would probably cut employment.



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The world has more than enough labour. Between 1980 and 2010, according to the McKinsey Global Institute, global nonfarm employment rose by about 1.1 billion, of which about 900m was in developing countries. The integration of large emerging markets into the global economy added a large pool of relatively low-skilled labour which many workers in rich countries had to compete with. That meant firms were able to keep workers' pay low. And low pay has had a surprising knock-on effect: when labour is cheap and plentiful, there seems little point in investing in labour-saving (and productivity-enhancing) technologies. By creating a labour glut, new technologies have trapped rich economies in a cycle of self-limiting productivity growth.

Fear of the job-destroying effects of technology is as old as industrialisation. It is often branded as the lump-of-labour fallacy: the belief that there is only so much work to go round (the lump), so that if machines (or foreigners) do more of it, less is left for others. This is deemed a fallacy because as technology displaces workers from a particular occupation it enriches others, who spend their gains on goods and services that create new employment for the workers whose jobs have been automated away. A critical cog in the re-employment machine, though, is pay. To clear a glutted market, prices must fall, and that applies to labour as much as to wheat or cars.

Where labour is cheap, firms use more of it. Carmakers in Europe and Japan, where it is expensive, use many more industrial robots than in emerging countries, though China is beginning to invest heavily in robots as its labour costs rise. In Britain a bout of high

inflation caused real wages to tumble between 2007 and 2013. Some economists see this as an explanation for the unusual shape of the country's recovery, with employment holding up well but productivity and GDP performing abysmally.

Productivity growth has always meant cutting down on labour. In 1900 some 40% of Americans worked in agriculture, and just over 40% of the typical household budget was spent on food. Over the next century automation reduced agricultural employment in most rich countries to below 5%, and food costs dropped steeply. But in those days excess labour was relatively easily reallocated to new sectors, thanks in large part to investment in education. That is becoming more difficult. In America the share of the population with a university degree has been more or less flat since the 1990s. In other rich economies the proportion of young people going into tertiary education has gone up, but few have managed to boost it much beyond the American level.

At the same time technological advances are encroaching on tasks that were previously considered too brainy to be automated, including some legal and accounting work. In those fields people at the top of their profession will in future attract many more clients and higher fees, but white-collar workers with lower qualifications will find themselves displaced and may in turn displace others with even lesser skills.

Lift out of order

A new paper by Peter Cappelli, of the University of Pennsylvania, concludes that in recent years over-education has been a consistent problem in most developed economies, which do not produce enough suitable jobs to absorb the growing number of college-educated workers. Over the next few decades demand in the top layer of the labour market may well centre on individuals with high abstract reasoning, creative, and interpersonal skills that are beyond most workers, including graduates.

Most rich economies have made a poor job of finding lucrative jobs for workers displaced by technology, and the resulting glut of cheap, underemployed labour has given firms little incentive to make productivity-boosting investments. Until governments solve that problem, the productivity effects of this technological revolution will remain disappointing. The impact on workers, by contrast, is already blindingly clear.

The first two industrial revolutions inflicted plenty of pain but ultimately benefited everyone. The digital one may prove far more divisive, argues Ryan Avent



MOST PEOPLE ARE discomfited by radical change, and often for good reason. Both the first Industrial Revolution, starting in the late 18th century, and the second one, around 100 years later, had their victims who lost their jobs to Cartwright's power loom and later to Edison's electric lighting, Benz's horseless carriage and countless other inventions that changed the world. But those inventions also immeasurably improved many people's lives,

sweeping away old economic structures and transforming society. They created new economic opportunity on a mass scale, with plenty of new work to replace the old.

A third great wave of invention and economic disruption, set off by advances in computing and information and communication technology (ICT) in the late 20th century, promises to deliver a similar mixture of social stress and economic transformation. It is driven by a handful of technologies—including machine intelligence, the ubiquitous web and advanced robotics—capable of delivering many remarkable innovations: unmanned vehicles; pilotless drones; machines that can instantly translate hundreds of languages; mobile technology that eliminates the distance between doctor and patient, teacher and student. Whether the digital revolution will bring mass job creation to make up for its mass job destruction remains to be seen.

Powerful, ubiquitous computing was made possible by the development of the integrated circuit in the 1950s. Under a rough rule of thumb known as Moore's law (after Gordon Moore, one of the founders of Intel, a chipmaker), the number of transistors that could be squeezed onto a chip has been doubling every two years or so. This exponential growth has resulted in ever smaller, better and cheaper electronic devices. The smartphones now carried by consumers the world over have vastly more processing power than the supercomputers of the 1960s.

Moore's law is now approaching the end of its working life. Transistors have become so small that shrinking them further is likely to push up their cost rather than reduce it. Yet commercially available computing power continues to get cheaper. Both Google and Amazon are slashing the price of cloud computing to customers. And firms are getting much better at making use of that computing power. In a book published in 2011, "Race Against the Machine", Erik Brynjolfsson and Andrew McAfee cite an analysis suggesting that between 1988 and 2003 the effectiveness of computers increased 43m-fold. Better processors accounted for only a minor part of this improvement. The lion's share came from more efficient algorithms.

The beneficial effects of this rise in computing power have been slow to come through. The reasons are often illustrated by a story about chessboards and rice. A man invents a new game, chess, and presents it to his king. The king likes it so much that he offers the inventor a reward of his choice. The man asks for one grain of rice for the first square of his chessboard, two for the second, four for the third and so on to 64. The king readily agrees, believing the request to be surprisingly modest. They start counting out the rice, and at first the amounts are tiny. But they keep doubling, and soon the next square already requires the output of a large ricefield. Not long afterwards the king has to concede defeat: even his vast riches are insufficient to provide a mountain of rice the size of Everest. Exponential growth, in other words, looks negligible until it suddenly becomes unmanageable.

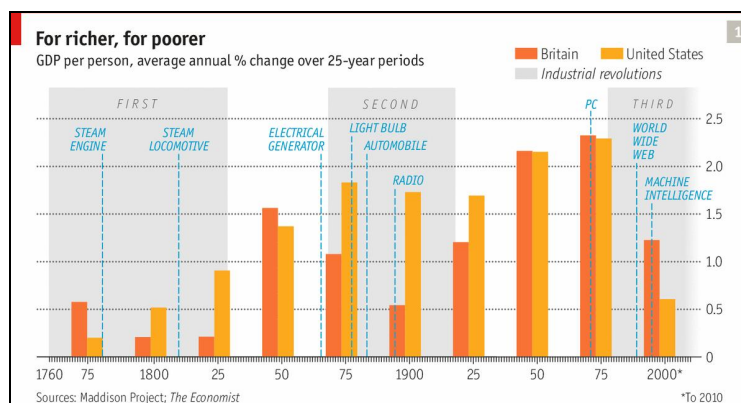
Messrs Brynjolfsson and McAfee argue that progress in ICT has now brought humanity to the start of the second half of the chessboard. Computing problems that looked insoluble a few years ago have been cracked. In a book published in 2005 Frank Levy and Richard Murnane, two economists, described driving a car on a busy street as such a complex task that it could not possibly be mastered by a computer. Yet only a few years later Google unveiled a small fleet of driverless cars. Most manufacturers are now developing autonomous or near-autonomous vehicles. A critical threshold seems to have been crossed, allowing programmers to use clever algorithms and massive amounts of cheap processing power to wring a semblance of intelligence from circuitry.

Evidence of this is all around. Until recently machines have found it difficult to "understand" written or spoken language, or to deal with complex visual images, but now they seem to be getting to grips with such things. Apple's Siri responds accurately to

many voice commands and can take dictation for e-mails and memos. Google's translation program is lightning-fast and increasingly accurate, and the company's computers are becoming better at understanding just what its cameras (as used, for example, to compile Google Maps) are looking at.

At the same time hardware, from processors to cameras to sensors, continues to get better, smaller and cheaper, opening up opportunities for drones, robots and wearable computers. And innovation is spilling into new areas: in finance, for example, cryptocurrencies like Bitcoin hint at new payment technologies, and in education the development of new and more effective online offerings may upend the business of higher education.

This wave, like its predecessors, is likely to bring vast improvements in living standards and human welfare, but history suggests that society's adjustment to it will be slow and difficult. At the turn of the 20th century writers conjured up visions of a dazzling technological future even as some large, rich economies were limping through a period of disappointing growth in output and productivity. Then, as now, economists hailed a new age of globalisation even as geopolitical tensions rose. Then, as now, political systems struggled to accommodate the demands of growing numbers of dissatisfied workers.



Some economists are offering radical thoughts on the job-destroying power of this new technological wave. Carl Benedikt Frey and Michael Osborne, of Oxford University, recently analysed over 700 different occupations to see how easily they could be computerised, and concluded that 47% of employment in America is at high risk of being automated away over the next decade or two. Messrs Brynjolfsson and McAfee ask whether human workers will be able to upgrade their skills fast enough to justify their continued employment. Other authors think that capitalism itself may be under threat.

The global eclipse of labour

This special report will argue that the digital revolution is opening up a great divide between a skilled and wealthy few and the rest of society. In the past new technologies have usually raised wages by boosting productivity, with the gains being split between skilled and less-skilled workers, and between owners of capital, workers and consumers. Now technology is empowering talented individuals as never before and opening up yawning gaps between the earnings of the skilled and the unskilled, capital-owners and labour. At the same time it is creating a large pool of underemployed labour that is depressing investment.

The effect of technological change on trade is also changing the basis of tried-and-true methods of economic development in poorer economies. More manufacturing work can be automated, and skilled design work accounts for a larger share of the value of trade, leading to what economists call "premature deindustrialisation" in developing countries. No longer can governments count on a growing industrial sector to absorb unskilled labour from rural areas. In both the rich and the emerging world, technology is creating

opportunities for those previously held back by financial or geographical constraints, yet new work for those with modest skill levels is scarce compared with the bonanza created by earlier technological revolutions.

All this is sorely testing governments, beset by new demands for intervention, regulation and support. If they get their response right, they will be able to channel technological change in ways that broadly benefit society. If they get it wrong, they could be under attack from both angry underemployed workers and resentful rich taxpayers. That way lies a bitter and more confrontational politics.

Wealth without workers, workers without wealth

The digital revolution is bringing sweeping change to labour markets in both rich and poor worlds

TECHNOLOGICAL revolutions are best appreciated from a distance. The great inventions of the 19th century, from electric power to the internal-combustion engine, transformed the human condition. Yet for workers who lived through the upheaval, the experience of industrialisation was harsh: full of hard toil in crowded, disease-ridden cities.

The modern digital revolution—with its hallmarks of computer power, connectivity and data ubiquity—has brought iPhones and the internet, not crowded tenements and cholera. But, as our special report explains, it is disrupting and dividing the world of work on a scale not seen for more than a century. Vast wealth is being created without many workers; and for all but an elite few, work no longer guarantees a rising income.

Computers that can do your job and eat your lunch

So far, the upheaval has been felt most by low- and mid-skilled workers in rich countries. The incomes of the highly educated—those with the skills to complement computers—have soared, while pay for others lower down the skill ladder has been squeezed. In half of all OECD countries real median wages have stagnated since 2000. Countries where employment is growing at a decent clip, such as Germany or Britain, are among those where wages have been squeezed most.

In the coming years the disruption will be felt by more people in more places, for three reasons. First, the rise of machine intelligence means more workers will see their jobs threatened. The effects will be felt further up the skill ladder, as auditors, radiologists and researchers of all sorts begin competing with machines. Technology will enable some doctors or professors to be much more productive, leaving others redundant.

Second, wealth creation in the digital era has so far generated little employment. Entrepreneurs can turn their ideas into firms with huge valuations and hardly any staff. Oculus VR, a maker of virtual-reality headsets with 75 employees, was bought by Facebook earlier this year for \$2 billion. With fewer than 50,000 workers each, the giants of the modern tech economy such as Google and Facebook are a small fraction of the size of the 20th century's industrial behemoths.

Third, these shifts are now evident in emerging economies. Foxconn, long the symbol of China's manufacturing economy, at one point employed 1.5m workers to assemble electronics for Western markets. Now, as the costs of labour rise and those of automated manufacturing fall, Foxconn is swapping workers for robots. China's future is more Alibaba than assembly line: the e-commerce company that recently made a spectacular debut on the New York Stock Exchange employs only 20,000 people.

The digital transformation seems to be undermining poor countries' traditional route to catch-up growth. Moving the barely literate masses from fields to factories has become harder. If India, for instance, were to follow China's development path, it would need skilled engineers and managers to build factories to employ millions of manufacturing workers. But, thanks to technological change, its educated elite is now earning high salaries selling IT services to foreigners. The digital revolution has made an industrial one uneconomic.

Bridging the gap

None of this means that the digital revolution is bad for humanity. Far from it. This newspaper believes firmly that technology is, by and large, an engine of progress. IT has transformed the lives of billions for the better, often in ways that standard income measures do not capture. Communication, knowledge and entertainment have become all but free. Few workers would want to go back to a world without the internet, the smartphone or Facebook, even for a pay increase. Technology also offers new ways to earn a living. Etsy, an online marketplace for arts and crafts, enables hobbyists to sell their wares around the world. Uber, the company that is disrupting the taxi business, allows tens of thousands of drivers to work as and when they want.

Nonetheless, the growing wedge between a skilled elite and ordinary workers is worrying. Angry voters whose wages are stagnant will seek scapegoats: witness the rise of xenophobia and protectionism in the rich world. In poor countries dashed expectations and armies of underemployed people are a recipe for extremism and unrest. Governments across the globe therefore have a huge interest in helping remove the obstacles that keep workers from wealth.

The answer is not regulation or a larger state. High minimum wages will simply accelerate the replacement of workers by machines. Punitive tax rates will deter entrepreneurship and scare off the skilled on whom prosperity in the digital era depends. The best thing governments can do is to raise the productivity and employability of less-skilled workers. That means getting rid of daft rules that discourage hiring, like protections which make it difficult to sack poor performers. It means better housing policy and more investment in transport, to help people work in productive cities such as London and Mumbai. It means revamping education. Not every worker can or should complete an advanced degree, but too many people in poor countries still cannot read and too many in rich ones fail to complete secondary school. In future, education should not be just for the young: adults will need lifetime learning if they are to keep up with technological change.

Yet although governments can mitigate the problem, they cannot solve it. As technology progresses and disrupts more jobs, more workers will be employable only at lower wages. The modest earnings of the generation that technology leaves behind will need to be topped up with tax credits or wage subsidies. That need not mean imposing higher tax rates on the affluent, but it does mean closing the loopholes and cutting the giveaways from which they benefit.

In the 19th century, it took the best part of 100 years for governments to make the investment in education that enabled workers to benefit from the industrial revolution. The digital revolution demands a similarly bold, but swifter, response.