

The third great wave



The third great wave

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

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A list of sources is at Economist.com/specialreports

An audio interview with the author is at Economist.com/audiovideo/specialreports

► 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, crypto-currencies 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

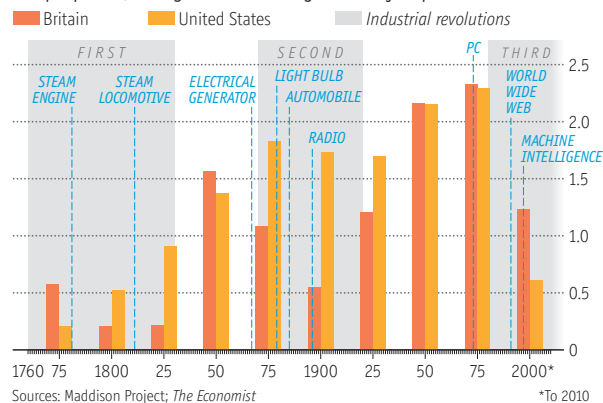


The digital revolution is opening up a great divide between a skilled and wealthy few and the rest of society

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

For richer, for poorer

GDP per person, average annual % change over 25-year periods



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. ■

Productivity

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 slow-down 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).

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.

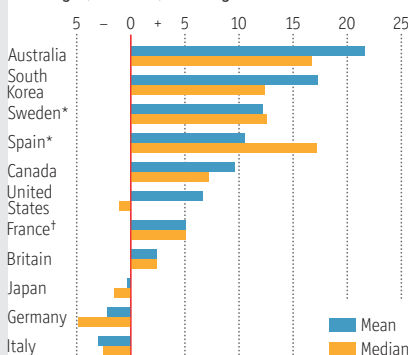
Have patience

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

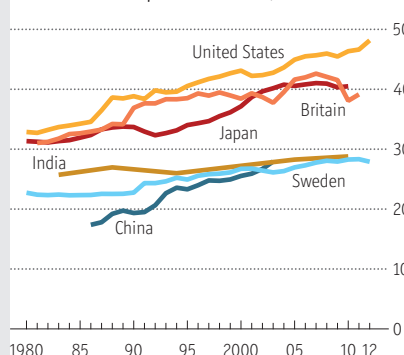
Get used to it

Real wages, 2002-12, % change



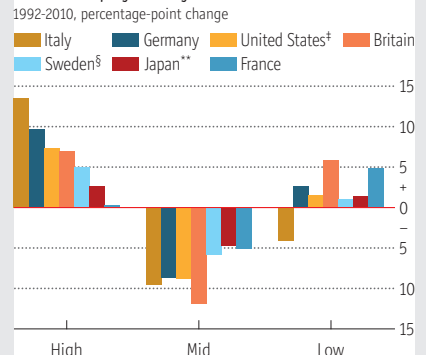
Sources: OECD; World Top Incomes Database; World Bank; ILO; BLS; *The Economist*

Income share of top 10% of earners, %



*2004-12

Share of employment by skill level



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

Interactive: For more countries and other labour-market indicators see Economist.com/worldecon14

► 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.

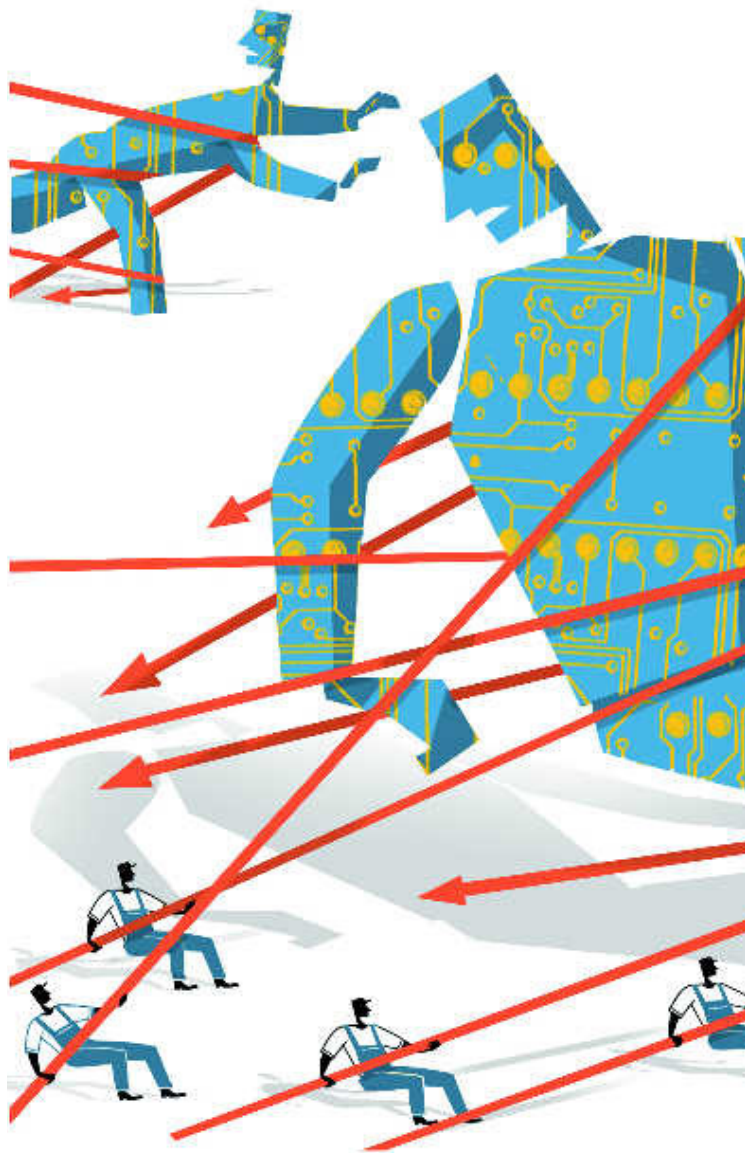
Such advances should boost both productivity and pay for those who continue to work in the industries concerned, using the new technologies. At the same time those services should become cheaper for consumers. Health care and education are expensive, in large part, because expansion involves putting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

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 privileged few

To those that have shall be given

Labour is steadily losing out to capital

JUST ACROSS THE road from Gothenburg's main railway station, at the foot of a pair of hotels, a line of taxis is waiting to pick up passengers. The drivers, all men, many of them immigrants, chat and lean against their vehicles, mostly Volvos. One of them, an older man with an immaculate cab, ferries your correspondent to Volvo's headquarters on the other side of the river. Another car is waiting there, a gleaming new model with unusual antennae perched on two corners of its roof. An engineer gets in and drives the car onto a main commuter route. Then he takes his hands off the wheel.

Volvo, like many car manufacturers, is putting a lot of work into automated vehicle technology. Such efforts have been going on for some time and were responsible for the development of power steering, automatic transmissions and cruise control. In the 2000s carmakers added features such as automated parallel parking and smart cruise, which can maintain a steady distance

between vehicles. In 2011 Google revealed it was developing fully autonomous cars, using its detailed street maps, an array of laser sensors and smart software. It recently unveiled a new prototype that can be configured to have no driver controls at all, save an on/off button. Traditional car manufacturers are taking things more slowly, but the trend is clear.

In many ways driverless cars would be a great improvement on the driven variety. Motoring accidents remain one of the leading causes of death in many countries. Automated driving promises huge improvements in both fuel efficiency and journey times and will give erstwhile drivers the chance to do other things, or nothing, during their trip.

Yet its effect on the labour market would be problematic. Only ten years ago driving a car was seen as the sort of complex task that was easy for humans but impossible for computers. Driving taxis, delivery vans or lorries has been one of the few occupations in which people without qualifications could earn a decent wage. Driverless vehicles could put an end to such work.

The apocalypse of the horsemen

Before the horseless carriage, drivers presided over horse-drawn vehicles. When cars became cheap enough, the horses and carriages had to go, which eliminated jobs such as breeding and tending horses and making carriages. But cars raised the productivity of the drivers, for whom the shift in technology was what economists call "labour-augmenting". They were able to serve more customers, faster and over greater distances. The economic gains from the car were broadly shared by workers, consumers and owners of capital. Yet the economy no longer seems to work that way. The big losers have been workers without highly specialised skills.

The squeeze on workers has come from several directions, as the car industry clearly shows. Its territory is increasingly encroached upon by machines, including computers, which are getting cheaper and more versatile all the time. If cars and lorries do not need drivers, then both personal transport and shipping are likely to become more efficient. Motor vehicles can spend more time in use, with less human error, but there will be no human operator to share in the gains.

At the same time labour markets are hollowing out, polarising into high- and low-skill occupations, with very little employment in the middle. The engineers who design and test new vehicles are benefiting from technological change, but they are highly skilled and it takes remarkably few of them to do the job. At Volvo much of the development work is done virtually, from the design of the cars to the layout of the production line. Other workers, like the large numbers of modestly skilled labourers that might once have worked on the factory floor, are being squeezed out of such work and are now having to compete for low-skill and low-wage jobs.

Labour has been on the losing end of technological change for several decades. In 1957 Nicholas Kaldor, a renowned economist, set out six basic facts about economic growth, one of which was that the shares of national income flowing to labour and capital held roughly constant over time. Later research indicated that the respective shares of labour and capital fluctuate, but stability in the long run was seen as a good enough assumption to keep it in growth models and textbooks. Over the past 30 years or so, though, that has become ever harder to maintain as the share of income going to labour has fallen steadily the world over.

Recent work by Loukas Karabarbounis and Brent Neiman, of the University of Chicago, puts the global decline in labour's share since the early 1980s at roughly five percentage points, to just over half of national income. This seems to hold good within sectors and across many countries, including fast-growing de ►►

▶ developing economies like China, suggesting that neither trade nor offshoring are primarily responsible. Instead, the two scholars argue, at least half of the global decline in the share of labour is due to the plummeting cost of capital goods, particularly those associated with computing and information technology.

By one reckoning the price of cloud-computing power available through Amazon's web services has fallen by about 50% every three years since 2006. Google officials have said that the price of the hardware used to build the cloud is falling even faster, with some of the cost savings going to cloud providers' bottom lines rather than to consumers—for now, at any rate. The falling cost of computing power does not translate directly into substitution of capital for labour, but as the ICT industry has developed software capable of harnessing these technologies, the automation of routine tasks is becoming irresistible.

From the end of the second world war to the mid-1970s pro-

ductivity in America, measured by output per person, and inflation-adjusted average pay rose more or less in tandem, each roughly doubling over the period. Since then, and despite a slowdown in productivity growth, pay has lagged badly behind productivity growth. From 2000 to 2011, according to America's Bureau of Labour Statistics, real output per person rose by nearly 2.5% a year, whereas real pay increased by less than 1% per year.

The counterpart to this eclipse of labour is the rise and rise of capital. In a landmark book that became an unlikely bestseller, Thomas Piketty, an economist at the Paris School of Economics and an authority on inequality, argues that economics should once again focus on distribution, as it did in the 19th and early 20th centuries. In those days the level of wealth in rich economies often approached seven times annual national income, so income earned from wealth played an enormous part in the economy and caused social strains that sometimes threatened ▶▶

Home economics

Sky-high house prices in the most desirable cities are holding back growth and jobs

A LARGE PART of the recent growth in wealth—in some economies nearly all of it—consists of rising property values, according to Thomas Piketty's analysis. House prices in many parts of the world have been booming for the better part of two decades. The biggest increases have been in rich cities such as London, New York and San Francisco.

Rising house prices are a response to an imbalance between supply and demand. Demand has been affected by the globalisation of economies. As transport costs started to fall at the beginning of the 20th century, many of the manufacturing firms clustered in cities in developed countries left in search of cheaper land and labour. This threw many of those cities into crisis as their tax base crumbled and their public services deteriorated, hastening the exodus. Yet starting in the 1980s cities that had retained a core of highly skilled workers enjoyed a rebound. Population decline slowed and eventually halted, and local economic growth and property prices picked up.

Ed Glaeser, an economist at Harvard University, links this turnaround to the ICT revolution. Cities enjoy a number of benefits that encourage people to live in them despite higher costs, crowds and congestion. A shorter distance between customers and suppliers (and indeed friends and lovers) is one. The ease with which ideas seems to spread within cities is another.

The Bay Area of California is a prime example: a place in which ideas seem to reverberate from person to person and firm to firm, and in which those with good ideas can easily tap into networks of engineers, designers and financiers. Similar forces are at work in other large cities around the world. In a

paper written with Matthew Resseger, also of Harvard, Mr Glaeser finds a strong relationship between city size and productivity per worker, but only in places with highly skilled workforces. Carl Benedikt Frey and Thor Berger of Lund University note that since the 1980s new work has been getting much more cognitive in nature. They link this to the ICT revolution and to the rapid growth of cities with a core of highly skilled workers.

Yet since the 19th century a dense thicket of zoning regulations has grown up in many of those cities, sending the cost of housing skywards in attractive cities. A generation ago only a handful of cities on American coasts had housing costs much above the cost of new construction. Today most large cities suffer from such an excess, which represents a regulatory "shadow tax" on new construction. Indeed, most of the value of properties in places like London and New York reflects the difficulty of building new homes.

So even as large, high-skill metropolitan economies are becoming more important, they are getting less affordable for anybody but the rich, prompting migration away from the most economically dynamic places towards those that offer good jobs and allow lots of construction. The maths are clearest in America. In Harris County in Texas, which takes in most of the fast-growing Houston metropolitan area, the median household income is about \$53,000 and the median value of an owner-occupied home is \$128,000. In California's Santa Clara County, which includes the heart of Silicon Valley, the median household income is over \$90,000 and the median price of a home is \$657,000. A Californian moving to Texas will almost certainly take a pay cut but nonetheless enjoy

a higher disposable income.

The difference in housing costs is mostly due to different attitudes to building. Freewheeling Houston approved more than 51,000 new dwellings in 2013 whereas San Jose, home to some of the nation's worst NIMBYS, approved just under 8,000.

The economic effect of keeping a tight lid on housebuilding is stunning. Enrico Moretti, an economist at the University of California, Berkeley, estimated the employment multiplier of different sorts of work in his book "The New Geography of Jobs", published in 2012. A new manufacturing job, he suggested, typically creates 1.6 new jobs in the local service economy. In innovative industries, one new position might yield four to five new service-sector jobs within a metropolitan area. But vertiginous house prices stunt this effect. Rich Googlers in San Francisco spend money on homes that might otherwise go to local restaurants or gyms.

In developed economies, all this is having a negative effect on employment, productivity and output. A new paper by Mr Moretti and Chang-Tai Hsieh, of the University of Chicago, estimates that between 1964 and 2009 output in America was 13% lower than it might have been because high housing costs encouraged people to move away.

For homeowners in London, New York or San Francisco, this is all excellent news as long as they plan to sell up some day. Sky-high housing costs mean that more of the gain of new job creation is captured by landlords (or homeowners who get out) than by employers or workers. Technology has raised the return to living in high-skill cities, but has done nothing to make it easier to find a home there.

▶ the capitalist system. In the decades following the first world war old fortunes were wiped out by taxation, inflation and economic collapse, so by 1950 wealth in rich economies had typically fallen to just two or three times the level of annual national income. But since then it has begun to creep up again.

Mr Piketty acknowledges that inequality today is different from what it was 100 years ago. Today's great fortunes are largely in the hands of the working rich—entrepreneurs who earned billions by coming up with products and services people wanted—rather than the idle gentry of the early industrial era. Yet even if the source of the new wealth is less offensive than that of the old, the eclipse of labour could still become a disruptive social force. Wealth is generally distributed less equally than capital; many of those getting an income from work own little or no wealth. And Mr Piketty reckons that as wealth plays a bigger part in an economy, it will tend to become more concentrated.

The decline in the role of wealth in the early part of the 20th century, Mr Piketty observes, coincided with a levelling out of the wealth distribution, as for the first time in modern economic history a broad, property-owning middle class emerged. That middle class has been a stabilising force in politics and society over the past 70 years, he reckons. If it were to disappear, politics could become more contentious again.

Labour in America would have lost out to capital even more dismally except for soaring pay among a small group of high earners, according to a study in 2013 by Michael Elsby, of the University of Edinburgh, Bart Hobijn, of the Federal Reserve Bank of San Francisco, and Aysegül Sahin, of the Federal Reserve Bank of New York. The typical worker has fallen behind even more than a straightforward look at the respective shares of labour and capital suggests.

One explanation for that is the changing nature of many jobs. In recent years economists such as David Autor and Daron Acemoglu of the Massachusetts Institute of Technology have pioneered a new way of looking at work: analysing occupations in terms of the tasks they involve. These can be manual or cognitive, routine or complex. The task content determines how skilled a worker must be to qualify for work in a particular occupation. Mr Autor argues that rapid improvement in ICT has enabled firms to reduce the number of workers engaged in routine tasks, both cognitive and manual, which are comparatively easy to programme and automate.

A manufacturing worker whose job consists of a clear set of steps—say, joining two sheets of metal with a series of welds—is highly vulnerable to being displaced by robots who can do the job faster, more precisely and at lower cost. So, too, is a bookkeeper who enters standard data sets and performs simple calcu-



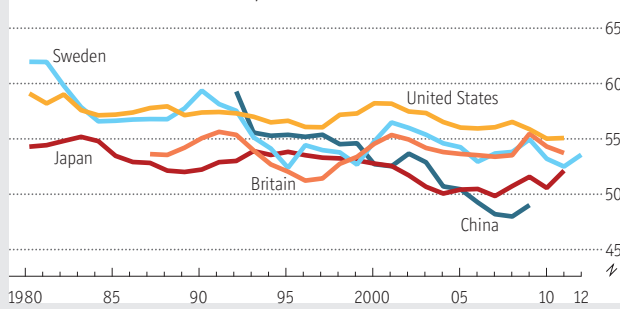
lations. Such routine work used to be done by people with mid-level skills for mid-range pay. Over the past generation, however, technology has destroyed large swathes of work in the middle of the skill and wage distribution, in a process economists call labour-force polarisation.

The hole in the middle

As recently as the 1980s demand from employers in rich countries was most buoyant for workers with a college education, less so for those with fewer qualifications and least so for those who had at best attended high school. But from the early 1990s that pattern changed. Demand still grew fastest for skilled workers and more slowly for less-skilled workers, but the share of employment in the middle actually shrank. In the 2000s the change became more pronounced: employment among the least-skilled workers soared whereas the share of jobs held by middle- and high-skill workers declined. Work involving complex but manual tasks, like cleaning offices or driving trucks, became more plentiful. Both in America and in Europe, since 2000 low-skill, low-productivity and low-wage service occupations have gained ground. ▶▶

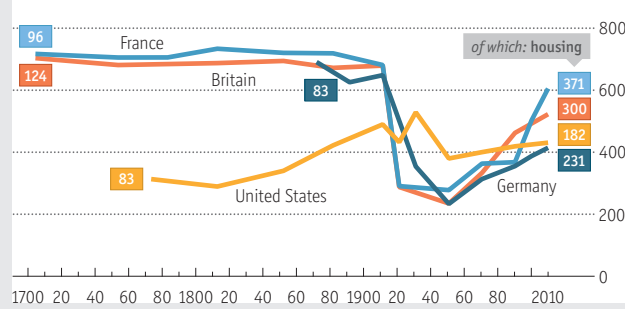
Workers of the world, despair

Labour's share of national income, %



Sources: University of Chicago Booth; "Capital in the Twenty-First Century", by Thomas Piketty, 2014

Wealth as % of national income



Highly skilled work, on the other hand, has become increasingly concentrated in jobs requiring complex cognitive or interpersonal tasks: managing a business, developing a new product or advising patients. As non-routine work has become more prized, supply and demand in the labour market have become increasingly unbalanced. Many cognitively complex jobs are beyond the abilities even of people with reasonable qualifications. The wage premium for college graduates has held steady in recent decades, but that is mainly because of the rising premium earned by holders of advanced degrees. The resulting competition for lower-level work has depressed wage growth, leading to stagnant pay for typical workers.

Technology has created a growing reservoir of less-skilled labour while simultaneously expanding the range of tasks that can be automated. Most workers are therefore being forced into competition both against each other and against machines. No wonder their share of the economic pie has got smaller, in developing economies as well as in the rich world. ■

Emerging economies

Arrested development

The model of development through industrialisation is on its way out

THIRTY-FIVE YEARS ago Shenzhen was a tiny fishing village just over the river from British Hong Kong. Its inhabitants, like most Chinese, lived in poverty. In 1978 the average income in America was about 21 times that in China. But in 1979 China's leader, Deng Xiaoping, chose Shenzhen as the country's first special economic zone, free to experiment with market activity and trade with the outside world. Shenzhen quickly found itself at the leading edge of Chinese economic development, using the same model as Japan, South Korea and Hong Kong itself had done at earlier stages. In the late 1970s China was bursting with cheap, unskilled labour. It opened its doors (a crack, in lucky places like Shenzhen) to foreign manufacturers waiting to take advantage of these low labour costs. Even though wages were at rock bottom, both productivity and pay in urban factories were dramatically higher than in agriculture, so China's fledgling industrialisation attracted a steady flow of migrants from the countryside.

Over time local production became more sophisticated and wages went up. Industrial cities served as escalators for development, linking the Chinese economy with global markets and allowing incomes to rise steadily. The fruits of this process are clearly visible. As visitors approach the checkpoints between Hong Kong and the mainland, a modern skyline rises on the horizon. Great glass-sheathed skyscrapers reach upwards in central Shenzhen, which boasts some of the world's tallest buildings. At street level Chinese workers stroll past shopfronts displaying Western luxury brands: Ferrari, Bulgari, Louis Vuitton.

Governments across the emerging world dream of repeating China's success, but the technological transformation now under way appears to be permanently changing the economics of development. China may be among the last economies to be able to ride industrialisation to middle-income status. Much of the emerging world is facing a problem that Dani Rodrik, of the Institute for Advanced Study in Princeton, New Jersey, calls "premature deindustrialisation".

For most of recent economic history, "industrialised" meant rich. And indeed most countries that were highly industrialised were rich, and were rich because they were industrialised. Yet this relationship has broken down. Arvind Subramanian, of the Peterson Institute for International Economics and reportedly soon to become chief economic adviser to the Indian government, notes that, at any given level of income, countries today are less reliant on manufacturing, in terms of both output and employment, than they were in the past, and that the level of income per person at which reliance on manufacturing peaks has also declined steadily (see chart 4). When South Korea reached that point in 1988, its workers' earnings averaged just over \$10,000 (in PPP-adjusted 2011 dollars) per person. When Indonesia got there in 2002, average income was just under \$6,000, and for India in 2008 it was just over \$3,000.

Premature non-industrialisation

Early loss of industry (or, in India's case, what Mr Subramanian calls "premature non-industrialisation") is a distressing trend, given the role that exports of goods have historically played in economic development. Productivity in export industries is generally high, otherwise they could not compete in global markets. Over time, productivity in making traded goods tends to rise as firms and workers in the industry become familiar with the technologies involved. Past developmental success stories such as the Asian tigers moved from low-margin, labour-intensive goods such as clothing and toys to electronics assembly, then on to component manufacture and, in the textbook cases of Japan and South Korea, to advanced manufacturing, design and management.

Export success trickles down to the rest of developing economies. Since producers of non-traded goods and services, such as housebuilders and lawyers, must compete with exporters for labour, they need to pay attractive wages. At the same time the chance of well-paid work in manufacturing creates an incentive for workers to move to cities and invest in education. An industrialising export sector is like a speedboat that pulls the rest of the economy out of poverty.

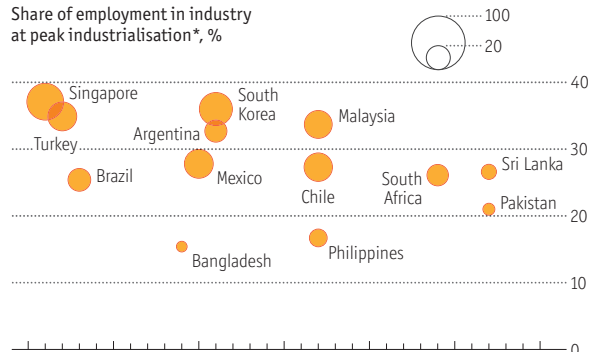
Loss of industry at low income levels, by contrast, caps the contribution that manufacturing can make to domestic living standards. That is no small problem: there is no obvious alternative strategy for turning poor countries into rich ones.

The change in technology's role in development began in the 1980s. Richard Baldwin, an economist at the Graduate Institute of International and Development Studies in Geneva, ex- ▶▶

Off peak

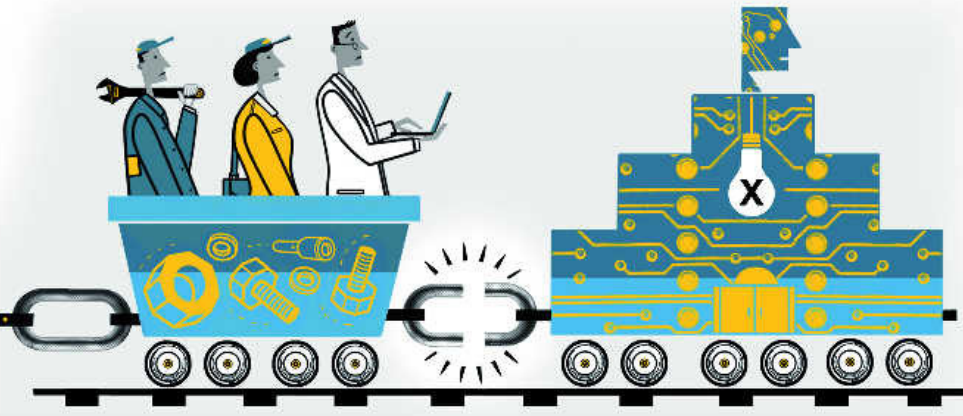
Share of employment in industry at peak industrialisation*, %

GDP per person As % of United States*



Sources: Amrit Amirapu & Arvind Subramanian; World Bank

* Highest share of people employed in industry



► plains that for much of modern economic history the driving force behind globalisation was the falling cost of transport. Powered shipping in the 19th century and containerisation in the 20th brought down freight charges, in effect shrinking the world. Yet since the 1980s, he says, cheap and powerful ICT has played a bigger role, allowing firms to co-ordinate production across great distances and national borders. Manufacturing “unbundled” as supply chains scattered across the world.

According to Mr Baldwin, this meant a profound change in what it is to be industrialised. The development of an industrial base in Japan and South Korea was a long and arduous process in which each economy needed to build capabilities along the whole of a supply chain to manufacture finished goods. That meant few economies managed the trick, but those that did were rewarded with a rich and diverse economy.

In the era of supply-chain trade, by contrast, industrialisation means little more than opening labour markets to global manufacturers. Countries that can grab pieces of global supply chains are quickly rewarded with lots of manufacturing employment. But development that is easy-come may also be easy-go. Unless the economies concerned quickly build up their workers’ skills and infrastructure, wage increases will soon lead manufacturers to up sticks for cheaper locations.

From stuff to fluff

Another mechanism through which new technology is changing the process of development is the dematerialisation of economic activity. Consumption the world over is shifting from “stuff to fluff”, reckons Mr Subramanian. People everywhere are spending a larger share of their income on services such as health care, education and telecommunications. This shift is reflected in trade. Messrs Subramanian and Kessler note that, measured in gross terms, goods shipments dominate trade as much as ever. They accounted for 80% of world exports in 2008 (the most recent figure available), down only slightly from 83% in 1980. Measured in value-added terms, however, the importance of goods trade tumbled, from 71% of world exports in 1980 to just 57% in 2008, because of the increasing weight of services in the production of traded goods. Much of the value of an iPhone, for example, derives from the original design and engineering of the product rather than from its components and assembly.

A recent report by the McKinsey Global Institute put the value in 2012 of “knowledge-intensive” trade—meaning flows of goods or services in which research and development or skilled labour contribute a large share of value—at \$12.6 trillion, or nearly

half the total value of trade in goods, services and finance. Physical assembly accounts for a declining share of the value of finished goods. The knowledge-intensive component of trade is also growing more quickly than trade in labour, capital- or resource-intensive products and services. At the same time the dramatic decline in the cost of information and communications technologies has opened up trade in some high-value services. Skilled programmers in India, for example, can sell IT services around the world despite the low overall level of development of the Indian economy.

India has masses of cheap, unskilled labour that ought to be attractive to firms wanting to set up low-cost manufacturing facilities. Yet operating them would require at least some skilled workers, and

the rising premium on these created by trade in ICT services makes it uneconomic for many would-be manufacturers to hire the necessary talent. Mr Subramanian and Raghuram Rajan, another Indian economist, have dubbed this the “Bangalore bug”, a reference to the extraordinarily successful ICT cluster in the southern Indian city of Bangalore. But other emerging economies are similarly affected.

Other advances are eliminating the need for human labour altogether. Walking through an electronics production line at Foxconn’s Longhua campus in Shenzhen, a worker points out places where people have already been replaced by machinery—“to reduce injuries to workers”, he says. Elsewhere on the line he indicates a place where a robot is being tested to take over a range of tasks from humans. Perhaps 10% of the staff at Longhua now consists of engineers working on such automation.

Successful solutions will be rolled out to other Foxconn facilities, says Louis Woo, a special adviser to Foxconn’s chairman, Terry Gou. And Foxconn has even greater ambitions. In Chengdu it is working on a “lights out”, entirely automated, facility which serves a single, as yet unnamed, customer. In fast-developing and rapidly ageing China workers are becoming increasingly expensive, as well as hard to find. Automation provides a means to hold on to work that might otherwise pack up and move to another country.

It also saves a lot of trouble. Vast areas of Foxconn’s Longhua campus are given over to support services for the roughly quarter of a million workers employed there: shops and restaurants, a massive central kitchen with automated rice-cooking equipment, dormitories that house about half the staff, schools for workers’ children and counselling services for distressed employees. Foxconn’s dormitories are ringed with netting, a precaution prompted by an epidemic of suicides by workers that set off a torrent of bad press for the company and its customers. Indeed, notes Mr Woo, it is often customers that are behind the push for greater automation of Foxconn’s facilities.

The falling cost of automation makes the use of robots attractive even in India, where cities are swarming with underemployed young workers. The main reason for that is the country’s thicket of red tape. Mr Subramanian thinks India’s best hope now may be to concentrate on churning out more highly skilled workers, rather than count on manufacturing to mop up its jobless millions.

The rapid growth in emerging economies over the past 15 years was good for many very poor countries in Africa and Central America, but most still grew more slowly than richer de ►►

▶ veloping countries in Asia and South America. Given the institutional weakness, inadequate infrastructure and modest skills base in many of the world's poorest places, even rock-bottom wages there may be insufficient to attract much manufacturing.

That is a distressing prospect. The United Nations estimates that sub-Saharan Africa's population will roughly triple over the next half-century, to about 2.7 billion. A development model in which rapidly rising incomes are limited to a highly skilled few is unlikely to be sustainable. Many talented workers are already thinking about emigrating, yet rich economies trapped by growing social spending and shrinking tax bases are more likely to slam their borders shut. Over the past decade or two inequality, despite rising within many economies, has shrunk at the global level, thanks to rapid growth in large emerging markets. But in the absence of a new development model, that happy state of affairs may soon be reversed. ■

New opportunities

Silver lining

How the digital revolution can help some of the workers it displaces

NOT FAR INLAND from where India's west coast meets the Arabian Sea, a modern high-rise building that looks a bit like a stack of hastily piled-up boxes grows from the streets of Mumbai. Called Antilia, it is the private residence of Mukesh Ambani, the chairman of Reliance Industries and reportedly the richest man in India. On a clear day, from the higher floors of his home, Mr Ambani can see the neighbourhood of Dharavi, about six miles to the north-east. The area, made famous by the film "Slumdog Millionaire", is one of the world's largest slums, a patchwork of blue tarpaulin, corrugated tin and teeming humanity. Few other places in the world display such a stark contrast in wealth and living conditions in such a small space.

Many of Dharavi's people have shown extraordinary ambition and entrepreneurial verve, but until recently they were limited to light industry, such as pottery or leather processing. Everything they made was sold in the immediate neighbourhood, to people of broadly the same income and prospects as those who made them.

That is beginning to change. A recent story published in the *Financial Times* featured a Dharavi resident, Mohammed Taushif Ansari, who earns nearly \$20,000 a year selling leather goods through eBay to customers around the world. The spread of e-commerce around the globe opens up a huge new reservoir of purchasing power to those motivated enough to seek it. And that is just one of the ways technology is creating economic opportunities to replace at least some of the work it destroys. The critical question is just how much of the world's available labour will find productive work in this supercharged new economy.

One hope rests on the creation of new kinds of jobs. In New York the old industrial warehouses and factories along Brooklyn's waterfront are being turned into a thriving tech-industry hub. One of its star companies, Etsy, recently signed a deal to move to a new office twice the size of its previous one, to make room for its growing workforce.

Or some of it, anyway. Apart from the 750 or so people working directly for the company from its offices in Brooklyn and elsewhere, there is a second labour force, consisting of

roughly 1m independent sellers the world over: craft-based entrepreneurs offering housewares, artwork, clothing and many other creative items. Sales last year were reported to be \$1.35 billion, half as much again as the year before. The company says that for 18% of its sellers this business is a full-time job. Many others use income from Etsy to supplement pay from other work.

The global artisan

Etsy is part of a broad movement that represents one possible entrepreneurial response to a new and different economy. This began more than a decade ago when the sort of private transactions previously conducted through classified ads, car-boot sales and flea markets moved online, courtesy of companies like Craigslist and eBay. That move dramatically increased the value of the market for such goods by increasing its scale and raising the odds of achieving a match between a buyer and a seller. This market has since grown dramatically, powered by the pull of new opportunities and the push of economic strain across the rest of the labour market.

E-entrepreneurship received a boost in 2008 when Apple launched its app store, through which third-party software designers could market their own iPhone applications. The "app economy" has since grown by leaps and bounds. According to an estimate by the Progressive Policy Institute, a think-tank, in 2013 it provided work for more than 750,000 people in America alone. Many more take part in it from elsewhere in the world, including employees at Rovio, the Finnish firm behind the wildly popular "Angry Birds" line of mobile games, and people like Dong Nguyen, a young programmer in Vietnam who scored an unlikely app hit with "Flappy Bird", a simple but addictive game that was at one point earning him \$50,000 a day.

Amazon and other e-tailers allow authors and artists to self-publish and market their work around the world. YouTube offers a platform to a cast of phenomenally successful video producers, makers of comedy clips or video-game reviewers who can rack up billions of views. Odd genres flourish, like "unbox- ▶▶



▶ ing clips” in which the star buys various trinkets and opens and describes them on camera. “DisneyCollectorBR”, an unboxing producer called Melissa Lima, specialises in unwrapping cheap toys. These clips, generally a few minutes long, apparently entrance small children. The advertising revenue from her videos may be earning Ms Lima up to \$5m a year. Social networks often contribute to such hits by drawing attention to particular apps or products. In the future, to paraphrase Andy Warhol, everyone may trend on social media for 15 minutes—and earn a bit of extra income as they do so.

Mobile apps and networks are also democratising capital ownership in some sectors of the economy, including accommodation and passenger travel. Airbnb, for instance, allows householders to earn money by letting their home while they are away. Uber and Lyft blur the line between professional drivers and those with a spare seat in their private car. The “sharing economy” is increasingly indistinguishable from the mainstream economy; things that can now be borrowed via online apps include server space, home appliances, bicycles and tools. Other services connect people who own pets with those willing to look after them while the owners are away.

The logistical hurdles to entrepreneurship are quickly shrinking. Selling surplus goods or putting underused capital to work is as easy as creating an online profile. Startups are benefiting as well. New firms can rent computing power from Amazon through the cloud rather than having to buy expensive servers. Office space and support services are becoming ever easier to find, as is finance, thanks to peer-to-peer lenders and crowdfunding platforms like Kickstarter. Easy and cheap access to all the off-the-shelf components needed for a startup is fuelling the rise of “weightless companies”, firms that can attain extraordinary valuations with minimal staff and capital.

That is a very good thing in the eyes of those who see the rich world’s problems as a matter of too little innovation rather than too much. Michael Mandel, a technology expert at the Progressive Policy Institute, reckons that innovation is generally fol-

lowed by growth in employment. That is most obviously true in ICT, but also in sectors like energy, where fracking technology has generated an oil boom and a jobs bonanza in states such as North Dakota and Texas. Mr Mandel invites sceptics to imagine a future in which doctors can 3D-print livers (and other organs) on demand—a technology that looks increasingly realistic. In addition to the significant health benefits that would result, organ printing would create new jobs, from workers to monitor the printers to nurses for the patients receiving transplants.

As innovation expands outward from ICT, so too should the jobs. Success in many of the newly available niches will often remain a matter of skill, whether the product on offer is a leather bag or a fancy app. But at least technology is making it easier and cheaper than ever to obtain new skills.

Beyond MOOCs

Informal online education is already a widespread and underappreciated aspect of modern economic life. YouTube is a treasury of how-tos, from making the perfect Bolognese to pronouncing words in an unfamiliar language. More important, teachers around the world have been putting academic coursework online for more than a decade, including reading material, syllabuses, video lectures and practice exams. For the price of a computer and an internet connection, motivated learners could work their way through several lifetimes’ worth of university degrees and save millions of dollars.

The online education market is now maturing. Massive Open Online Courses, or MOOCs, have struggled to live up to expectations, but online offerings are improving and expanding. America’s three largest providers of online education—edX, a non-profit service run by Harvard University and the Massachusetts Institute of Technology (MIT); Coursera, a for-profit service set up with academics from Stanford University; and Udacity, another for-profit with Stanford roots—have provided courses for an estimated 12m students so far. Other individuals and universities are also getting into the game. Some of them will offer complete online degrees.

Online education programmes have several big advantages over traditional models. These probably weigh most heavily with people living in developing economies who have few other options. MOOC enthusiasts like to tell the story of Battushig Myanganbayar, a Mongolian teenager who performed brilliantly in an online computer-science course offered by MIT. His story is no longer exceptional. Edx, which had nearly 400,000 students in 2012-13, reckons that almost half of them live outside the rich world.

Online education offers flexibility that the bricks-and-mortar sort cannot match. Busy students can fit it around their job or family schedule, work at their own pace and sample courses from universities the world over without leaving their homes. And, critically, online courses are significantly cheaper than the in-person kind. Many are offered free, though providers sometimes charge to certify exam results. Fees at Minerva Schools, an online institution that aims for top-notch students, are half of those at Ivy League universities. A new online master’s degree in computing at Georgia Tech costs just ▶▶



▶ \$7,000, compared with \$25,000 for the on-campus alternative. Lower costs not only make courses more accessible, they also encourage experimentation. Students can start work on a degree with little financial risk. This freedom to experiment has boosted drop-out rates, increasing scepticism about the courses' viability. Yet the ease of dipping in and out is a virtue, improving the chances that students will take up on-line education in the first place and that if they keep trying they will hit on the right subject eventually.

A reduced price for higher education would be a boon to many families in America, where university can take a large bite out of household budgets (or saddle students with loads of debt). And education is just one of many things that



For many workers, cheaper goods and services may be the only pecuniary gain they see from new technologies

new technology could deliver more cheaply. Over the past couple of decades prices of many physical goods, including televisions, computers and household appliances, have tumbled, particularly allowing for improvements in quality. The cost of communicating with friends and family, watching many videos and listening to many kinds of music is now close to zero.

Yet the cost of other items just keeps going up. In 1990 Americans on average spent 38% of their income on housing, health care and education. By 2010 that share had risen to 43%. In recent decades prices for all three of those categories have risen faster than for goods and services as a whole. Even if technology does not create many new jobs, if it brings down the cost of education and medical care as well as that of other goods and services, workers may nonetheless breathe a sight of relief.

Drops in the bucket

For many workers, those cheaper goods and services may be the only pecuniary gain they see from new technologies. New job and self-employment opportunities will provide some counterweight to the disruptive power of the digital revolution, but they are unlikely to offset it entirely. Tyler Cowen, an economist at George Mason University, Virginia, agrees that such innovations will allow highly motivated, talented and conscientious individuals to claw their way into a small elite of very well-paid workers, but fears that the remaining 85-90% of the population may find little to do in the new economy.

In the past, industrialisation often involved a loss of skills: a small group of first-class artisans was replaced by factories full of less-skilled workers producing goods at a much lower cost. Similarly, future advances in education and health care could reduce the earning power of many highly paid academics and doctors while creating jobs for more workaday tutors to help the laggards, or nurses enabled by technology to do much of the work now reserved for expensive physicians. Yet even these more mundane new jobs will still require specialised training and a combination of social and cognitive skills that will elude a large part of the labour force. And at the very top of these professions, “superstar” teachers or doctors using technology to reach many more people will do better than ever.

Expansion of online education and mobile health care might also give a boost to global trade in services, which could offer an alternative route to economic development in countries

like India. People there might find work monitoring the vital signs of patients or marking essays from students across the globe. But first they would have to obtain the necessary skills, so this is unlikely to provide jobs for the masses. It might also prove controversial in some rich economies, where people who are currently doing such jobs could face downward pressure on their pay or lose them altogether.

Likewise, the employment effects of the sharing economy are not obviously egalitarian, since many drivers and hotel staff affected by it are relatively low-skilled and poorly paid and have few occupational options. New online labour services could help match former hotel staff with new jobs, perhaps cleaning homes let through schemes like Airbnb. Yet that begins to sound like a more efficient version of the domestic-service economy of the 19th century. America is already well on its way to that. A service called Taskrabbit allows well-off busy people to hire poorer and less busy ones for errands such as doing the shopping or

queuing for theatre tickets on their behalf.

Meanwhile much of the work that can easily be done by those with minimal training—in retailing, for instance, or wholesale warehouses—is gradually being automated away. And the crowds of underemployed workers competing for jobs that robots still cannot do—such as caretaking—will ensure that pay for such work remains low.

This technological revolution could still hold many surprises. It may create vast numbers of jobs nobody has yet imagined, or boost the productivity of less-skilled workers in entirely novel ways, perhaps through robotic exoskeletons or brain implants. But for now, and despite the opportunities opened up by some new tech-based ventures, a generation of workers the world over is facing underemployment and stagnant pay. Governments will be sorely tested to deal with that. ■

Easing the transition

Means and ends

How governments can deal with the labour imbalance

IF THE WORLD is thought to be suffering from both too little innovation and too much at the same time, it may be reasonable to think that the future will look a lot like the past. That strategy offers some room for optimism. Thanks to technological change and the resulting economic growth, many countries are now vastly richer than they were 300 years ago, and rich in ways pre-industrial societies could not have conceived of. Fears of mass unemployment raised by earlier technological leaps never came to pass. Instead, technology allowed people to live longer, fuller lives. Quite possibly this time will be no different. Humans' greatest advantage over machines has always been their flexibility, which should help them adapt to the new world around them. A generation from now people everywhere will almost certainly be richer and live longer, and most of those looking for work will probably still be able to find it. ▶▶

Yet history also offers plenty of reason to worry. Humans may be flexible, but their governments typically are not: they act only when forced to do so. In past economic revolutions it took a shift in the balance of political power, sometimes achieved only after violent conflict, to ensure that the gains from growth were broadly shared. The necessary investment in education and infrastructure and the provision of a social safety net proceeded in fits and starts and did not always go right.

Over the past few decades technology has hollowed out workforces, leaving too many people competing for jobs that require minimal skills and offer minimal pay. Rising inequality and stagnant wages are eating away at the legitimacy of existing tax and redistribution systems. Governments' responses so far have ranged from the uninspiring to the negligent.

Broadly speaking, there are three ways of dealing with the labour imbalance: raising the productivity of less-skilled workers; turning less-skilled workers into more-skilled workers; and providing income support for those who find it hard to earn a living in this new world.

Raising the productivity of less-skilled workers may not be as hard as it sounds, but it requires governments to get their economic policies right. Often they simply need to get out of the way. A prime example is occupational licensing. Between the 1950s and 2008 the share of employment in America covered by occupational regulation rose from roughly 5% to nearly a third. It now includes not only professions like nursing and teaching but jobs in interior design and even in nail salons. Excessive regulation reduces mobility and makes it harder for workers to change careers or earn extra income. In Europe non-transferability of professional qualifications restricts migration. In parts of the emerging world jobs involve so much red tape that many global firms would rather automate than employ more people.

Having workers in the right places is critically important to generating more and better jobs. In both the rich and the emerging world unmet demand for housing is a significant constraint on growth. In developing economies many large cities have outgrown their capacity to house their populations, resulting in sprawling slums that harbour crime and disease. India's government, for example, tightly restricts land use, making new construction costly and modern housing extremely expensive.

In rich countries restrictions on the supply of housing can be just as pernicious. In economically dynamic places such as New York and London the shortage of housing is a serious constraint on growth in output and highly paid jobs. Inadequate investment in infrastructure exacerbates the problem. As roads and trains become more crowded, residents grow wary of agreeing to new developments, and so it goes on.

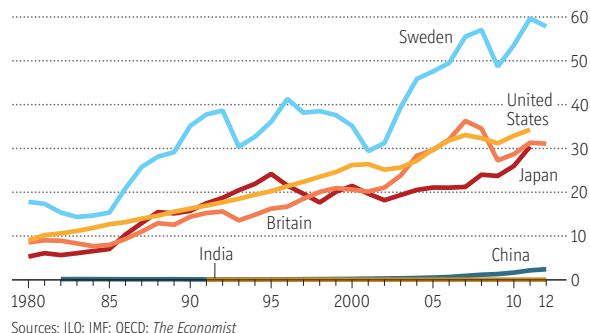
Back to school

The best hope for reducing the glut of less-skilled labour is to transform some of it into the more-skilled sort through higher spending on education. In the 19th and 20th centuries it took significant public investment to ensure that newly industrialised economies had a supply of labour with the right qualifications. Something similar is needed today. Rich countries are short of highly skilled workers, and many developing economies lack the basic educational infrastructure to produce a more effective labour force. Immigration from poor countries to rich ones might help adjust that global imbalance, but is too politically contentious to make a big difference. Across the world more effort is needed to improve primary and secondary education.

A good standard of literacy and numeracy across populations in emerging countries will be critical if large numbers of workers there are to take part in trading global services. Governments need not turn every student into a PhD candidate to boost

Plucking the goose

General government tax revenue per employee, \$'000



his or her earnings prospects. Demand for skilled tradespeople such as plumbers and electricians remains high. Recent studies of the long-term effect of good teaching indicate that improving the quality of teachers just from poor to middling has a significant effect on the lifetime earnings potential of a typical school class. Long-run analyses of intensive pre-school programmes suggest that they achieve annual social returns on investment (allowing for expected cost savings from reduced crime and welfare spending) of 7-10%.

But providing better opportunities through education and deregulation may not be enough to ensure that the benefits of technology-based growth are sufficiently widely spread. As in past economic revolutions, the social safety net will also need to be strengthened. That might include measures such as introducing or extending minimum wages. This time, however, governments face a sticky problem. If such policies make workers more expensive, firms will hire fewer of them. If on the other hand wages are kept very low and benefits are reasonably generous, workers may be dissuaded from looking for jobs. And at a time when fiscal demands on taxpayers are rising, governments cannot afford to allow labour-market participation to fall and thus reduce their tax base.

Some research suggests that modest increases in minimum wages can lead to productivity improvements. That may be because they reduce worker turnover, or because they prompt firms to invest in their workers or get them to work harder. Yet although higher minimum wages can be politically appealing, their use will need to remain limited. The easier it becomes to automate basic work, the less of a nudge firms will need to swap workers for machines when wages rise.

One way of squaring that circle would be for governments to provide wage subsidies. Such payments encourage participation in the labour force by making work more worthwhile for low-paid workers without discouraging firms from recruiting. America's earned-income tax credit and Britain's working tax credit both use the tax system to help families with low incomes. In America the subsidy available to poor families with children is relatively generous, but the maximum paid to the childless is a miserly \$496 a year.

Economists frown on the idea of sharing out work to make it go further, but as a temporary measure it has been used with some success. The best-known example is that of the *Kurzarbeit* programmes used in Germany during the recession following the 2008 financial crisis. Workers accepted a shorter working week in lieu of lay-offs, and the government helped make up the resulting shortfall in income.

If the dislocating effect of technology turns out to be really ▶▶

▶ severe this time, governments might consider offering a universal basic income, just sufficient to live on, to which all working-age adults would be entitled. A basic income for all is an old idea receiving new attention because of the recent labour-market upsets. Switzerland is getting closest to trying this out: last year campaigners there obtained enough signatures to force a referendum, to take place in the next couple of years, on introducing a basic income of SFr30,000 (\$32,000).

The idea of a guaranteed income runs smack against core beliefs regarding the meaning and importance of work. Allowing people to become full-time couch potatoes at public expense is abhorrent to those who reckon that healthy adults should contribute to society in order to benefit from its economic output, as well as to those who see work as a source of personal dignity or a means to maintain mental balance, to say nothing of the majority who would still be working for their living and generating the tax income that would fund such a scheme.

What would you do if you didn't have to work?

Entitlement to a basic income might be linked to a requirement to seek a regular job, take part in make-work schemes or engage in volunteering. Yet economic liberals might argue that such paternalism is unlikely to make anyone better off. And freedom from want might create scope for other socially benign activities, such as work or self-employment that generates some income, just not enough to live on. Given a basic income, many more budding entrepreneurs might launch businesses doing something they feel passionate about.

Whichever way governments respond, budgets will be tested. Even modest increases in income subsidies imply both a rise in government spending as a share of GDP and a concentration of the tax burden on a smaller share of the population. A higher tax burden will encourage tax avoidance among the very rich and distort economic decisions. In America and Britain the top 1% of earners already contribute 46% and 28% respectively of all tax revenues. If they are squeezed too much, some of them might take their money and move elsewhere. Governments got much bigger after previous technological revolutions. They cannot expand much more without running into serious fiscal constraints.

Tax competition may become an increasingly divisive international issue. Some of the highly mobile rich will be attracted by countries with low-tax, low-spending regimes, whereas the relatively immobile poor will hope for generous state bene-

fits at home. Governments may need to tighten up their residence rules to prevent the rich from pretending to live in a low-tax country to minimise their tax bill, and tax regimes may need to be co-ordinated to discourage avoidance and evasion.

Preventing fiscal disaster may also require comprehensive reforms to make tax systems more efficient, so that a given tax burden is more difficult to dodge and less disruptive to the economy. One way of doing that would be to tax immobile factors such as land more heavily. Land taxes within cities, if combined with a loosening of zoning restrictions, should encourage denser construction, which could help alleviate housing shortages in some of the most expensive places.

Taxing undesirable activities such as emitting carbon and causing pollution would also raise revenues at minimal economic cost. Shifting the brunt of taxation from income to consumption in America could help the country resolve its fiscal and inequality problems at the same time—provided the money is used to boost sagging incomes. In Europe the use of value-added taxes has allowed governments to maintain high public expenditure at relatively low economic cost. America, which currently has a progressive tax system but spends less on helping the poor, might need to review its system.

The first two industrial revolutions fundamentally changed the relationship between the individual and the state. The digital revolution now in progress will inevitably bring about yet another such change. Governments may need to develop new economic approaches, giving technology freer rein to transform production while providing workers with more of a cushion against the painful effects of that creative destruction. Some might instead tolerate the emergence of a growing underclass that is hard to escape from while continuing to search for a technological solution to underemployment. Governments themselves might be transformed by new political movements emerging in response to the dissatisfaction generated by technological change: in benign ways, through political reform and realignment, or in uglier fashion.

Technologies are tools without an agenda of their own, but their influence on society is never neutral. They blindly sweep aside the livelihoods of some people and enrich others. Politics must craft rules and institutions that harness technology to suit society's values and vision of itself. ■

Politics must craft rules and institutions that harness technology to suit society's values



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