



Industrial revolution 4.0: ghosts of disruption past, present and future

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1. Executive summary

- We argue that the transitional challenges posed by a "fourth industrial revolution" - dubbed "IR 4.0" - are already well under way. We define this revolution as one featuring much greater use of "capital" - via digitisation, automation and artificial intelligence (AI) - across areas of human endeavour that have hitherto been the province of "labour".
- IR 4.0 has the potential to transform economic and financial activity at global, national, firm and household levels. The macro, geo- and national political implications are as significant as those of the first, second and third industrial revolutions, which themselves transformed the world.
- Although still early-stage, the effects are already profound. In concert with globalisation, liberalisation of labour markets, migration and inflation targeting, they are affecting growth and inflation, investment, wages, productivity and employment. This view stands in contrast to what we take to be consensus - that transition lies in the future; that the effects are largely microeconomic, operating on prices and quantities of goods and services or wages in sectors rather than national, regional or global economies; and that the promise of a higher-productivity, higher-income future for the majority mitigates transitional and political risks.
- Several of IR 4.0's macro and micro effects and implications echo those of prior industrial revolutions. These include divergences between productivity and real wages; divergences in inequality between and within countries; and divergences across skill and income segments of labour markets.
- The first three industrial revolutions redistributed shares of activity across economic sectors and national economies and ultimately shifted the global balance of power. They contributed to universal suffrage; the welfare state in the West; the rise and fall of the Soviet Union; central planning and industrial policy; and choices by many countries among capitalism, socialism or a mixed economy.
- Unlike the first three industrial revolutions, IR 4.0 has elements that substitute capital for labour rather than complement labour. Automation and AI are foremost among these. IR 4.0 therefore poses major public policy challenges, including fear of mass unemployment, even greater income inequality and threats to the historical catch-up growth model for emerging markets - the shift from agriculture to manufacturing to boost productivity and real wages.
- We consider if and how these challenges might be overcome and whether radical innovation's power to keep us ahead of the curve will ultimately outweigh its potential to bring disruption, destruction and inequality. National political and policy choices, as well as geopolitics, are likely to make a major difference in distinguishing winners and losers. Competition is already afoot between the US/Western model of decentralised, devolved innovation (with returns flowing to private capital) and China's model (with state coordination leading the way to the technological frontier), with Europe's mixed social model in the middle.
- IR 4.0 is already influencing politics and policies everywhere. It should be factored into asset allocation here and now and tracked and reassessed regularly, for change is no longer a mere constant - it is now an accelerant.

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2. Introduction

Any student of economic history knows that the idea of destruction has been a fascinating constant - sometimes bleak, sometimes uplifting - in efforts to define the relationship between capitalism and consumption. In the late 1840s, in the wake of the first industrial revolution, Karl Marx and Friedrich Engels warned of enforced destruction, in which "industrial mutation" would result in repeated destruction of the existing capital stock and extreme cycles that would eventually push labour to take social control of private capital. In the early 1940s, between the second and third industrial revolutions, Joseph Schumpeter outlined a potent culture of creative destruction, in which gales of innovation repeatedly cause a renewal of the industrial structure and existing capital stock.

So what form of destruction might come to characterise the fourth industrial revolution, in whose dizzying midst we currently find ourselves? With technology advancing at an unprecedented rate and the resultant disruption almost relentless in its impact, this is a question that demands serious and increasingly urgent attention - particularly when a growing body of research suggests that some of the effects could be unlike any previously witnessed.

The chances are that what lies ahead will borrow heavily from Marxist and Schumpeterian traditions alike - which is to say that it will be both enforced and creative in nature. It will be enforced because revolutions always bring winners and losers and because the latter usually have little choice but to yield to whatever is reckoned to represent progress. It will be creative because radical innovation - which does not seek merely to improve existing practices or products but instead sweeps them aside and replaces them with something completely different - is now arguably more prevalent than at any point in the annals of human endeavour.

Since the process of destruction invariably rewards the most efficient and profitable innovations while punishing their lesser counterparts, revolutions are of obvious relevance to investors. In this white paper we look beyond the rudimentary attractions of identifying "the next big thing" and explore the long-term geo-economic and geopolitical implications of what is now widely known as IR 4.0 - a global transformation powered by the advent of data ubiquity, the emergence of cyber-physical systems and the rise of automation¹.

We compare the industrial revolution of today with those that have gone before and analyse what unites them and what sets them apart. We examine the links between innovation, productivity, wages and employment and ask what the lessons of the past might teach us about the probable shape of the future. We investigate nascent evidence that the spread of robotics is influencing the complexion of politics and consider whether workers, voters and policymakers will ultimately respond to the march of the machines in ways that are reactionary, regressive or rational.

Niccolò Machiavelli wrote: "The innovator has for enemies all those who have done well under the old conditions... and lukewarm defenders in those who may do well under the new." Let us see if this observation, made almost 250 years before the first industrial revolution, still holds in the face of IR 4.0 - and, perhaps tellingly, whether it might even be more resonant now than ever before.

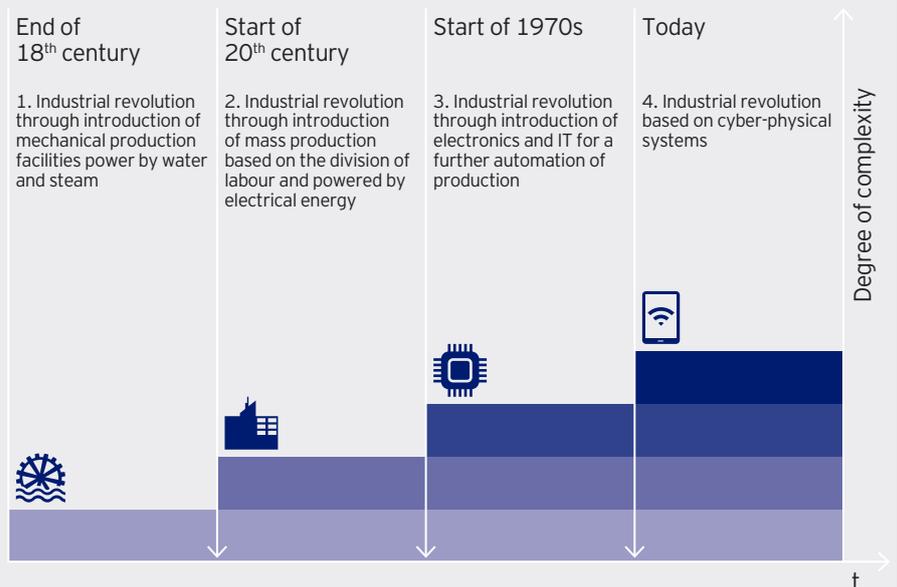
"We look beyond the rudimentary attractions of identifying 'the next big thing' and explore the long-term geo-economic and geopolitical implications of IR 4.0."

Figure 1

Four industrial revolutions

The first three industrial revolutions gradually replaced physical labour with installed, financial and human capital. They boosted skilled and educated workers but displaced lower-skilled workers.

IR 4.0 is set to substitute artificial intelligence and automation for labour across swaths of the global division of labour. The nature and content of jobs is very likely to change, and the value of skills and education may shift both rapidly and radically.



Source: Accenture, Invesco.

3. Discovery, digitisation and divergence

3.1. Two thousand years of innovation

There was a time when most civilisations or nation states were routinely at or near what then constituted the technological frontier. The main drivers of growth, income and wealth were population size, labour force and demographics. Amid an enduring belief that all wisdom came from the “ancients”, the notion that knowledge might be found elsewhere or even created – and that progress could therefore be continuous – was still in its infancy. There were innovations, but they were typically incremental and idiosyncratic rather than cumulative.

The Age of Discovery propelled humanity beyond this quasi-stasis by allowing novel practices and products to be discerned, developed, deepened and disseminated. A key corollary was that the West was at last able to appreciate that many of the most important breakthroughs were to be found in the East. Francis Bacon, the philosopher-statesman who established the inductive method of scientific inquiry, hailed printing, gunpowder and the magnetic compass – all pioneered in China – as having “altered the face and state of the world”.

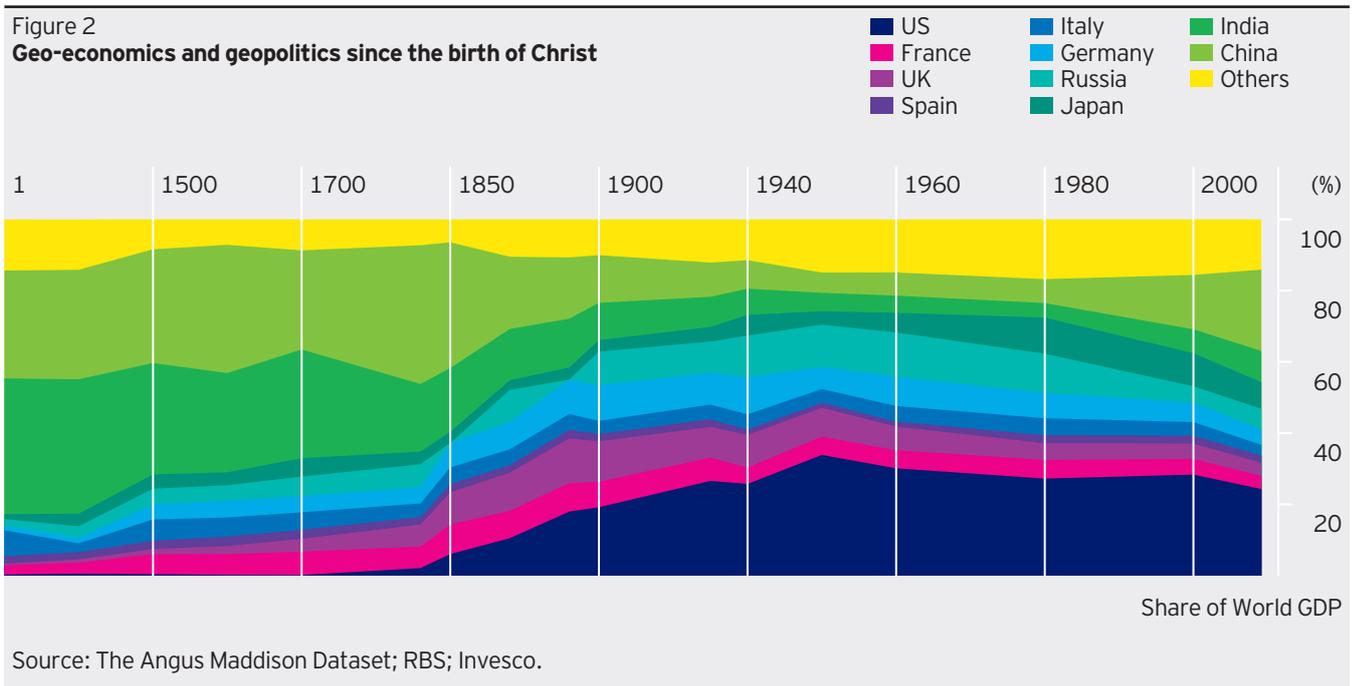
For reasons that scholars are still debating today, it was the West that took all three of these and used them to the greatest effect. This was in keeping with an East-to-West shift in both innovative activity and consequent power – a rebalancing that was markedly accelerated when the first industrial revolution began to unfold in the latter half of the 18th century.

As figure 2 shows, the epochal move to mechanised production not only fuelled enormous growth: it also substantially augmented the standing of many Western economies. Foremost among these, of course, was Great Britain, cradle of the first industrial revolution.

By the start of the 20th century, with electricity and the division of labour ushering in the second industrial revolution, it was the US that was starting to surge clear. In the early 1970s, as milestone advances in electronics and information technology heralded the onset of the third industrial revolution, the likes of the US and Japan were the principal beneficiaries.

Surveying the sweep of 2,000 years of human activity and the cumulation of innovation and investment over the past 200 to 300 years, we can draw three fundamental conclusions. Firstly, levels of and changes in gross domestic product, per capita income and productivity were broadly similar around the globe for at least one-and-a-half millennia – that is, prior to the first industrial revolution. Secondly, with isolation giving way to exploration, the West rapidly supplanted the East in terms of the scale and influence of its innovative output. Thirdly, the impact of genuinely radical innovation has always had a significant geo-economic and geopolitical dimension – one that, as we will see next, has exhibited a uniquely worrying mix of the familiar and the new during the past half-century.

“Levels of and changes in gross domestic product, per capita income and productivity were broadly similar around the globe for at least one-and-a-half millennia.”



3.2. Technology takes hold

The first, second and third industrial revolutions can generally be said to have replaced physical labour with installed, financial and human capital – thereby establishing complementary relationships between labour and capital over time. In so doing they boosted the cause of educated workers while displacing the lower-skilled. One result, as a wealth of research and data confirms, has been a massive increase in productivity² – of land, labour and capital (that is, “total factor productivity”) – with labour income and returns to capital assets rising over time.

As illustrated by data for the UK and the US³, none of these early industrial revolutions had any significant sustained effect on the level of unemployment. Instead unemployment has largely followed the economic cycle during the past 300 years or so, with major surges in joblessness tending to accompany financial crises and economic depressions. That said, as figure 3 demonstrates, average levels of unemployment have risen since 1973; in addition, studies have also shown that the labour share of national income in the US, for instance, has been in decline since the same year⁴.

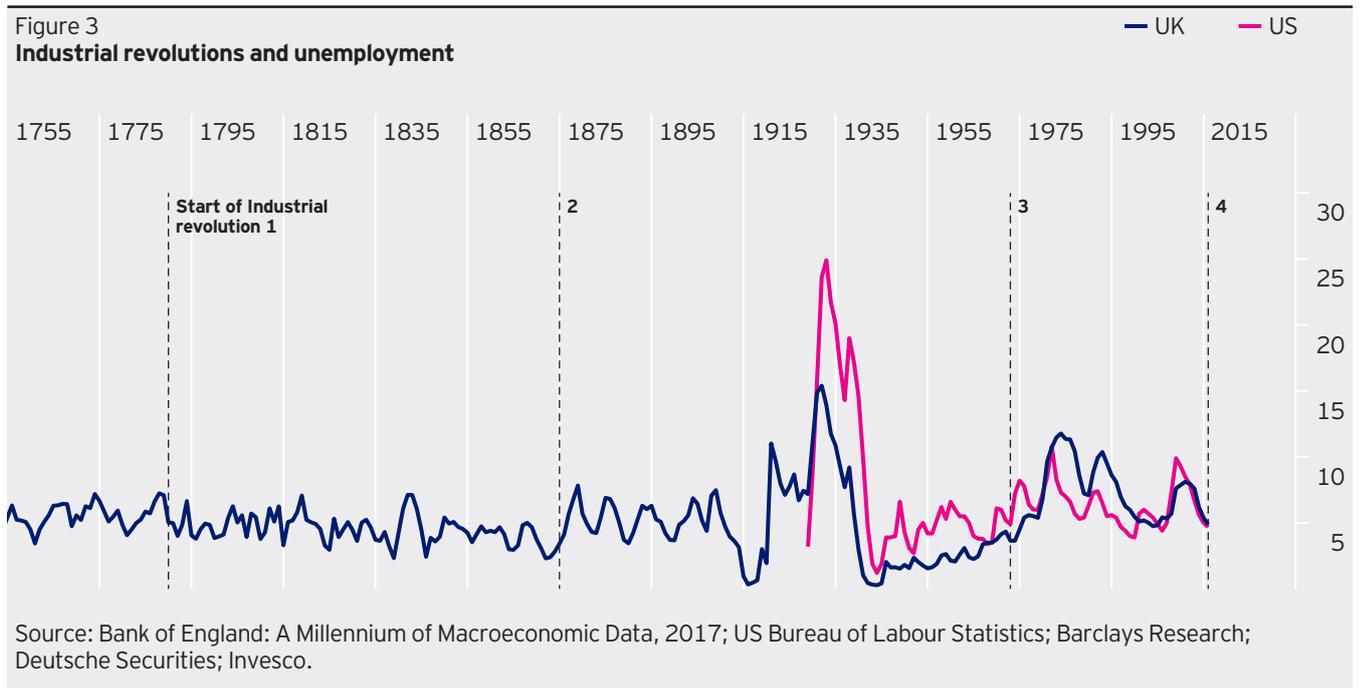
This prompts an obvious question: was there anything especially noteworthy about 1973? In fact, geo-economically and geopolitically, it was a rather eventful period. Developed economies were getting to grips with globalisation and the liberalisation of labour markets. The Bretton Woods system of fixed exchange rates, which had been in place since the end of World War II, was in its death throes. Inflation was nudging towards the rampant – above 8% in the UK and above 6% in the US – as the first oil shock hit following the Arab Oil Embargo. Inspired by the success of ping-pong diplomacy, China had begun normalising relations with the US. Under the aegis of Kissinger, Nixon had reached out to Chairman Mao in an effort to isolate the USSR. China had yet to set on its long march to economic reform, but the preconditions were being put into place.

Meanwhile, far from mainstream headlines, major strides were being made in a field that would soon come to be known as information technology (IT). The first transistor and the first microprocessor had recently been invented; so, too, had the forerunners of email and the internet. Motorola built the first mobile phone in 1973, while both Microsoft and Apple were already gleams in the eyes of Bill Gates and Steve Jobs and would both be founded within two short years. It was the dawn of the third industrial revolution: the digital age was under way.

It would be fanciful to claim, given all of the other events listed above, that a sudden burst of innovations in IT was solely responsible for the uptick in average levels of unemployment in the early 1970s. Similarly, it would be fanciful to claim that these and subsequent innovations have been solely responsible for perpetuating the trend during the past four decades and more. Yet it would seem equally fanciful to claim that they have not played some part: after all, the general environment of liberalisation and of labour markets – in the US in particular – would suggest that unemployment should have fallen rather than risen⁵.

“None of these revolutions comprehensively destroyed employment. That said, average levels of unemployment have risen since 1973.”

All of this raises further questions. If, as appears to be the case, the third industrial revolution contributed to higher unemployment – unlike the first and second – then what effect might the fourth have? How are the links between innovation, productivity, wages and employment developing today? Is it possible, even at this early stage, to identify likely winners and losers from IR 4.0?



3.3. Pause for thought

In the early 1800s, as the first industrial revolution took hold, England in particular experienced huge growth in output. It also experienced mass urbanisation, a rise in per capita income and landmark changes to its political, education, social security, transport and planning systems - in short, a near-all-encompassing societal transformation. What it did not experience was an increase in real wages: between the turn of the century and 1830, despite soaring productivity, wages remained stagnant.

Economic historian Robert Allen named this phenomenon "Engels' pause". He took his cue from Engels' *The Condition of the Working Class in England*, originally published in 1844, which painted an unremittingly grim picture of "the vast majority of the English people... those propertyless millions who own nothing and consume today what they earned yesterday".

The pause was precisely that: in time, partly in light of concerted efforts to restore the purchasing power of income relative to capital, real wages once again began to grow in line with productivity. As Allen wrote in his 2009 paper, *Engels' Pause: Technical Change, Capital Accumulation and Inequality in the British Industrial Revolution*: "The pause had a progressive side... for the bourgeoisie saved from its growing income, and the ensuing investment drove the economy forward."

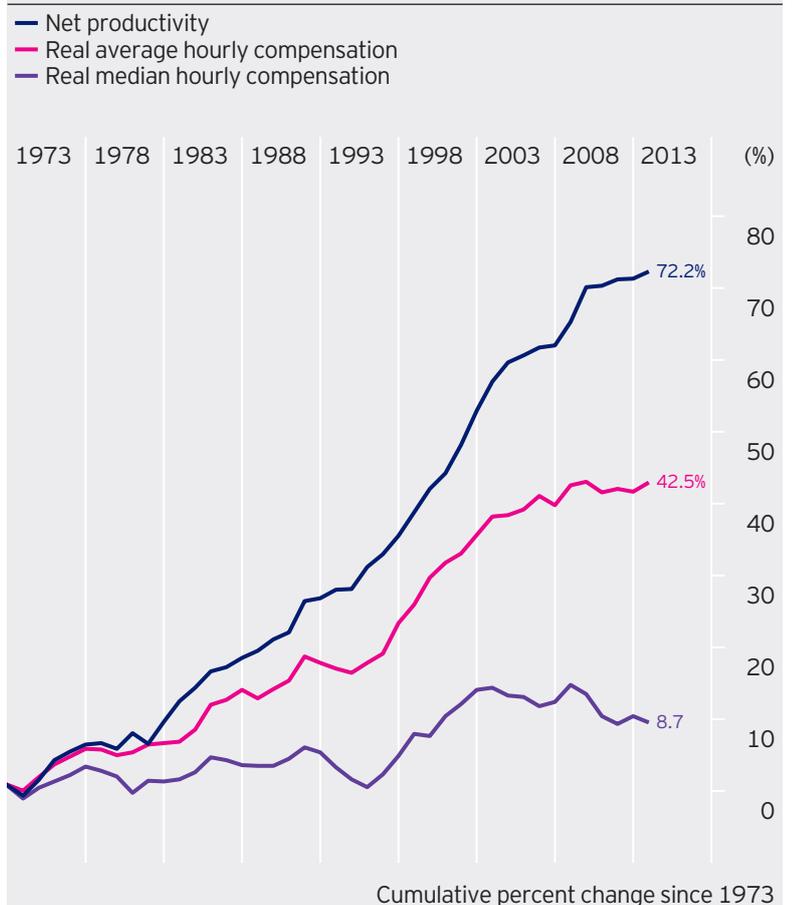
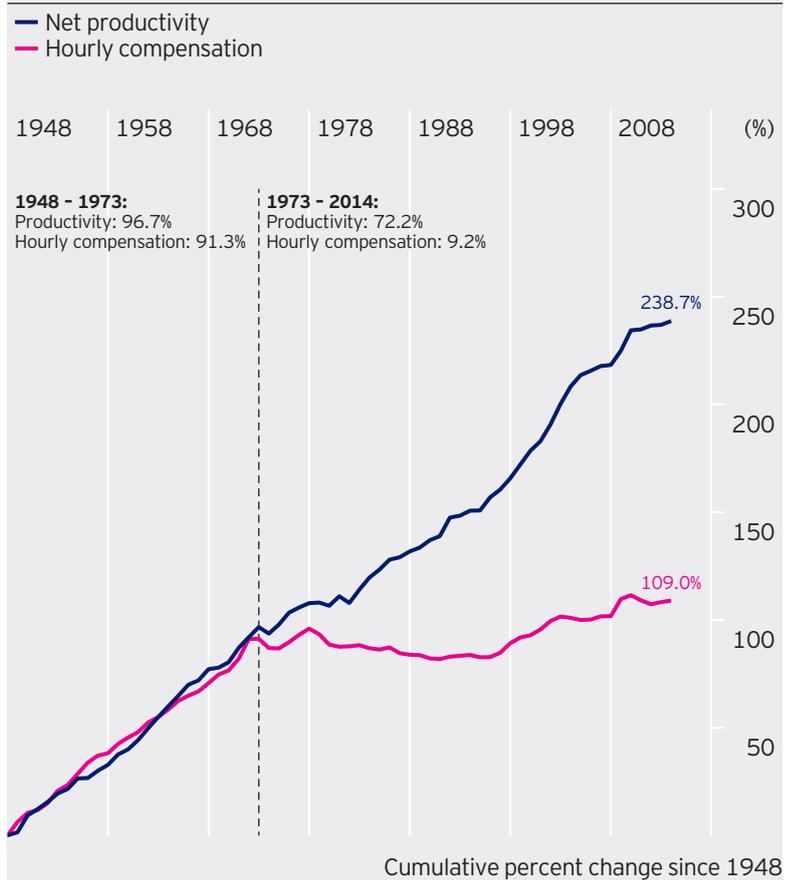
This is true enough, but it neither disguises nor excuses that "those propertyless millions" spent 30 years in comparative misery. It may also be worth remembering some of the longer-term repercussions of their plight, which might be said to have included a revolution of a different ilk. As Engels warned in *The Condition of the Working Class in England*: "The workers have taken it into their heads that they, with their busy hands, are the necessary and the rich capitalists, who do nothing, the surplus population." It could be argued that the ultimate political expression of popular discontent with Engels' pause was the Soviet Union.

Going forward, there are two reasons why these observations may prove pertinent. Firstly, productivity is again diverging from real wages during IR 4.0 - and this divergence may be more severe. Secondly, how workers, voters and policymakers respond to another Engels' pause is likely to go a long way towards shaping a societal transformation potentially every bit as far-reaching as that seen during the first industrial revolution.

Figures 4 and 5, which draw on data for the US, offer evidence to support the first of the above points. We will consider the second in more detail in the next chapter, focusing on the geo-economic and geopolitical challenges posed by persistent inequality and IR 4.0's ever-larger role therein.

"How workers, voters and policymakers respond to another Engels' pause is likely to go a long way towards shaping societal transformation."

Figures 4 and 5
Engels' pause revisited



Source: Bivens, J, and Mishel, L: *Understanding the Historical Divergence Between Productivity and a Typical Worker's Pay: Why It Matters and Why It's Real*, 2015; Invesco.

4. Inequality, automation and anger

4.1. The death of the dream

We remarked earlier that the first, second and third industrial revolutions boosted the cause of educated workers while displacing the lower-skilled. IR 4.0 is essentially carrying on this pattern, but in this revolution there are some additional twists - the first of which has been memorably described by Nobel Prize winner Paul Krugman as “disturbing”.

To appreciate this twist - and to understand why Krugman felt compelled to express his alarm so explicitly - we need to familiarise ourselves with two individuals. The first is a Princeton University Professor of Economics, Alan Krueger. The second is Jay Gatsby, anti-hero of one of F Scott Fitzgerald’s great American novels, *The Great Gatsby*.

Professor Krueger helped to pioneer the use of natural experiments to investigate issues such as the relationship between education and earnings and the effect of minimum wages on employment. In one such experiment he compared fast-food restaurant jobs in New Jersey, where the minimum wage was raised, and neighbouring Pennsylvania, where the minimum wage was not raised, and found - contrary to the predictions of most textbook supply-and-demand models at the time - that employment went up in the former setting and down in the latter. Simply put: Professor Krueger is a highly respected expert on economic inequality.

Gatsby was born into a poor farming family. He attended college but dropped out within weeks, unwilling to work as a janitor to support himself financially. Having reached the rank of major during World War I, he made a fortune during the Prohibition era and used the proceeds to live the life of a multi-millionaire on Long Island. Simply put: Gatsby was a poster child - albeit fictional and fatally flawed - for social mobility, the rags-to-riches trajectory of the American dream.

In January 2012, as Chair of President Obama’s Council of Economic Advisers, Professor Krueger unveiled what he and his staff called “the Great Gatsby curve”⁶, a means of plotting the likelihood that someone will inherit their parents’ income level. As figure 6 shows, the curve reveals the extent to which social mobility tends to be higher in those countries with a more even distribution of wealth and lower in those countries with greater wealth inequality; crucially, it also makes plain that inequality has become an intergenerational problem in the age of IR 4.0.

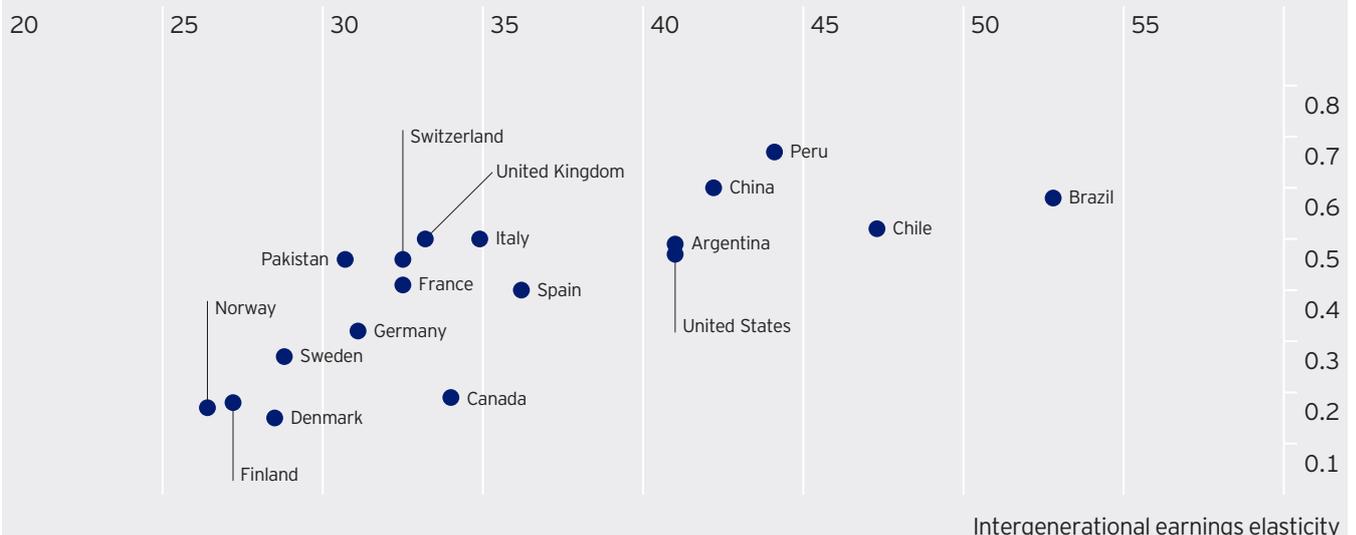
Introducing the curve, Krueger posited that “the persistence in the advantages and disadvantages of income passed from parents to children” in the US would “rise by about a quarter for the next generation as a result of the rise in inequality that the US has seen in the last 25 years”. In other words, because inequality is breeding more inequality, social mobility could become a further 25% less likely well before 2050. So much for the American Dream - and many other dreams besides.

“Because inequality is breeding more inequality, social mobility could become a further 25% less likely well before 2050.”

Figure 6

The Great Gatsby curve

GINI index (World Bank estimate)



Source: Krueger, A: The President’s Economic Report to Congress, 2013; Invesco.

4.2. The rise of the robots

At this juncture it may be worth pausing briefly to recap what we know so far about IR 4.0 and some important comparisons and contrasts to the prior three industrial revolutions. We know that unemployment has largely followed the economic cycle during the past 300 years or so; we know that average levels of unemployment nonetheless rose with the advent of the third industrial revolution; we know that productivity and real wages are now diverging, as they did during the first industrial revolution, and that the divergence in this instance is more pronounced; and we know that inequality not only persists but has become intergenerational. While resisting the temptation to deploy a trope such as “perfect storm”, we must now add to the fray a further complication: automation.

And here is the second twist: lower-skilled workers undoubtedly bore the brunt of the first, second and third industrial revolutions, but the would-be victims of automation are less easily pigeon-holed. According to an OECD study⁷, the occupations most likely to be automated in the years ahead span a wide spectrum of skills and qualifications.

As figure 7 shows, the professions whose probability of surrendering to automation is rated above 98% include telemarketers, insurance underwriters, mathematical technicians, watch repairers and accounts clerks; and those whose probability of surrendering to automation is rated below 1% include recreational therapists, social workers, audiologists, dietitians and choreographers⁸. From this we can infer that jobs oriented around routine or repeated tasks are likely to be automated and that jobs that require manual dexterity, human interaction and judgment are unlikely to be automated.

Taking a broader view, it seems reasonable to speculate that workers earning low-middle wages could be hit hardest. Automating the lowest-paying jobs makes little or no economic sense, while automating the highest-paying jobs is liable to prove difficult for a number of reasons - which leaves those between the two extremes, with those closer to the lower end of the scale most vulnerable.

It is right to stress that at present nobody can presage with certainty the longer-term impact of automation. If we take, say, telemarketing, which is deemed the most threatened sector of all, can we sincerely presume that the average consumer would be happier to deal with a machine than with a fellow human being? There are many unknowns, including the degree of sophistication that artificial intelligence might one day achieve⁹.

Nonetheless, there is no disputing that automation is taking place and gathering pace. Moreover, as we will see next, it may already have played a part in the biggest political shock in recent history.

“Lower-skilled workers undoubtedly bore the brunt of the first, second and third industrial revolutions, but the would-be victims of automation are less easily pigeon-holed.”

Figure 7

Probability of automation of occupations

Occupation	Probability (%)	Occupation	Probability (%)
Telemarketers	99.0	Recreational therapists	0.3
Title examiners abstractors and searchers	99.0	First-line supervisors of mechanics installers and repairers	0.3
Sewers Hand	99.0	Emergency management directors	0.3
Insurance underwriters	98.9	Mental health and substance abuse social workers	0.3
Mathematical technicians	98.9	Audiologists	0.3
Watch repairers	98.8	Occupational therapists	0.3
Cargo and freight agents	98.7	Orthotists and prosthetists	0.4
Tax preparers	98.7	Healthcare social workers	0.4
Photographic process workers and processing machine operators	98.7	Oral and Maxillofacial surgeons	0.4
New accounts clerks	98.7	First line supervisors of fire fighting and prevention workers	0.4
Library technicians	98.6	Dietitians and nutritionists	0.4
Data entry keyers	98.5	Lodging managers	0.4
Timing device assemblers and adjusters	98.5	Choreographers	0.4

Source: Berger, T, and Frey, C: Structural Transformation in the OECD: Digitalisation, Deindustrialisation and the Future of Work, 2016; Invesco.

4.3. The rage of the relegated

The revival of populism has become a defining element of present-day politics. Although it has assumed numerous nuanced forms – ranging from Russia’s ultra-resolute brand of patriotism to the UK’s public rejection, as rubberstamped in the vote for Brexit, of the purported surrendering of national sovereignty – it has almost invariably flourished in the face of mounting popular dissatisfaction with the status quo.

In Western Europe, as explained in depth in another Invesco white paper¹⁰, the origins of this dissatisfaction have very rarely – if at all – been traceable only to economic discontent. Notwithstanding the lingering consequences of the Great Recession, concerns such as mass migration and cultural liberalisation have usually been more to the fore.

In the US, however, the dominant narrative for Donald Trump’s surprise ascent to the White House has been that his “America first” rhetoric appealed directly to those who feared being “left behind”. So could IR 4.0 in general and automation specifically have affected voters’ behaviour?

Research published earlier this year investigated this theory by building on what the authors described as “the intuition that voters who have lost out to technology are more likely to opt for radical political change”¹¹. The study examined the region-by-region Republican share of the vote in the 2012 and 2016 presidential elections and compared them with levels of automation, again on a region-by-region basis, during the same timeframe. It was found that greater intensity of exposure to robots could be roughly associated with a shift in the popular vote and that this shift was less marked in relatively high-skill, high-education, high-income states. Figures 8 and 9 offer a basic snapshot of the suggested correlation.

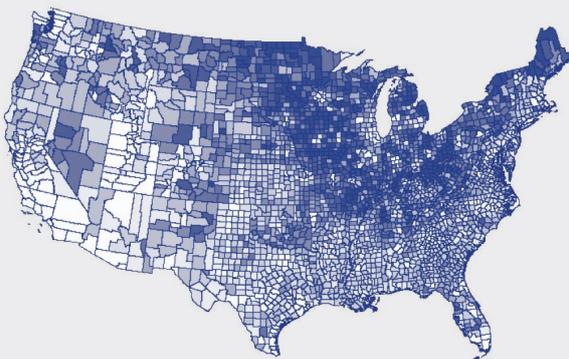
The possible historical parallels did not escape the research authors. Referring to the Luddite riots that targeted machinery during the first industrial revolution, they hypothesised that in the run-up to the 2016 election, as in the early 1800s, “a sizeable share of the workforce was left worse off... as it lost its jobs to technology”. Did the “left behind”, like the Luddites before them, seek revenge? The study concluded that Michigan, Pennsylvania and Wisconsin would have swung to Hillary Clinton, leaving the Democrats with a majority in the Electoral College, if “exposure to robots” in those states had not intensified in the years immediately preceding Trump’s triumph.

So now we have an apparent maelstrom of shifts in employment, diverging productivity and real wages, intergenerational inequality and, as highlighted above, simmering and politically charged tensions between the proponents of automation and those whose livelihoods it threatens. As if for good measure, we should not forget that people are living longer and that many therefore need to work longer. Given the magnitude of the geo-economic and geopolitical implications, are there any realistic responses?

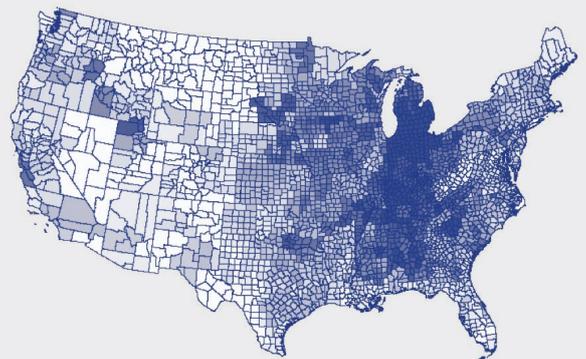
“Could IR 4.0 in general and automation specifically have affected voter behaviour? Did the ‘left behind’, like the Luddites before them, seek revenge?”

Figures 8 and 9
Automation and the shifting political economy of the US

Changes in the Republican two-party vote share



Changes in the exposure to robots



Source: Frey, C, Berger, T, and Chen, C: Political Machinery: Did Robots Swing the 2016 US Presidential Election?, 2018; Invesco.

5. Reactionary, regressive or rational?

5.1. Populism and the new Luddites

In this chapter we give some thought to potential responses to the issues discussed. We deliberately use the word “responses”, since it might be unduly optimistic – if not dangerously naive – to talk about “solutions”. Let us begin with the response touched upon in section 4.3: the reactionary cause seemingly preferred by those who lean towards populist politics.

Since we have featured research focusing on the US, it is important to acknowledge at this stage that IR 4.0 as a whole and automation in particular were not the only concerns in the minds of Trump voters – or, for that matter, Trump strategists. Trump may have punctuated his campaign with recurrent demands for companies to “buy American and hire American”, yet his pledges to recreate and safeguard jobs were routinely framed in terms of protectionism and isolationism rather than in terms of halting the march of the machines. Speaking in 2017, Treasury Secretary Steven Mnuchin went so far as to dismiss automation as “not even on our radar screen”, insisting that the risk of giant swaths of the American workforce being rendered obsolete could be “a hundred more years away”.

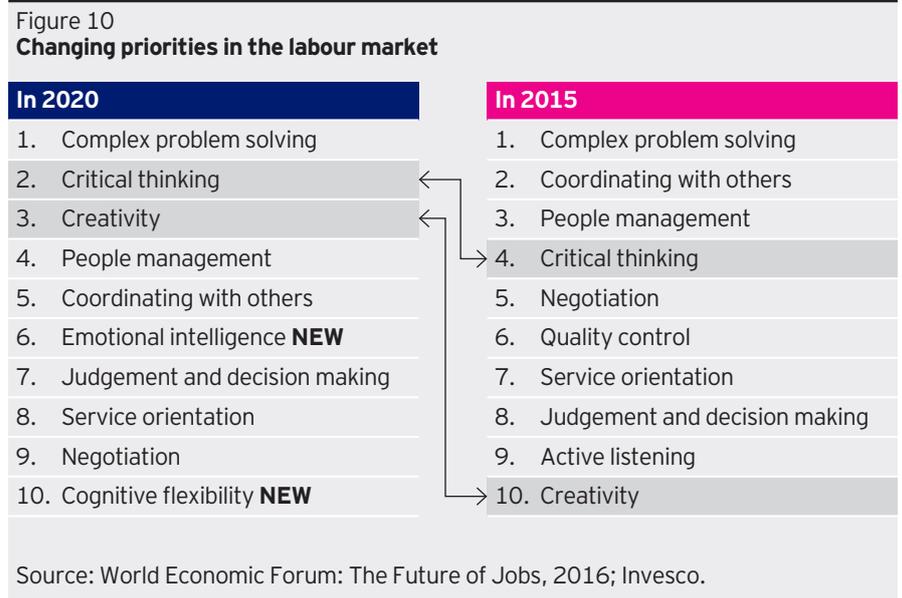
Yet the fact is that many American jobs have been lost not to other nations but to US-based robots¹². As Brian Alexander, author of *Glass House: The 1% Economy and the Shattering of the All-American Town*, wrote earlier this year after visiting Toledo, Ohio, the most roboticised metropolitan area in the US¹³: “The disruptions caused by robots and other technologies are deeply affecting the communities involved. These technological forces have joined many others – some cultural, some political – to create a generalised anguish that much is being lost. People have come to believe that they, their jobs, their communities and the social contract that binds them to work and place and each other are under threat.”¹⁴

Alexander’s assessment merits quoting at length, because it captures the feelings and perceptions of many workers and voters in the US and elsewhere. So, too, does his assertion that the displaced are “expressing their worries at the ballot box”. Furthermore, it follows that these workers and voters must expect populist politicians to repel the “technological forces” that they regard as a threat to their way of life. In some cases the mere arresting of automation’s spread might not be enough to assuage populist sentiment: nothing less than its undeniable reversal would suffice.

But Luddite-like regression would overlook several problems, the first and most patent of which is that the technology genie is well and truly out of the bottle. As figure 10 illustrates, priorities in the labour market are already in a state of flux – one that clearly reflects IR 4.0’s global influence. A regressive response might bring short-term gains – whether genuine or ostensible – in countries where populism has secured a foothold, but its longer-term legacy could very easily be a lot of noise and a lasting lack of competitiveness.

What if there were a worldwide determination to stem the tide of automation? Such a scenario appears implausible. China, if anything, has the opposite idea – of embracing rapid technological change. As we saw in section 3.1, the Age of Discovery heralded the separation of the West from the rest in the innovation stakes: today China yearns for a return to the economic pre-eminence once enjoyed by the Middle Kingdom, and IR 4.0 is central to its plans. The reality is that any country that willingly removes itself from the cutting edge – irrespective of how disruptive or destructive the cutting edge might be – is likely to be left in the dust.

“Luddite-like regression would overlook several problems, the first and most patent of which is that the technology genie is already well and truly out of the bottle.”



5.2. Long-term thinking and the quest for balance

The Chinese model is increasingly entering the debate over which economic and political structure might be best equipped for the future. Respected political scientist Ian Bremmer has noted that China's authoritarian-capitalist ethos, far from requiring reform, is now being seized upon, at least to some degree, by other countries - India and Turkey among them - that see attractions in "building systems where government embraces commerce while tightening control over domestic politics, economic competition and control of information"¹⁵.

There is no doubt that China has an unshakeable resolve to further its own cause. Some of the means by which it does so might be viewed by the West as dystopian, if not distasteful, but the result is an economic and political model that commentators such as Bremmer now consider more sustainable than that of the US. Here, without pondering the underlying rights or wrongs of the model in its entirety, we can at least accept that a key component of China's approach is to encourage innovation while at the same time preserving employment; and we can also accept that such a balancing act is extremely desirable for all economies.

In 2016, in a report entitled *The Future of Jobs*, the World Economic Forum (WEF) predicted that IR 4.0 would cause a net loss of more than five million jobs by 2020. This forecast was confined to 15 developed and emerging economies surveyed by the WEF. Earlier this year, in a follow-up report entitled *Towards a Reskilling Revolution: A Future of Jobs for All*, WEF founder Klaus Schwab wrote: "As the types of skills needed in the labour market change rapidly, individual workers will have to engage in life-long learning if they are to remain not just employable but are to achieve fulfilling and rewarding careers that allow them to maximise their employment opportunities."

What Schwab and the WEF advocate is firmly rooted in the long-term and the rational; and it is the long-term and the rational that should constitute the most promising response to the immensely complex set of interrelated challenges now confronting the global economy. Knee-jerk, at-a-stroke reactions are not the answer: they are more likely to be the harbingers of downturns. Policies need to row with the megatrends - that is, with the tailwinds very much in their favour - which means fostering innovation while striving either to maintain or to restore people's productive, wage-earning capacity.

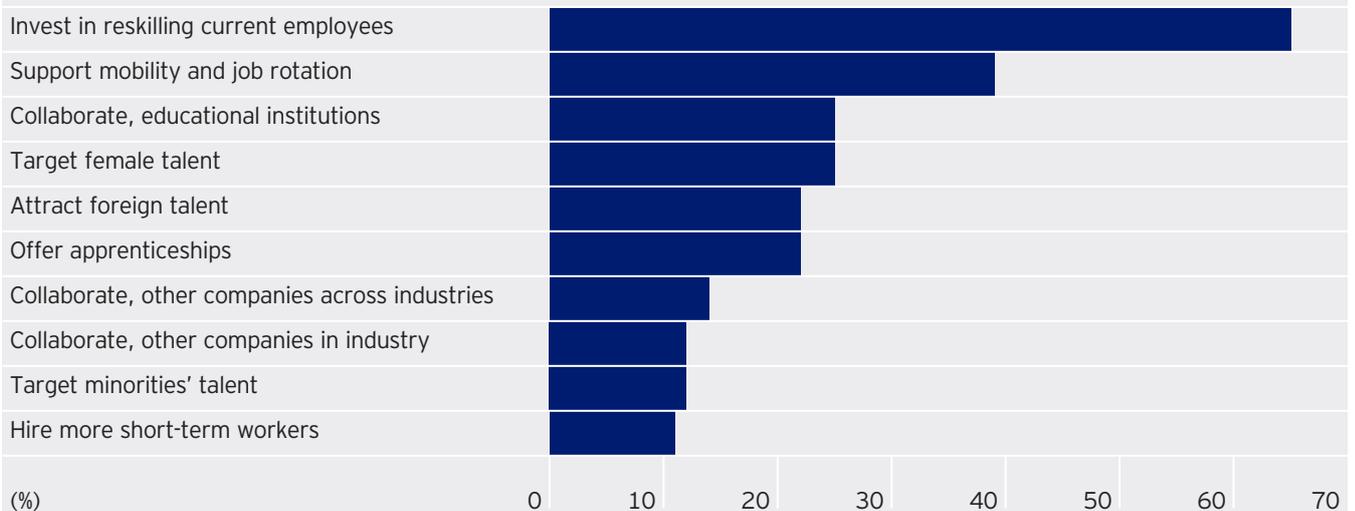
Schwab has emphasised the need to "think practically yet holistically about managing reskilling, upskilling and job transitions". "For companies," he wrote in *Towards a Reskilling Revolution*, "reskilling and upskilling strategies will be critical if they are to find the talent they need and to contribute to socially responsible approaches to the future of work. For policymakers, reskilling and retraining the existing workforce are essential levers to fuel future economic growth, enhance societal resilience in the face of technological change and pave the way for future-ready education systems for the next generation of workers."

This was hardly the prevailing mindset during the first industrial revolution. Even during the second and third it was not a conspicuous priority. Maybe this time, as figure 11 suggests, things will finally be different - in which instance investors' attention is likely to be drawn more and more to industries, sectors and companies that are discernibly committed to effective, responsible future-proofing.

"Policies need to row with the megatrends, which means fostering innovation while striving either to maintain or to restore people's productive, wage-earning capacity."

Figure 11

Future workforce strategies



Source: World Economic Forum: *The Future of Jobs*, 2016; findings based on survey of senior talent and strategy executives representing more than 13 million employees across nine industries in 15 developed and emerging economies; percentages indicate share of respondents pursuing given strategy.

5.3. Emerging markets and the threat of premature de-industrialisation

It is obvious that national political and policy responses, along with geopolitics, are likely to play a major role in deciding IR 4.0's winners and losers. As we have seen, competition is already afoot between the US/Western model of decentralised and devolved innovation and the Chinese model of state-coordinated progress towards the technological frontier.

China's apparently relentless pursuit of the latter course arguably makes it uniquely well placed among emerging markets (EMs) in tackling the unprecedented challenges that IR 4.0 poses. Its idea of the way ahead could scarcely be firmer. For many other EMs, however, the future is altogether less clearly defined.

EMs are especially vulnerable to IR 4.0's impact on the labour market. According to a World Bank study, up to 85% of workers in some EMs - compared to just 50% in developed markets (DMs) - could lose their jobs to automation and other technological advances. This is extremely significant, because it threatens the long-established growth/development model of manufacturing-led catch-up.

Historically, developing economies have sought to close the gap to their developed counterparts by raising productivity through industrialisation. This remains the most straightforward route to achieving DM-like levels of per capita growth and output. Yet IR 4.0, because it is liable to substitute capital for labour rather than complement labour, could block this avenue by making industrialisation itself much more difficult.

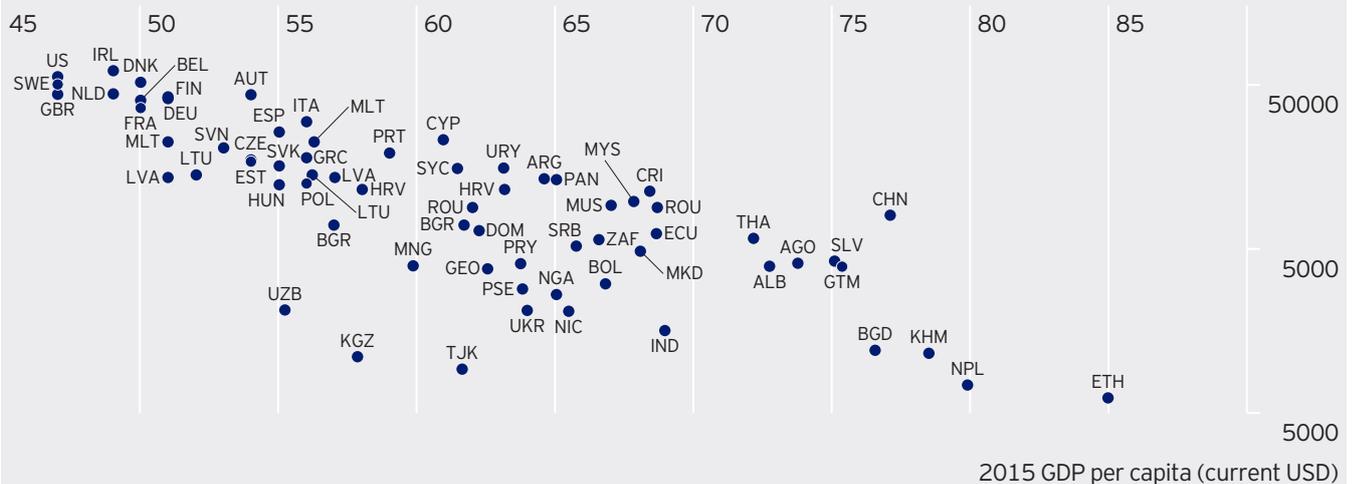
Many EMs could thus instead be left facing premature de-industrialisation. Their levels of manufacturing employment would peak far below those of DMs, and their hopes of catching up would be further diminished. Remember, too, that most EMs have already been victims of the "middle-income trap", having failed to cling to DMs' coat-tails even during the era of traditional manufacturing.

As figure 12 shows, although DMs are by no means immune from the gales of creative destruction, EMs can expect to bear the brunt of the coming storm. To quote a United Nations Industrial Development Organisation report: "The limited scope for extensive industrial growth and a higher share of jobs at risk poses a twin challenge for maintaining employment in emerging economies over the next decades." It could well be that the chances of the not-so-rich getting richer will soon be even slimmer than before; and it is very hard to say what political or policy responses might be available - and less still acceptable - in such circumstances.

"It could well be that the chances of the not-so-rich getting richer will soon be even slimmer than before."

Figure 12
Countries most at risk of job losses through IR 4.0

Share of employment at "high risk" of computerization



6. Conclusion: disruption and destruction revisited

Five hundred years and four industrial revolutions have not lessened the relevance of Machiavelli's observation that innovation "has for enemies all those who have done well under the old conditions... and lukewarm defenders in those who may do well under the new". The disruption and destruction that innovation customarily leaves in its wake still bring winners and losers, and even many of those who are likely to find themselves among the former cannot be sure that radical change will serve them well in every respect.

Yet radical change is all but inevitable. It always has been. Marx wrote of "explosions, cataclysms, crises". Schumpeter extolled "relentless necessity". In the late 1970s, when the IT-driven third industrial revolution was poised to take off in earnest, German economist Gerhard Mensch outlined how the macro-economy could suffer diminishing returns and eventually slip into "stalemate" if wholly reliant on incremental innovation. Ultimately, it is in nobody's interests to stand still forever.

In light of all of the above, it seems apt to recall George Santayana's much-used quote: "Those who cannot remember the past are condemned to repeat it." Historically, tensions have been at their greatest when the interests of the few have manifestly outweighed the interests of the many - that is, when the losers from radical innovation have massively outnumbered the winners. Many of the questions we are asking ourselves now have to some extent been asked before, and whether better answers will be forthcoming on this occasion remains to be seen. Will innovation skew global income distribution away from the renowned "elephant chart"¹⁶ and towards a society in which the means of production are owned by a handful of trillionaires or could it actually serve to reduce inequality over the long term?

By way of concluding on an optimistic note, perhaps it is also worth recalling the tale of biologist Paul R Ehrlich and his nemesis, economist Julian Simon. In 1980, 12 years after envisaging societal meltdown in *The Population Bomb*, Ehrlich famously wagered that resource depletion would drive up the prices of copper, chrome, nickel, tin and tungsten during the ensuing decade; Simon bet that prices would fall.

At first it appeared Ehrlich would claim the \$10,000 stake, but in the end, having initially risen, the price of each metal dropped to lower than it had been 10 years earlier. The price of chrome fell because of better smelting techniques; the price of copper fell because of the invention of fibre-optic cable; the price of nickel fell because improvements in mining technology unearthed enormous new reserves; the price of tin fell because aluminium emerged as a more abundant and inexpensive alternative; and the price of tungsten fell because of the growing use of ceramics.

Ehrlich's prophecy of doom proved unfounded, and Simon thus made his point: we might well innovate our way into trouble, but we can also innovate our way out of it. This truth resonates ever more heavily as IR 4.0 continues to unfold.

"Many of the questions we are asking ourselves now have to some extent been asked before, and whether better answers will be forthcoming on this occasion remains to be seen."

6.1. IR 4.0 and capital markets - general investment implications

We have argued that IR 4.0 has rebooted change from a clichéd constant to an undeniable accelerant. It has amplified, widened and deepened the processes of both enforced and creative destruction and has changed the nature of capital formation and accumulation all along both the dark and bright visions of capitalism offered by the Marxian and Schumpeterian traditions. We believe that these changes are already fomenting disruption in all areas of human endeavour, transforming economic activity and driving all financial asset classes, and that they will almost certainly continue to do so.

Furthermore, the accelerating aspect of disruptive innovation - especially radical and unprecedented use of capital to substitute for labour up and down the value chain and across wage, skill and income levels - implies not only that some emerging technologies may generate major shifts in the ways of life of people, firms and countries, thereby redirecting corporate earnings, but also that others will themselves be disrupted by future change. Many will be constrained and others uplifted by regulation. The business lifecycle of emerging technologies may not only be deeper, generating oligopoly profits, but also in some cases shorter as change accelerates - perhaps exponentially in some cases.

How such technological shifts will reconfigure output, employment and corporate profits across sectors and countries - and, indeed, at the firm level - is impossible to forecast with confidence. Nevertheless, we see several crucial market implications; and these should inform asset allocation and market strategy jointly with other major global economic themes, many of which we explore in other white papers.

These other crucial macro-, geo-economic and geopolitical themes touch on or are themselves directly influenced by IR 4.0, so to leave them aside would be a form of “partial equilibrium” thinking that might work tactically or temporarily but would take insufficient account of the overarching nature of IR 4.0 and its reach.

- Discontent with globalisation, migration, cross-border investment and trade – these are at once partial scapegoats for the effects of IR 4.0 on labour markets, to which innovative firms may well respond with technologies that circumvent these political and social challenges.
- The rise of China and associated geopolitical, geo-strategic and geo-economic competition in Asia and globally (for the US in particular) – a major front of which is attaining and maintaining pole position at the technological frontier, reflected in Made in China 2025 and in US/EU resistance to technology transfer requirements for investment and trade.
- Europe’s still-incomplete Economic and Monetary Union and Brexit – which partly reflect a desire for greater local control and rejection of a unified approach across political borders to shared challenges, including disruption and globalisation.

All of the above, along with IR 4.0 itself, represent a substantial challenge for the growth and catch-up models of many emerging market countries. Most of these models aim to raise per capita incomes by moving labour up the value chain, skill spectrum and productivity scale and by thus shifting from near-subsistence farming to manufacturing, supported by free trade, investment and at least a degree of migration.

Our three key views on the economic and financial implications of IR 4.0 are as follows:

1. We expect the effects of IR 4.0 to include continued moderate or low inflation pressures, pointing to subdued nominal bond yields amid cyclical shifts in the level and shape of yield curves in major government bond markets. With low nominal bond yields relative to history, there should be limited disruption to other fixed income asset classes, like credit, from a top-down perspective, but single-name shifts are likely to result from industry-level or firm-level disruption – about which more below.

The pressures of competition between countries and companies to maintain or even accelerate the pace of technological change should support returns on capital and constrain the ability of labour to sustainably, significantly and rapidly raise labour productivity. Sure, wages are now finally rising in the US and the UK, at historically low rates of unemployment; but many jobs are in low-productivity sectors and are unlikely to structurally alter the underlying trend of segmentation in labour markets, which in turn implies moderate wage pressure and inflation (assuming that constraints to rapid credit and money growth remain in place).

2. We expect significantly greater national differentiation, reflected in the shares of activity and in stock market capitalisation and earnings streams. This is because of IR 4.0 itself; because of efforts to limit the joint socioeconomic impact of globalisation and IR 4.0; and because countries, businesses and firms will morph into producers and users of IR 4.0 technologies.

These effects are already clearly under way and are likely to be accentuated as many firms and countries embrace technological change and keep adapting faster than others that are less able or willing to be flexible. There are likely to be bifurcations or at least considerable distinctions across both DMs and EMs.

We expect the **US** and Japan to keep leading the way among DMs. The US seems very likely to remain at the cutting edge of transformational technologies – as it repeatedly has throughout all four industrial revolutions, especially IR 4.0. The US equity market is therefore likely to continue to be the main market for the emergence of transformative technologies, disruptive firms and major new stock market titans.

Europe is likely to present a kind of barbell, with considerable room for leading-edge innovation in low/moderate-scale entrepreneurial sectors such as fintech and in the machinery and manufacturing of high-end and large-scale automation technologies and their application to existing technologies. However, Europe and Japan seem unlikely to incubate entirely new transformational technologies in the same way as the US, given the greater difficulty of generating large-scale venture capital funding, as well as the greater rigidity of product, services and labour markets (which protects them against disruption to some degree and may therefore restrain innovation).

As a subset, the effect of Brexit may well be to push the **UK** back towards the technological frontier not just in academic, military or financial sectors but also in commercialism. This could occur via reducing labour supply through migration controls; reducing importing power, as the collapse of sterling suggests; and through somewhat higher trade barriers with the rest of the EU but not with the rest of the world – all depending, of course, on the final form of Brexit.

Japan is likely to continue to excel in certain areas that reflect its own intrinsic and rare economic circumstances - both strengths and challenges - notably robotics and direct substitution of physical labour for manufacturing and, increasingly, services. Major Japanese multinationals and firms are likely to remain front and centre, given significant scale economies in R&D, manufacturing and sale.

We expect the large Asian economies, especially **China** and **Korea**, to lead the way among EMs. China's centralised model of innovation and industrial strategy, which emphasises social and state priorities via coordination, stands in stark contrast to the US model of devolved competition and has proven very adept, as variants with less state determination have across much of East Asia. It remains to be seen how and whether a centralised model will generate new technologies, in effect contributing to IR 4.0 as well as making use of it.

India will likely retain leading high-tech software, consulting and other IR 4.0 segments, but it is also likely to lag in hardware and to retain a very large agrarian economy, as well as traditional old-economy manufacturing sectors. High economic growth may therefore not be enough to sustain the traditional high valuations of Indian equities across the board, with greater discrimination between leading sectors likely as old-economy industrials suffer disruption worldwide.

Russia is likely to remain at the forefront of military technologies, tools and hardware but seems unlikely to be a driving force in commercialisation, given the state focus on national security and ongoing control of the commanding heights of the economy rather than on devolving economic control (whether regionally or to private firms or entrepreneurs). There is also a material probability that US-China and US-Russia tensions will encourage at least a degree of coordination and complementary specialisation between Russia and China.

The natural fit would be for Russia to lead on military capabilities and China to lead on big data, platform companies and consumer/services segments. While the China side of any such bargain is likely to be accessible in the stock and credit markets, the Russia segment may be in effect or formally renationalised, especially if US sanctions continue to bite and spread further. Russian assets are therefore likely to reflect the partially privatised swaths of the economy as a commodity exporter in the main, with bonds, currencies and stock markets dominated by global growth/inflation and financial conditions rather than disruptive technologies per se.

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3. We expect much more disruption in the structure and relative market capitalisation ratios across sectors and national indexes. It is early days yet, but an "Amazon effect" seems likely not only to affect inflation expectations via price transparency, competition and margin pressure but to continue to shift both underlying cashflow streams and the discount rates applied to these as they move.

Sectors and firms that are being disrupted by novel technologies or by new entrants applying technologies in new ways are likely to see lower market shares, plunging profitability and rising credit risk and spreads, as well as surging equity risk premia as their viability is questioned. This is hardly a new financial phenomenon, especially in the US stock market, but the speed and extent of such changes may well be qualitatively different. Examples already abound, including the US bricks and mortar retail segment; many others, such as airport parking and perhaps rail or short-haul economy air travel, may well be affected by driverless cars, for instance.

7. References and suggested further reading

References

- ¹ This white paper draws on a presentation delivered at Invesco's Global Investor Forum Summit, which was held in Houston in June 2018. Copies of the presentation are available upon request.
- ² See, for example, the Bank of England's A Millennium of Macroeconomic Data (2017) or studies by the US Bureau of Labour Statistics.
- ³ Much of our discussion here – and by others assessing these processes – seems to have a distinct Anglo-Saxon bias, for the simple reason that the available data for the UK and the US is more detailed and covers a longer time period than that for other countries.
- ⁴ See, for example, Bivens, J, and Mishel, L: Understanding the Historical Divergence Between Productivity and a Typical Worker's Pay: Why It Matters and Why It's Real (2015).
- ⁵ Globalisation was in the works but not yet in full steam, so it cannot take the lion's share of the blame for higher average unemployment, lower average wage growth or stagnating median wages – all features of the period since the mid-1970s in the US.
- ⁶ Carter Price, an applied mathematician at the Washington Centre for Equitable Growth, has suggested that a better name would be “the line to serfdom”.
- ⁷ See Berger, T, and Frey, C: Structural Transformation in the OECD: Digitalisation, Deindustrialisation and the Future of Work (2016).
- ⁸ The OECD's study indicates that market strategists and economists are at little risk of automation. We should perhaps say no more about that.
- ⁹ There are already stories – possibly apocryphal – of cutting-edge artificial intelligence systems becoming “bored” with their tasks. This suggests that they crave purpose and meaning, which in turn suggests that their ever-greater sophistication could bring ever more human-like flaws – so why, opponents might say, should we use them to replace humans in the first place?
- ¹⁰ See Rostowski, J, and Das, A: A Map for the Future of the Euro: Navigating Political Conflicts (2018).
- ¹¹ See Frey, C, Berger, T, and Chen, C: Political Machinery: Did Robots Swing the 2016 US Presidential Election? (2018).
- ¹² A 2015 study by Ball State University found that improved technology and automation accounted for 87.8% of manufacturing jobs lost in the US between 2000 and 2010.
- ¹³ According to a 2017 study by the Brookings Institution, there are nine robots for every thousand workers in the Toledo metropolitan area, where the automotive industry dominates manufacturing.
- ¹⁴ See Alexander's article in the July/August 2018 edition of MIT Technology Review.
- ¹⁵ Writing in Time in November 2017, Bremmer observed: “Americans and Europeans have always assumed that the long arc of human development bends toward liberal democracy. What if they're wrong?”
- ¹⁶ See Milanovic, B: Global Inequality by the Numbers: in History and Now (2012).

Suggested further reading

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