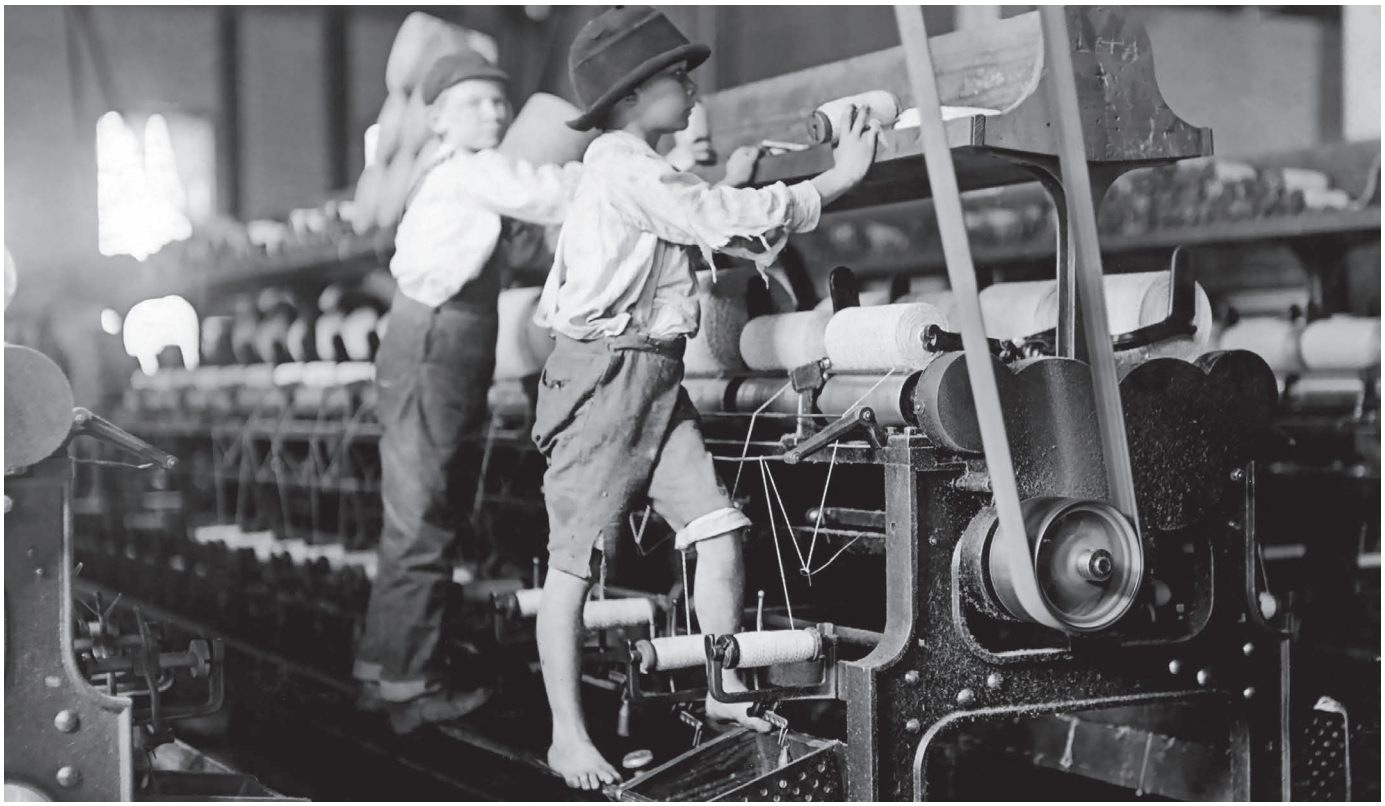
COMMENT



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Children working in a cotton mill in Macon, Georgia, in January 1909.

Lessons from history for the future of work

Global comparisons of previous social and economic upheavals suggest that what is to come depends on where you are now, argues **Robert C. Allen**.

Today is not the first time that people have worried that machines will render human labour obsolete, making a few very rich and the majority very poor.

Since the Industrial Revolution, mechanization has been controversial. Machines pushed up productivity, raising incomes per capita. But they threatened to put people out of work, to lower their wages and to divert all the gains from growth to the owners of businesses. The stocking-frame operators of Nottingham, UK (the Luddites), wrecked improved knitting machines that threatened their jobs. Mobs burnt down the first mills housing spinning and weaving equipment in the 1760s and 1790s.

Now, it is robots that threaten work, wages and equality[1]. Are the gains of technological progress destined to benefit only the top 1% of earners?

Economists' stock answer to this question is 'no'[2]. Technical progress in the past three centuries has led to incomes in the West (that is, the developed nations of today) that are much higher than they were in 1700 in real terms, and the fraction of the adult population employed in these countries is at record levels. Despite mechanization, automation and ▶

THE FUTURE OF WORK
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computerization, people have found jobs. Somehow the economy has always adjusted; somehow in the future it always will.

I think this answer is too simplistic.

PHASE SHIFT

There have been long periods of economic history in which things did not work out well, and we must wonder whether we are in another. Also, the 'future of work' depends very much on where you are in the world. Most discussions in the West focus on how technological evolution in the West affects jobs in the West. This frame is too narrow for the twenty-first century: we must investigate the effect of technological change on work everywhere. For the past three centuries, the global economy has been sufficiently integrated that new technology in one place affects work in others.

Rather than ask (unanswerable) questions about how machines will affect work over the next centuries, we can ask what the invention of the textile mill meant for a girl growing up in Manchester, UK, in 1800 or the wife of a subsistence rice farmer in China's Yangtze Delta at the same time. Technological change affected their futures of work very differently and often detrimentally. Similar things are happening now.

We need to divide the past into periods defined by trends. The periods I suggest here reflect Western history, which is not as limiting as it sounds: globalization means that developments in one region affect others.

The three phases are: the Industrial Revolution (1750–1830); the Western ascent to affluence (1830–1970); and the problem-ridden present (since 1970). Each holds lessons and pressing research questions for today.

THE INDUSTRIAL REVOLUTION

The Industrial Revolution was Britain's creative response to the globalization of the world economy that occurred after Columbus's voyage to America in 1492 and Vasco da Gama's sail around Africa to India in 1498. Britain's colonies in North America, the Caribbean and India formed a large market for Britain's handicraft industries. Exports boomed, and by the mid-eighteenth century about one-third of Britain's workforce was employed in making metal goods and cloth.

Large data sets of wages and prices over this period[3] have been assembled since the 1980s and show that real wages rose as a consequence of this export boom[4]. Inventors designed machines to save expensive labour. Mechanization paid in Britain rather than elsewhere because labour was more expensive relative to capital; that is why the Industrial Revolution was primarily a British affair.

Textiles were the world's most important manufactured product in terms of employment before the Industrial Revolution, and the first to be mechanized. Indian cotton cloth was imported to Europe, where it was a smash hit. English manufacturers struggled to compete because English wages were so high. The invention in the 1760s and 1770s of spinning machines to speed up cloth-making, including Hargreave's spinning jenny, Arkwright's water frame and Crompton's spinning mule, solved the problem. The first victims of technological unemployment were the British women spinning cotton by hand and, later, the much-larger number spinning wool, once machinery was adapted to that fibre.

Soon jobs were lost from Casablanca to Canton. Investing in spinning machines made sense only in the high-wage economy of eighteenth-century England, thus they greatly increased English competitiveness without benefiting other nations. As jobs proliferated in the British cotton mills, massive technological unemployment spread across Africa and Asia[5]. The collapse of the Indian cotton trade around the 1830s led the British governor general to remark[6]: "The bones of the cotton-weavers are bleaching the plains of India."

"The first victims of technological unemployment were the British women spinning cotton by hand."

In 1820, the future of work for the wife of a farm labourer in England was an unhappy one. She had lost the opportunity to increase her family's income by spinning part-time, as her mother had done. The same impoverished fate befell a farmer's wife in the Ganges or Yangtze deltas. Some British women found work in the cotton mills (but a smaller number than had been employed to spin cotton by hand). By contrast, the future of work was auspicious for railway engineers, bricklayers and metal workers, to say nothing of the vast number of middle-class entrepreneurs and professionals who directed and serviced the industrial economy.

Machines were invented to save labour in most sectors of the economy in the first half of the nineteenth century. As one trade after another was eliminated in Britain, earnings collapsed in the affected trade, and that, in itself, lowered average national earnings. The displaced workers shifted into other trades, pushing down those wages. The Luddites and other opponents of mechanization are often portrayed as irrational enemies of progress, but they were not the people set to benefit from the new machinery, so their opposition makes sense.

The implications were stark (see 'Trends in work, pay and manufacturing'). Although output per worker grew from 1770 to 1890, there was little growth in the real wage from 1770 to about 1830. During the Industrial Revolution (phase one) the 'normal' relationship was booming productivity and constant average wages — rather like the past 40 years.

THE WESTERN ASCENT TO AFFLUENCE

The average real wage only began to rise in the middle of the nineteenth century, when higher-productivity factory work replaced the hand trades. By 1850 Britain was the 'workshop of the world'. Comprising only around 3% of the world's population, the United Kingdom produced about half of the world's iron, for instance.

Industrial pre-eminence saw in the next phase of history. The new normal in the West was productivity and wages advancing together, as the Industrial Revolution spread across Europe and North America. Although there were shocks along the way owing to the depression of the 1930s and the Second World War, the period from the mid-nineteenth century to 1970 was one in which the working class benefited from the growth in productivity. Incomes became more equal. This is the economic performance that many have come to regard as normal.

How this favourable situation arose is a fundamental question. It seems that a positive-feedback system was in operation. Rising incomes led to the demand for fancier manufactured goods (for example, bicycles then cars) and more services (such as travel, retail trade and medical care). These created markets that encouraged technological change and led to jobs that were performed more effectively by educated people[7].

The need for educated workers led to the expansion of state provision of education. The increasing number of educated people prompted the invention of technologies that took advantage of education[8]. Those technologies led to further demand for education. At the same time, the public provision of infrastructure — roads and airports, for instance — was crucial for the development of industries involving cars and aircraft. Public support for research in medicine, agriculture and technologies with military applications, such as electronics and aircraft, underlaid many advances. The welfare state helped to spread the benefits of this economic development across the population.

The upshot was a pattern of economic growth in which technical progress benefited most people in the West.

The same was not true in Asia and Africa. Before the Industrial Revolution, China and India had the largest manufacturing sectors in the world because they had the largest populations, and nations were mostly self-sufficient in the pre-globalization era. As the Industrial Revolution gathered pace, Britain's share of goods manufactured worldwide increased, reaching a peak of about one-quarter in the late nineteenth century. Western Europe's share and that of North America also increased. In the same period,

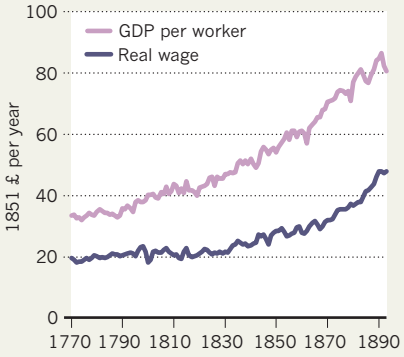
SOURCES: SEE SUPPLEMENTARY INFORMATION

TRENDS IN WORK, PAY AND MANUFACTURING

The relationship between wages and output has altered over time and place, as regions' roles in global trade have shifted. Understanding these fluctuations could help to predict future changes.

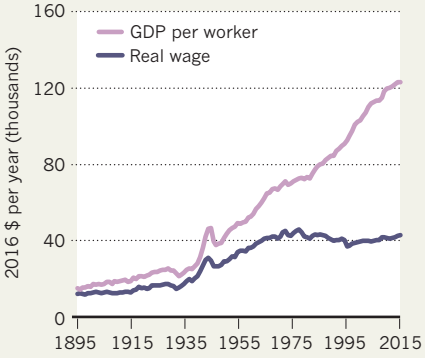
Wages in Britain 1770–1893

At the start of the Industrial Revolution, productivity grew, but wages did not; after 1830, as mechanization gathered pace, wages and output moved in lockstep.



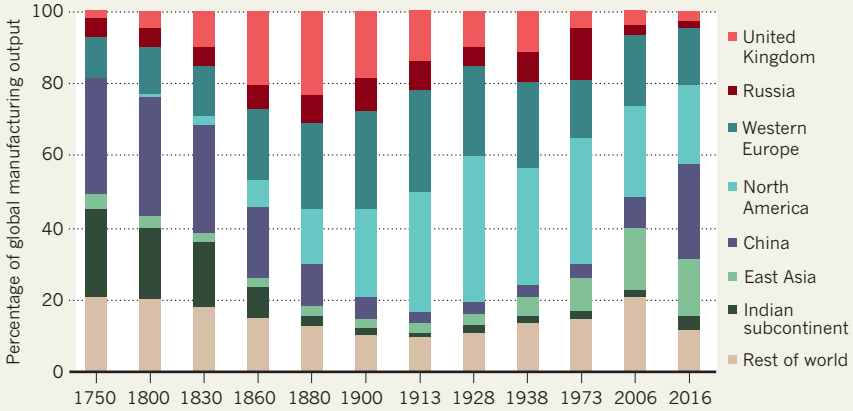
Wages in the United States 1895–2015

At the beginning of the twentieth century, wages rose with increasing productivity; since the 1970s, they have stagnated as output per worker has continued to rise.



Distribution of world manufacturing

Over the past three centuries, self-sufficiency gave way to shifting patterns of dominance in global trade.



the shares of India and China collapsed. This drop represented absolute de-industrialization and not simply shifting percentages.

The technological revolution that spread prosperity in the West created modern 'underdeveloped countries' in the East (that is, Asia, Africa and South America). It converted them into economies that exported solely primary products — wheat, rice, bauxite, oil — rather than secondary ones such as cloth and porcelain.

By the 1830s, technological progress in the West meant a bleak future of work elsewhere.

THE PROBLEM-RIDDEN PRESENT

The past four decades have seen many job losses in the manufacturing sector in Western countries, static or falling real wages, and rising inequality as the gains from growth accrue to the top 1%. Did the 'new normal' end in 1970, or are the recent trends just a blip? Might what was 'normal' in 1850–1970 return soon — that is, the concurrent advance of productivity and wages?

Some people believe that the feedback loops between education and technology will kick in again, generating new knowledge-based, high-income jobs in the West to replace lost manufacturing jobs. Computers and robots will save us.

I am more pessimistic. The rise in real wages that began in the mid-nineteenth century and tracked the rise in output per worker ended in the 1970s (see 'Trends in work, pay and manufacturing'). Real wages rose at a slower rate than productivity in the 1980s and 1990s — or stagnated altogether, as in the United States. In some cases (for example, the United Kingdom) wages have actually been falling in real terms over the past decade. A deviation of this magnitude from the trend suggests that the new pattern may not be transitory.

Similarly, the rebound in overall inequality in mature economies, such as the United States, over the past 40 years is unprecedented. Inequality rose in many countries as they industrialized and fell thereafter — this trend is called a Kuznets curve (after the Nobel laureate Simon Kuznets)[9]. The rise in inequality since 1970 has shown that this is a reversible feature of economic history.

Inequality is an area that has seen much recent research, with large data sets assembled and interrogated. Some scholars have focused on the share of total income going to the top 1% or 5%[10]. Others use indices that incorporate information from every level of the income distribution[11]. How we interpret the results depends on our breadth of vision. A common pattern in many countries is a fall in inequality from the early twentieth century to the 1970s and then a rise. This is true of the United States, the United Kingdom and China, for instance. At the global level, inequality increased steadily from 1820 to 1990 and then declined slightly. This pattern takes into account inequality between countries as well as within. Rising per capita incomes in the West in phase two increased global inequality. In phase three, global inequality fell even though inequality increased in many rich and poor countries[12].

Why are the feedback loops that led to general prosperity in the West between 1850 and 1970 seemingly inoperative now[13–15]? A big change is the industrialization of Asia — first Japan starting in the 1870s, then South Korea and Taiwan since the Second World War, and now China (see 'Trends in work, pay and manufacturing'). These countries have supplanted Western nations as the low-cost producers of manufactured goods. Trade flows have reversed, with Asia shipping textiles and steel to Europe rather than the other way around. Technological progress in Asia has raised incomes and levels of employment dramatically in the region.

The future of work to someone born in China in 1990 is bright indeed — provided that the country can avoid environmental crises and resource depletion.

Globalization means that Asia's bright future causes havoc elsewhere. Imports of cheap Japanese steel and vehicles caused the collapse of the rust belt in the United States and its counterparts in Western Europe (with Germany as something of an exception). Western de-industrialization was the flip side of the East Asian miracles. And cheap Chinese imports may benefit Africans as consumers, but could blight their employment prospects as African industries struggle to compete. Indeed, China is now purchasing large areas of land in Africa to guarantee access to food and minerals. It is hard to believe that manufacturing or information technology will ever recover in the West, no matter how many robots are installed, visas rescinded, trade agreements

ripped up or walls built.

We cannot forecast the future without an understanding of the relationships between science, technology and the economy, because technical change is such an important determinant of the future. I have studied these questions for the Industrial Revolution using business accounts and histories of inventions. The steam engine, for instance, was an application of seventeenth-century science (the discoveries that the atmosphere has weight and that condensing steam creates a vacuum). By contrast, the cotton mills owed little to science and much to attempts to cut costs of relatively expensive employment[16].

How has the balance between knowledge and incentives evolved? The more technology advances in response to economic incentives rather than 'random' scientific discoveries, the more feasible it is to direct the course of technical progress to benefit more people. Furthermore, the cotton mills of the Industrial Revolution increased the demand for workers without education, whereas more-recent technology requires more education. Why the difference? Will the recent trend of needing educated workers persist? If not, then the hope that a knowledge-based future will make everyone better off is doomed. ■

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Supplementary information accompanies this article online; see go.nature.com/2i5dj4r.

A robot conducts the Orchestra Filarmonica di Lucca at Teatro Verdi in Pisa, Italy, this September.

Reboot for the AI revolution

As artificial intelligence puts many out of work, we must forge new economic, social and educational systems, argues **Yuval Noah Harari**.

The ongoing artificial-intelligence revolution will change almost every line of work, creating enormous social and economic opportunities — and challenges. Some believe that intelligent computers will push humans out of the job market and create a new 'useless class'; others maintain that automation will generate a wide range of new human jobs and greater prosperity for all. Almost everybody agrees that we should take action to prevent the worst-case scenarios.

The automation revolution is emerging from the confluence of two scientific tidal waves. Computer scientists are developing artificial intelligence (AI) algorithms that can learn, analyse massive amounts of data and recognize patterns with superhuman efficiency. At the same time, biologists and social scientists are deciphering human emotions,