Millennium issue: WEALTH

The road to riches

Dec 23rd 1999
From The Economist print edition

Western man is incomparably richer than his ancestors of 1,000 years ago. And he takes it for granted that he will grow richer still. Yet, seen in its long-term context, the past 250 years' rise in incomes and living standards looks less like an inevitable process and more like a single, astonishing event

FOR nearly all of human history, economic advance has been so slow as to be imperceptible within the span of a lifetime. For century after century, the annual rate of economic growth was, to one place of decimals, zero. When growth did happen, it was so slow as to be invisible to contemporaries—and even in retrospect it appears not as rising living standards (which is what growth means today), merely as a gentle rise in population. Down the millennia, progress, for all but a tiny elite, amounted to this: it slowly became possible for more people to live, at the meanest level of subsistence.

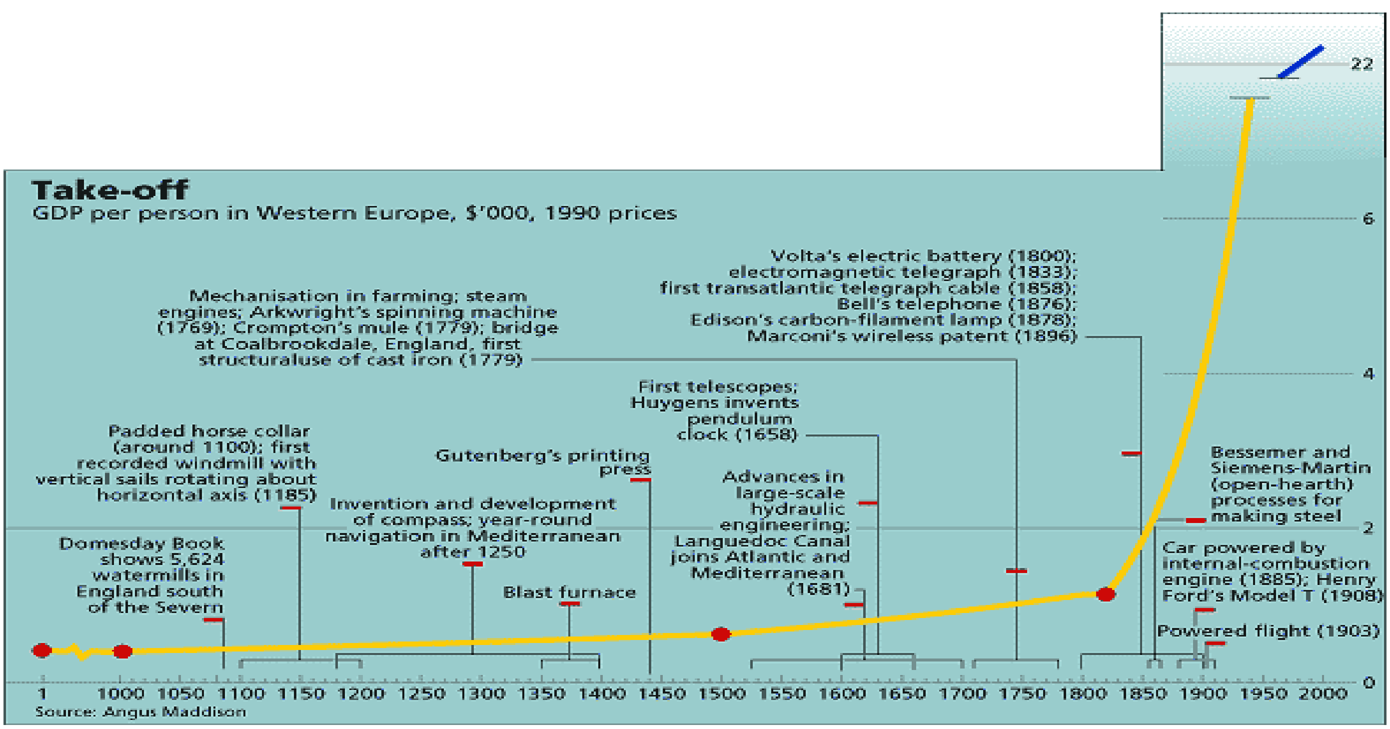
From about 1750, this iron law of history was broken. Growth began to be no longer invisibly slow nor confined, as it largely had been before, to farming. The new increase in human productivity was staggeringly large: it not only supported a hitherto unimaginable 7 1/2-fold rise in the world's population, but entirely transformed the lives of ordinary people throughout the West.

This surge of growth was due to industrialisation. Thanks to it, material prosperity has risen more in the past 250 years than in the previous 10,000. And so conditioned to growth have people become that most westerners now expect their standard of living to improve automatically year by year; if it does not, something is wrong. This taking for granted what would once have seemed miraculous is the measure of the change.

What, why, there, then?

What happened? And why at that particular time, in that particular place, Western Europe and its American offshoot? The answer to the first question seems straightforward: technology happened. Yes, but that doesn't tell us much: "better technology" is much the same thing as "economic growth". The real issue is: why? What set off this technological upheaval, and why there and then?

One theory goes as follows. Technology is driven by knowledge, and especially by scientific knowledge. Knowledge is cumulative: once it exists, it does not cease to exist. So this process of accumulation, with discovery building on discovery, is strongly self- reinforcing, with a built-in tendency to accelerate. When a certain critical mass of knowledge exists, the pace of future accumulation can increase very sharply, as previously unsuspected connections between different branches of knowledge are exploited, each breakthrough creating new opportunities. If something like this is correct, then a technological take-off point was bound to come along somewhere, some time.



Why, then, did it come along in 18th-century Europe? On this view, because the scientific preconditions were in place. European science had flowered in the 17th century—the age of Galileo and Newton, of Hooke and Huygens. These and others, note, were technological innovators as well as scientists. Galileo, a pioneer of mathematics and astronomy, made telescopes and other instruments. Hooke, he of Hooke's law of the compression and extension of elastic bodies, a brilliant chemist and physicist, built an air pump and developed balance-springs for watches. Huygens, a mathematician and physicist, invented the pendulum clock, and proposed a kind of internal-combustion engine (using gunpowder for fuel); even Newton, generally disdainful of technology, worked on improving the marine sextant and invented the reflecting telescope.

Mathematics and mechanics had come together. By the end of the 17th century, understanding and application had converged. Knowledge had expanded, you might say, up to and beyond that point of critical mass. The intellectual foundations for the technological revolution were in place.

The discovery of atmospheric pressure is probably the best illustration of how an early scientific finding gave rise to a crucial new technology. The technology in question was literally the driving force of the industrial revolution: the steam engine. Evangelista Torricelli and Otto von Guericke were the first Europeans to show that the atmosphere existed; in 1654 von Guericke, mayor of Magdeburg, demonstrated the fact with his famous public experiment in which teams of horses were unable to separate two hemispheres that had had the air between them drawn out. Many others then began to explore the possibilities of harnessing this atmospheric force as a source of power. After more than a century of improvements and iterations, the result was James Watt's celebrated steam engine, which went into full-scale production in 1774.

This "science leads technology" theory is plausible. Large parts of it are undoubtedly true—yet as it stands it will not quite do.

Central though it may be to the history of the industrial revolution, the case of atmospheric pressure and the steam engine is far from typical. Until the latter part of the 19th century, technological progress did not in general rely on scientific progress. Few of the inventors responsible for the astonishing wave of innovation between 1750 and 1860

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were scientists; most were artisans or engineers with little or no scientific training. They were men of common sense, curiosity, energy and vast ingenuity, standing on the shoulders not of scholars but of similarly practical types. Their goal was not to understand, but, as Watt said of his own efforts, to make machines that worked better and (he emphasised) at lower cost. And remember that, for every one who succeeded in this aim, perhaps another hundred tried, at great expense of money and time, only to fail.

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This was true across the whole range of 18th-century industries. For about 100 years after 1750, radical innovations in shipbuilding, mining, metallurgy, textiles, food-processing and machine tools were the fruit not of scientific breakthroughs but of indefatigable trial and error, under the guidance of experience and craft tradition. The improvements in cotton-spinning that were soon to transform the British economy—from Arkwright's spinning machine to Crompton's mule—had not been waiting upon science. So far as science was concerned, these technologies could have been invented decades or even centuries earlier.

At the start of the 19th century, a Frenchman, Nicolas Appert, found that food could be preserved in bottles that had been boiled and sealed airtight. Within 20 years, tin-coated cans came into use. It was a crucial innovation for the development of urban society. But Appert did not know why his process worked, nor did anybody else; Louis Pasteur did not discover the role of micro-organisms in spoiling food until 1873. First came work, inspiration and luck; later, chemistry.

After 1860 or so, gradually at first and then more rapidly, science began to play a bigger role. Chemistry was indeed the first industrial science. Soon the better understanding of chemical phenomena gave rise to new industrial techniques and, more important, to new materials and entirely new goods. When physics became an industrial science, the results were even more startling: electricity and telecommunications. Thomas Edison, a remarkable pioneer in these fields, was a transitional figure. He was trained as a telegraph operator, not as a scientist. In 1876 he set up his legendary "invention factory" at Menlo Park, New Jersey, began hiring scientists, and set them to solve industrial problems. It was the first industrial research laboratory: the modern pattern was established.

A question of timing

Yet the fact remains that the decisive break between the economic stagnation which kept most of mankind in poverty for thousands of years and the modern era of rapid innovation and growth occurred fully a century before science was harnessed to technology. Moreover, western science had already moved significantly ahead of that of other societies by the beginning of the 17th century; yet the West was no richer at that time than those other societies. It was another 150 years before the real surge in western growth began. The link between science and technology is subtler than you might think.

In its day, ancient Greece was pre-eminent in science. But the knowledge of Aristotle and his students was never applied in the economic realm. The Romans continued that tradition. Far ahead of the barbarians of early medieval Europe, they also established what many today regard as the preconditions for growth in the third world and in the ex-communist economies of Eastern Europe—physical infrastructure and the rule of law. Yet more was achieved in technological innovation during the five or six "dark" centuries after the collapse of the Roman empire than in its heyday. One example: among the most significant innovations of the early Middle Ages was a horse-collar that did not half-throttle the animal as soon as it began to pull with any force. The sophisticated Romans had accepted this handicap, and the flimsy chariots and lack of heavy transport that went with it, for centuries.

But there is a greater puzzle than all this: the course of China's economic development after 1400. In a different way, this poses an even greater challenge to the view that science and technology move in a virtuous, self-sustaining, naturally accelerating circle.

At the start of the 15th century, China's supremacy in science and technology alike was dazzling. The economy was on the verge of industrialising. Farming was technologically advanced, using sophisticated hydraulic engineering, ingenious ploughs and other tools, various natural and artificial fertilisers, and carefully documented veterinary medicine. The casting of iron, requiring blast furnaces, began in China before 200BC, in Europe some 1,500 years later.

China invented paper about 1,000 years before the idea reached the West. It was printing by the 8th century, and using a form of movable type by the 11th, four centuries before Johannes Gutenberg got round to it (in a superior, cast-metal, version) in Europe. More mundanely, the Chinese thought of the wheelbarrow in about 200, a fine invention not used in Europe until the 12th century. And that non-throttling horse-collar dreamed up by medieval Europe was in use in China from 250BC. Add in explosives, ship design, clock making, weaponry and so on, and the list seems endless.

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Then, after about 1400, China's technological progress slowed. By 1600 it had fallen behind Western Europe. By 1800 the gap was very wide. It is thought that the Chinese understood atmospheric pressure before the West; but they did not develop the steam engine. The spinning wheel appeared in China about when it did in Europe; but the elaborations that gave Europe the spinning jenny and the industrial production of textiles never followed. In some cases what happened was worse than stagnation: ideas were lost. Su Song's "great cosmic engine" of 1086—an elaborate water-powered clock, 13 metres high, which tracked time and the positions of the moon and planets—was forgotten by the 16th century.

Science and technology, in short, can get far and then stop. The same happened to Islamic science, which achieved great sophistication up until around 1200, and then came almost to a halt. What happened in Western Europe in the 17th and early 18th centuries that failed to happen in the Western Europe of antiquity, or in China after 1400, or in the Islamic world after 1200?

The question is ferociously debated by economic historians: there is no consensus on the factor that played the single most important role. But there is pretty wide agreement that three broad and overlapping things, between them, made the difference: values, politics and economic institutions.

The bases of progress

Economic growth is a process of economic change. So an appetite for change, or at least a willingness to live with it, is essential if a society is to get richer (except by conquest). This helps to account for China's falling behind. Its elite valued stability above all. New ideas, especially foreign ones, were suspect. Until the 15th century, the social order could accommodate technological progress reasonably well. The faster and deeper changes required in the early stages of industrialisation were another matter. China's rulers often blocked change: in the 15th century they ended long-sea trade ventures, choking off commerce and shipbuilding alike.

A readiness for change is only one of the values required. Acquisitiveness is another—an interest in worldly goods, a regard for the material as well as the spiritual, a will to exploit nature for man's benefit. Yet naked greed is no use. Growth requires investment—and investment is gratification deferred. The enlightened self-interest praised by Adam Smith combines the desire for wealth with prudence and patience.

Growth also requires another kind of selflessness. A modernising society has to move away from self-sufficiency, in individual households, villages, towns, regions and states, towards interaction at all those levels, through specialisation and trade. This in turn demands that enlightened self-interest include an ethical component. Without trust and regard for one's reputation, the wheels of commerce do not spin.

Altogether, it is an improbable blend. Partly through religion, however, Western Europe developed a system of values that favoured all of the above. Other cultures, it seems, were less conducive to growth. The ruling elites of antiquity, for instance, prized military prowess and intellectual achievement above all; the mundane business of getting and spending was beneath their dignity. China's rulers, in their own way, were equally uninterested in economic progress.

From time to time, of course, western elites also tried to resist change. But this is where politics comes in. The rulers concerned were always rivals. For the past 1,500 years, no unitary system of control has ever been imposed across Western Europe as a whole. The Roman empire and imperial China stand in marked contrast.

China's rulers could ban some advance, and their ban was obeyed. Europe's regimes might try such things. Some did: Florence issued an edict in 1299 forbidding bankers to use Arabic numerals; in 1397 Cologne ordered its tailors not to use machines; after the invention of the ribbon loom in 1579, the city council of Danzig is said to have ordered the inventor to be drowned. But their efforts were in vain, indeed self-damaging: a rule that hurt the economy hurt the state that made it, as against others economically more enlightened. In Europe, rivalry among governments wore away at the interests opposed to economic growth.

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In this pluralistic setting, the institutions conducive to growth gradually took shape. Within each state, under a variety of pressures, the economic sphere came to be separated from political control. Magna Carta, which ended the quarrel between King John and his English barons in 1215, established the rights of subjects to their own property, protecting them from the threat of arbitrary confiscation by the crown. It also gave protection to merchants, English and foreign. A new kind of "property right" was recognised for the first time.

Over the next few centuries this slowly nurtured another, no less important, kind of pluralism. A crucial aspect of the separation of politics and economics was that producers (farmers and merchants, in the first instance) kept some of the fruits of their success: the incentive to compete and innovate was in place. In contrast, in China the state long continued to play a central, dominating economic role—and innovators were usually civil servants, with no stake of their own in growth. Arbitrary seizure remained common in the Asian and Islamic worlds; merchants, in effect, were forbidden to get too rich. Yet by replacing arbitrary levies with taxes, western rulers managed to raise more money. As their economies grew, so did the tax base. Law-governed taxation proved to be a better fiscal technology than arbitrary seizure, for rulers and subjects alike.

A host of other innovations followed, extending and refining that fundamental right of property: laws of contract, patents, company law and so on. With time, these allowed a flourishing of many different types of economic enterprise—different in size, ownership and method of organisation. This organisational diversity is the hallmark of the advanced western economies. Here was yet another form of pluralism: just as governments competed, and producers or traders competed, so did different forms of economic organisation. The result was a social framework more effective than any other in history at fostering technological advance.

And so on and on?

Does rapid growth, once started, ever stop? Nuclear war, falling asteroids or man-made environmental catastrophe could all intervene. These risks aside, 250 years of rapid progress is not, in the historical scheme of things, a long period to extrapolate from.

One reason for doubting that growth will roar on and on is that the frontier of technology has moved much closer to the frontier of science; there are fewer wheelbarrows waiting to be invented. On the other hand, the progress of science today seems especially fruitful, technologically speaking: consider the Internet and the prospects for genetic engineering. Values, politics and institutions permitting, the stimulus of competition should flourish yet awhile. If it does, so may the flow of technological advance—and there is no reason why it should not be channelled, for the next 250 years as for the past 250, into improving human lives.