The X Factor

A thousand years ago, China appeared to have assembled all the pieces for an industrial revolution. What happened?

By Mark Elvin

Early in the 11th century, Chinese government arsenals manufactured more than 16 million identical iron arrowheads a year. In other words, mass production. Rather later, in the 13th century, machines in northern China powered by belt transmissions off a waterwheel twisted a rough rope of hemp fibers into a finer yarn. The machine used 32 spinning heads rotating simultaneously in a technique that probably resembled modern ring-spinning. A similar device was used for doubling filaments of silk. In other words, mechanized production, in the sense that the actions of the human hand were replicated by units of wood and metal, and an array of these identical units was then set into motion by inanimate power.

Common sense thus suggests that the Chinese economy, early in the millennium just coming to a close, had already developed the two key elements of what we think of as the Industrial Revolution: mass production and mechanization. That, nonetheless, nothing much more happened in this direction during the next 600 or 700 years is also a matter of common knowledge. Even the spinning machine went out of use, and survived only in literature and ever less comprehensible copies of copies of diagrams made by artists who had never set eyes on the real thing.

Much later, from the middle of the 19th century on, China had to import, then service, adapt and even at times improve, mechanical engineering from the West. This was done with considerable flair, particularly by Chinese firms in Shanghai, a city which during treaty-port days turned into a nonstop international exhibition of machine building. So Chinese technical capability can hardly be said to have withered in the intervening centuries. But what went wrong the first time? Why did the first industrial revolution not take place in China, as it seems it should have?

Of course, there is much more to such a revolution than technology alone. It requires a large-scale market economy, and that presupposes cheap transport and communications, extensive commercialization, monetization and credit instruments. China during the Song dynasty (960–1279 A.D.) delivered all of these.

The Song enjoyed the results of an economic revolution that featured the rapid development of wet-field rice farming in the lower Yangtze valley, the burgeoning of a dense network of low-coasts, and a money supply increased by many means, including fiduciary money (some of it the world's first paper money) and credit. A proliferation of petty local markets supported three great market-regions in the north China plains, the lower Yangtze and Sichuan. Above these rose a nationwide market and an overseas commerce so vigorous that taxes on it were the main financial support of the Southern Song (1127–1279) government.

To these we may add a growing literacy, linked with woodblock printing, a growing numeracy and some of what were then the largest cities on the globe, in one or two cases with more than a million inhabitants. Many of these were now also producer cities, not just consumer cities living off administrative revenues. What could be called the "textbook package" of factors that we commonly assume produces an industrial revolution was all in place. And still there was no breakthrough. Why?

The disruption caused by the conquests of the Jurchen in the north during the 12th century, and then the Mongols in the whole of China during the 13th, is the most direct answer, and should not be discounted just because it is obvious. At a deeper level, the economic driving force provided by the expansion of production in the Yangtze valley had diminished. From the late 10th century until about 1100, the 26 prefectures of the lower Yangtze had maintained an average annual growth rate in population of more than 1%. For premodern times, this is impressive, approaching a tripling within a century.

But land fills up, and opportunities once taken cannot be taken again. The coherent pattern fell apart during the Southern Song and, with a few local exceptions, this sustained growth was not maintained. The climate also grew more variable and colder, dropping at times to two degrees Celsius below the annual average at the start of the medieval economic revolution.

Economic vitality returned in the later 16th and early 17th centuries. It was then disrupted again, by internal rebellions, the Manchu conquest, and one of the

coldest periods of what in Europe at this time was called the "Little Ice Age." When growth picked up spectacularly in the warmer 18th century, it had distinctive characteristics.

First of all, it was more quantitative than qualitative. Some diffusion of technology that was new in China occurred, notably food crops, like sweet potatoes introduced from the New World, and some fine-tuning, notably of "intermediate" rices. There was no major innovation or invention. The pattern was more of the same, multiplied over and over again, and greater intensification, based on the input of more labour. Accounts of women working regularly in the fields become much more common at this time.

Second, the growth was environmentally destructive on an unprecedented scale. The stripping of vegetation cover of course had a long history in China. The Qing-period removal of original vegetation and forests, and exploitation of other resources like accessible coal and metallic ores, was on a new scale. China's population reached more than 400 million by 1850, about twice what it had been around the end of the 17th century. The literature is filled with a litany of woes about deforestation, shortage of construction timber and firewood, devastating erosion, loss of fertility in upland soils, salination of unsuitable lands opened for farming, and exhaustion of veins of copper and other materials. It was an ecosystem under a new intensity of attack.

Third, the general style of economic organization was to subcontract, employing commercial relationships instead of management. This can be seen in the production of cotton cloth. A legion of rural spinners bought raw cotton in local markets and sold their thread through intermediaries to another legion of weavers. A pyramid of lesser and greater brokers then purchased the cloth, putting it out to independent workshops for dyeing and, separately, calendering–hardening the cloth with pressure. The best of the cloth ended up with wholesalers who might have a turnover of a million bolts a year.

In one sense, this was an efficient system, based on pitting basic producers against each other in competition. On the other, it made technical innovation difficult, by separating marketing from production, and leaving producers with minimum reserves or incentives for experiment. Only in a few businesses, where there was a need for large-scale management was there much innovation. An example is some of the mountain timber-cutting organizations that pioneered more technically effective ways of getting timber out of difficult terrain, such as precursors of cable-skidder trackways that used overhead tow-lines to drag cut trunks along rough tracks.

Finally, the productivity of farming, both in per-hectare terms and seed-to-yield ratio (in better areas, about 1:35 for rice), was breathtakingly high in a comparative perspective. But success was beginning to block progress. Without modern science, and modern productive techniques, to draw on, there was a ceiling on further improvement. With usable land largely occupied, there were few if any easy ways to create the surges of extra demand that can have domino effects through an economy, and often prompt invention. And the Chinese economy was now too big for foreign trade to be able to deliver impulses of this sort on the required scale. This was the famous high-level equilibrium trap.

Was there, beyond this, still some "X factor" missing? Two possibilities are worth consideration. The first is that the analytical-experimental aspect of culture that crystallized in the West into modern science, but which often crucially affected technology, too, was much weaker in China. One can see this by comparing Chinese and Western analyses of water-pumping technology, a field located on the interface between science and technology (which it is an error in any case to distinguish too sharply). By the start of the 18th century, the French hydraulicist B.F. de Bélidor was already using formal geometry in his quest for the perfect trough-pump—which consists of a trough up which water is drawn by a continuous chain of pallets at a given slope. Chinese texts of this time merely noted empirically that effective high-angle and low-angle lifts needed trough–pumps with parts of differing dimensions.

The second possibility is democracy as a way of running public business. Jean Baechler at the Sorbonne has recently insisted that this is the aspect of the modern West for which premodern parallels in China are the weakest. The democratic style for safeguarding argument within a stable framework, and facilitating broadly acceptable change, may have helped the West develop new ways of thinking and new types of social organization. If we follow this line of thought, then the fifth modernization—to borrow Chinese dissident Wei Jing-sheng's phrase for democracy—appears as less of a luxury and more of an essential.

The late-imperial decline in inventiveness has also sometimes been ascribed to "Confucianism" or to the heavy hand of the Chinese state. This raises a difficulty. Weren't these exact features also associated in the Middle Ages with China's rise to economic world leadership? Can one rationally have it both ways? At best, these factors, suitably nuanced, might perhaps be included as part of a more complex analysis of the historically changing patterns in later times.

The riddle remains.

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From *Far Eastern Economic Review*, June 10, 1999, pp. 66-69.