China's Technological Renaissance

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> "*... that long succession of technical discoveries which the West took over from China during the first thirteen centuries of the Christian era, often without the slightest realisation of where they had come from.*"
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> —Joseph Needham, *Science and Civilisation in China*[1]

Compass ... paper ... printing ... gunpowder. These are the "Four Great Inventions" that every Chinese can recite as China's contribution to world technological development. It is a list that has not been updated in 900 years. Moveable-type printing, the most recent development of the four, made its appearance back in the 11th century. Though Joseph Needham's tireless scholarship has shown that this list greatly undersells China's contribution to scientific thought and technology, it is also true that China has long lost her pre-eminent position as a leader of innovation.

It is no coincidence that the most populous nation today punches far below its weight both economically and politically. The modern world order is defined by those nations wielding industrial, technical, and military superiority. China is not in that top tier.

But China may once again be ready to assume a leading position in scientific society, a position more commensurate with her size and illustrious history. As a consequence, that modern world order may need to be redefined.

Before we consider where China is today, let us take a brief look at how she arrived there, beginning with the decline of the imperial era.

Development up to 1978

A combination of an isolationist policy and a focus, perhaps because of cultural or political reasons, on the humanities and the arts, led to China's slumber throughout the Western flowering of science and discovery—the Renaissance, the Age of Exploration, the Age of Steam, the Industrial Revolution.

When, inevitably, a curious and expansionist West came knocking on China's door, a few short, sharp lessons, mostly delivered down the barrel of a cannon, demonstrated to the Chinese the considerable advances made during the years of their self-imposed isolation. A form of technology transfer began to take place during the last years of the Qing dynasty and the first years of the Republic (roughly from the mid-19th century to the Second World War). The foreigners brought the telegraph, the railways, and their factories. But it was an imposed modernization and was confined to the trading concessions that the foreigners had carved out by force along the coast of China.

This path of development, such as it was, was interrupted by the Second World War and never resumed as, first, civil war wracked the country and then as the Communists took power. The freshly-minted People's Republic under Mao Zedong was intent on reversing the humiliations of the pre-war era, when China was powerless against foreign interests. This New China would establish parity with the West but without the help of a West that, anyway, was shunning the new government and its ideology.

With initial assistance from the Soviet Union, China set out to acquire a heavy industry (not to mention an atomic bomb) of its own. This it eventually achieved, but the massive social dislocations of the Mao era greatly hindered economic and technological development. The Great Leap Forward (1958-1960) promoted a wasteful diversion of resources. Agriculture and light industry suffered while farcical attempts were made to increase steel production and eradicate "pests," such as sparrows and rats. "Intellectuals," including scientists, scholars, and professors, were persecuted and forced to abandon their positions during the Anti-Rightist Campaign (1957) and the Cultural Revolution (1966-1976). The Cultural Revolution also saw a whole generation of youth denied education as schools and universities shut down.

The modern period (1978 to today)

Real economic and technological development thus began after the death of Mao Zedong. The pragmatic Deng Xiaoping became leader of China in 1978 and at once set about far-reaching reform. Of the "Four Modernizations" proposed in that year, Deng nominated science and technology as the key:

> "Without modern science and technology, it will be impossible to construct modern agriculture, modern industry and modern defense, and it will be impossible

> to have the development of national economy at high speed." [2]

In pursuit of this goal, the China State Science and Technology Commission created a set of guidelines. One of these guidelines was:

> "The learning, assimilation and absorption of foreign scientific and technological achievements should be taken as an important path for the development of China's science and technology ... [but] with the aim of maintaining independence and keeping the initiative in her own hands."[3]

From 1981 to 1987, state-controlled imports of technology were divided into two main categories: a "3000 item plan" which aimed to update technology in existing enterprises; and a "twelve production lines plan" which sought to jump-start certain industries in China, including color TVs, ships, clothing, and beer by importing whole production lines. The bulk of technology imports at this time came from Japan, the U.S., and Germany.[4]

Academic research institutes and universities assisted the production enterprises in the absorption of these new technologies. The government also allowed up to 20 percent of profits generated using imported technology to be used for assimilation of those technologies.

1988 to 1991 saw a decline in technology imports for two reasons. First, new, contractionary macroeconomic policies were designed to bring inflation under control. Second, the outcome of the Tiananmen Square protests in 1989 led to sanctions being imposed by Western nations. Recalling the state of affairs in the early 1950s, the countries of the former Soviet Union (along with Italy) became the main sources of imported technology during this time.

By 1992, relations with the West had more-or-less renormalized. Deng Xiaoping embarked on his now-famous "Southern Tour," visiting the south of China and giving his blessing to renewed, rapid economic growth. A subsequent change in the constitution formalized the new goal of a "socialist market economy."

The period after 1992 saw spectacular growth in Foreign Direct Investment (FDI). By means of FDI, multinationals could set up their own operations in China. There were inducements for doing so—low tax rates, for example. In keeping with government policy to retain control over development, the foreign companies were, until quite recently, hobbled by a requirement to form joint-ventures with Chinese firms. This, combined with poor distribution networks, a changing and arbitrary regulatory environment, bureaucratic entanglements and the various other difficulties of doing business in China, has meant that foreigners have, on the whole, not done particularly well. Nevertheless, they poured money and ever-higher technologies into the country. Since 1993, China has consistently been the largest recipient of FDI among developing countries.[5] The ultimate prospect of a market of 1.3 billion people means that no multinational can really afford to stay away. No Western business leader wants to be remembered as the CEO that "lost China."[6]

So, whether or not the Chinese government was pursuing optimal policies, the Americans, Europeans, Japanese, and Taiwanese continued to pour investment (and, just as importantly, technological know-how and management expertise) into China. Over the years, this investment has progressed from low-tech manufacturing for domestic sales to high-tech production for export. China is currently the low-wage production center of choice for flashy consumer electronics and the components that comprise them. This is the well-worn path to prosperity that has already been blazed by Taiwan and Korea, and before them Japan.

The central and regional governments of China, as befits a planned economy, have a large say in which particular technologies flourish. The Shanghai government, for example, has already decided that the Pudong area of Shanghai will be a center of excellence for the silicon chip industry.

Technological parity?

It would seem that China is on the point of achieving its goal of attracting the most leading-edge technologies to its shores. And yet this last step might prove the most difficult. There are two reasons for this.

First, companies earn higher margins on the newest products. Competitors may be some way behind and so pressure to reduce costs is low. The higher wage costs of producing in the company's home country are offset by the higher profit margins. As the technology matures and is replaced, the company will probably want to shift manufacture abroad, to a lower cost producer. China is often the recipient of such second-hand production lines.

By manufacturing at home, companies can also keep a closer watch on new production processes that may need to be tweaked as they are developed.

The second reason is political. The chip industry provides a good example of the limits of China's import strategy.

Progress in the integrated circuit business is measured in line widths and wafer sizes. The finer the line width, the more components you can squeeze onto a single chip. The larger the size of the silicon wafer, the more chips can be etched at the same time. Every 18 months to two years, the chip industry upgrades its fabrication facilities (known as fabs) to work with a finer line-width and/or a larger wafer size.

The most advanced chip foundries in Taiwan are building fabs that will use 12-inch wafers and 0.18 micron line-width technology. In contrast, the most recently announced chip factory in China (a Taiwanese-Chinese partnership) will use 8-inch wafers and 0.25 micron line-widths. In general, China is considered to be two generations of technology behind Taiwan.[7]

It is not simply that Chinese manufacturing skills and support services are still inadequate, though this is true. The main reason is political. The United States will not permit what it considers strategic technologies to wind up in the hands of the Chinese. In doing so, the U.S. expects both to maintain considerable military superiority over a potential adversary and to prevent the latest technologies from filtering down to China's clients in the arms trade. These clients include Pakistan and Iran, among others.

The U.S. has also wrung its hands recently over the probable leak of missile technology to China during a collaboration in launching civilian satellites. And the U.S. Commerce Department, three years ago, was fretting over the diversion of a high-performance supercomputer from its listed export destination of Hong Kong to the Chinese People's Liberation Army. For export control purposes, the U.S. divides the world's countries into four "tiers". China is placed in Tier 3, for nations posing a security risk, only one notch above Tier 4—"terrorist" nations.

Since the United States and nations friendly to the U.S. (Britain, Germany, Taiwan, Israel, etc.) are the producers of the most cutting-edge technologies, it is relatively easy for the U.S. to prevent Chinese industry from ever catching up. This is a very real constraint. But it only remains a constraint if China continues to rely on the importation of technology.

Research and development

The obvious next goal for China's technology policy is to develop an indigenous research and development capability. This does not imply that China has nothing more to gain from foreign expertise. On the contrary, multinationals in the last couple of years have been providing the industrial model for such an endeavor. Well-known companies such as Nortel, IBM, Agilent, and Intel have been joined by other equally notable firms in creating research facilities within China.

Intel's Beijing research center opened in November 1998. It was Intel's fourth research center and the first anywhere in Asia. Its function is to lead Intel's research effort in next-generation computer interface technologies—speech recognition, for example. It will collaborate with academic and research institutions worldwide, take part in standardization efforts, and generally make new technologies available to industry.

Originally employing 40 researchers, this will grow to 100 in 2001. According to the director, Dr. Robert Yung, who spoke at a seminar at Stanford University last winter,[8] there is no cost advantage to locating in China. With the same $50 million budget (spread over five years), Dr. Yung claimed he could set up an identical facility anywhere in the world. When selecting China, Intel just went "where the talent is." Beijing has a high concentration of top-flight universities—Peking University, Tsinghua University, etc. Intel expects that its intake of engineers will come directly from these universities.

Education

Such research centers offering plum jobs to Chinese graduates will be necessary to stem the export of brainpower to the West. The flight of talent from Chinese universities to work and study opportunities overseas has been considerable. From 1978 to 1998, more than 320,000 Chinese went to 103 countries for further studies.[9] Fifty thousand of those were sent by the state, 100,000 by the government units they work in, and 170,000 at their own expense. Most of those who leave do not return.

China can ill-afford such generosity towards building the talent pools of other countries. Although China's third-level institutions are well-respected internationally, too few of China's young can take advantage of them. In 1998, there were 220,140,000 children enrolled in primary schools across China. In the same year, there were only 10,840,000 enrolled in "institutes of higher learning" which includes universities and other third-level colleges.

The competitive struggle to achieve a place in a good university ensures that those who graduate are of the highest standard. It is this that attracts the Intels and the IBMs. But it also means that a lot of talent has been discarded along the way. This waste is well recognized by the education authorities who are trying to increase the number of third-level places available. This is necessarily a slow process, however. Teaching staff must be trained and expensive facilities provided.

The top universities are already tapping a new source of income, one that is very familiar in the U.S. philanthropic foundations are bankrolling some of the recent expansion. Visitors from Stanford to Peking University's campus last summer would have recognized the familiar din and dust of summer construction work. Li Ka-Shing, the Hong Kong property tycoon, has provided a magnificent new library building housing the largest collection of any university in Asia.

If China's universities can supply the research talent, can Chinese industry tap it? Or will the benefits continue to flow to Western firms? The most interesting recent development has been the appearance of a handful of Chinese

companies that will truly establish China as a center of innovation.

Indigenous R&D

One entirely Chinese company blazing a trail for others to follow is Huawei Technologies.[10] Huawei is a young telecom equipment manufacturer with ambition. Founded in 1988, Huawei reported $2.66 billion in revenue for 2000. This is some way behind the global industry leaders, but Huawei managed sales growth of 100 percent in 2000 alone. It anticipates revenues rising to $5 billion in 2001.

Huawei's strategy for success is interesting. It is clearly a new breed of Chinese enterprise. Unlike most hi-tech operations in China, Huawei was never a joint-venture with a foreign multinational. For the first two years of its existence, it was a simple reseller of other companies' products. This enabled Huawei to understand the telecom business and gave its engineers experience with telecom hardware. After two years, it began to offer simple products designed and manufactured in-house. With experience, the products became more sophisticated, e.g. application-specific integrated circuits (ASICs). Today, Huawei offers a complete telecom product portfolio that includes digital switches, transmission systems, access networks, and so on. It can compete on quality and price with any Western manufacturer. Cisco recently lost a contract to Huawei to supply a 120,000-port Internet server in Shanghai.[11]

To achieve such rapid development, Huawei allocates 40 percent of its 16,000 staff to research and development (R&D). It hires 2000 to 3000 graduates from China's top universities each year. This intake of fresh talent keeps the average age of Huawei employees at 28.

For the moment, Huawei is heavily reliant on its home base, claiming to have captured over 30 percent of the China telecom market. Only 8 percent of its sales come from overseas but the company's intention is that 20 to 40 percent of sales should come from overseas over the next 3-5 years. It has already opened 35 branches outside of China, avoiding until recently the home-turf of Western telecom multinationals, i.e. North America and Western Europe. Instead, it has built up a healthy presence in Pakistan, Iraq, Iran, Zimbabwe, Ukraine, and other non-traditional markets. It can leverage the good diplomatic relations that China enjoys with less-developed nations. Now that it is comfortable overseas, Huawei is poised to enter the North American market.

In fact, Huawei is already in the U.S. An office in San Jose sources materials and components for the Chinese manufacturing operation. And a brand-new R&D facility has just opened in Richardson, Texas, joining other famous industry names—Ericsson, Alcatel, and Nortel among them—in Richardson's "Telecom Corridor."

Huawei is providing China with a new model for employee compensation. Performance-related pay, bonuses, and stock options for most employees are a way to attract and retain the most talented. This, combined with the lure of interesting work, should reduce the outflow of China's best students to foreign universities and companies.

The next stage

China has achieved much in the 20 or so years since reform began. A modern industry was initially jumpstarted by the importation of production lines and manufacturing equipment. Then foreign companies were enticed to set up in China, first as manufacturers of basic commodities, then as producers of more sophisticated items for export. Lately those same companies that gained experience of operating in China through such ventures have begun to locate the critical R&D parts of their organization there.

Chinese companies themselves are beginning to establish global brands. Chinese-designed technology, such as that from Huawei, is already being sold to Western businesses. A visitor to the largest Chinese trade exhibition—the Chinese Export Commodities Fair held twice a year in Guangzhou—will be astonished by the variety and quality of Chinese-manufactured goods on sale. These range from the humble plastic shoe to agricultural machinery to radar systems.

The Chinese government can take much credit for this success. But what policies are most suited to this stage of development? There are several:

> 1. Use a hands-off approach to business. This may be the most difficult one. The legacy of a centrally-planned economy and an apparent record of success so far will encourage the bureaucrats to continue their micromanaging ways. But there is no reason to think that the Chinese government will be better at picking winners in business than the government of any other nation. Japan's once-admired MITI (Ministry of International Trade and Industry) has overseen a succession of national innovation programs which have had little impact.

Worryingly, China's leaders have expressed admiration for the Korean chaebol (or conglomerate) model.[12] The chaebol were once seen as the flagships of the Korean economy. As these government-favored giants expanded into ever more lines of business, small, entrepreneurial companies were denied the capital that they needed to grow. Resources were poured into prestige industries such as car manufacture. Kia, Hyundai, Daewoo, Samsung and Ssangyong all launched new car marques. When the Asian crisis struck in 1997, the heavily-indebted chaebol began to fall apart. But there was no safety net of smaller compa-

nies to absorb the workers being laid-off.

In an effort to create such bulky "national champions," the Chinese government has been "encouraging" successful Chinese businesses to incorporate failing state-owned enterprises, crippling them with large payrolls and inefficient plants.

> 2. Continue to invest in infrastructure. One of the striking features of the Chinese countryside is the thin copper wire threading its way over hills and valleys, bringing telephone service to the remotest villages. Oasis towns in the Gobi desert can boast mobile telephony service. Several massive optical fiber networks already connect every major Chinese city. Likewise, road and rail links continue to be upgraded all over the country. This will enable the reliable distribution networks that are essential to business and will eventually bring greater prosperity to the lagging interior of the country.
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> 3. Continue to invest in education. China already boasts high literacy rates. It needs to expand the opportunities for education at secondary and tertiary levels. Currently, only about 11 percent of students reach the tertiary level.[13]

Curriculum development is also important. From the next school year, information technology will be a compulsory subject in all senior secondary schools. Later, this will be extended to junior secondary and primary schools.[14]

> 4. Loosen restrictions on access to information. The Communist Party regards unfettered access to information as a danger to its own survival and to the stability of the country. The result is that foreign newspapers and magazines are, in general, not available to Chinese people. It also means an abysmally slow Internet, since every access to a site outside of the country must be screened for "harmful" content. The list of proscribed sites includes "http://www.stanford.edu". It is harder for innovation to thrive under such conditions.
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> 5. Strengthen the rule of law. Foreign companies have never been able to rely on the Chinese legal system for protection. Whatever rules exist are applied erratically if at all. However, as more privately-owned Chinese companies demand these same protections, the situation should improve. Foreign companies have long complained about the illegal reproduction of software, music, and movies. While this unlawful copying of intellectual property (IP) was all one-way, it suited China not to clamp down too heavily on the practice. But as China becomes a significant producer of IP, it will suddenly find ways to protect copyright.

The imminent accession of China to the WTO will also help to foster a more transparent business environment.

> 6. Provide regulatory support for local technologies. This is an interesting tool in the hands of governments that is not often recognized as such.

The technocrats in government will pull whatever levers are available to them to support Chinese business. They will have to be increasingly clever in this as WTO rules seek to level playing fields between countries. One new trick is to promote home-grown technological standards. The most prominent example is in the race to define the coming third generation (3G) mobile telephony technologies.

China has embraced the mobile phone. It is already the world's second-largest market for mobile service and is on its way to becoming the largest. The benefit of this rapid deployment has largely gone to foreign manufacturers—Nokia, Ericsson, and Motorola, for example. The so-called second-generation mobile systems—GSM and CDMA—were designed in the West. It is known that the Chinese government is unhappy with foreign control of this important industry.[15] Thus, it intends to rectify the situation before the 3G systems are installed. China has submitted its own standard—known as TD-SCDMA—for 3G wireless to the International Telecommunications Union (ITU), the global standards-setting body. It was approved, the first time that a Chinese standard has achieved such recognition.

The benefit to Chinese industry is that the native equipment manufacturers will not have to license as many technologies from abroad. Indeed, given the size of the Chinese market, western firms will want to support any standard in use in China and so must obtain licenses from Chinese enterprises, a neat reversal.

Development of technical standards and ownership of the associated intellectual property (IP) are large components of Beijing's current industrial strategy. Expert groups are already working on other hot areas of development, for example digital high-definition TV.

> 7. Support basic research and development. Most governments believe that they have an important role in stimulating basic research. Such research shows no immediate prospect of financial return but, nevertheless, becomes the basis of future product development. Given that business expects a foreseeable return in the short to medium term, governments often take over the funding of "blue-sky" research. Universities have an obvious contribution

to make here. Less obviously, private companies can be funded to undertake basic high-tech research.

The American model of subsidizing industry might prove very attractive to China. In a world governed by WTO regulations strictly limiting direct government aid to industry, the U.S. disguises its subsidies as military spending. The U.S. military budget for 1998 was $281 billion.[16] In the same year, China spent $37.5 billion.[17]

The large disparity between the U.S. budget and that of any other nation accounts for a significant part of the United States' technical lead. Projects originally funded by defense spending often become commercially viable at a much later stage, the Internet and GPS being two famous examples.

Conclusion

This article has argued that China's technological development has been motivated not only by the desire to increase prosperity but by a determination to stand as the economic and political equal of any world power. Technological self-sufficiency brings economic wealth, which provides political muscle. China's path will be different from the Asian nations that preceded it. Korea achieved great industrial growth but still relies on the importation of foreign technology to sustain it. Japan achieved the status of economic superpower but chooses not to exercise that power politically. China, on the other hand, regards itself as the natural anchor power in Asia. Her size probably makes this inevitable but there is an element of reclaiming her historical position as well.

Development by importation of technology is probably reaching its limits. Foreign countries and companies will be reluctant to supply China with the very latest of techniques for competitive and political reasons.

But just as China is opening its markets to freer world trade, Chinese companies are ready and able to make their mark as innovators. China's research institutions and students will provide a steady stream of talent and ideas to these companies.

It will be interesting to see how those ideas take shape. China can draw on a very deep cultural well that stretches back thousands of years. It will stamp its own, unique impression on world progress. It has been in this position before but became distracted for a thousand years or so. For the last twenty years, just like one of its young students aiming for a coveted place in Peking University, China has kept its head down, studying assiduously all that the outside world had to teach it. The study has finally paid off. Once a leader of science and technology, China is becoming so again.

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[1] Joseph Needham, Science and Civilisation in China, 1 (Cambridge: Cambridge University Press, 1954), 9.

[2] Deng Xiaoping at the First National Science Congress, 1978. Quoted in Q. Y. Yu, The Implementation of China's Science and Technology Policy, (Westport, Connecticut: Quorum Books, 1999), 9.

[3] Outline of the Report on the Guidelines for China's Scientific and Technological Development, created by the China State Science and Technology Commission and submitted to the State Council on 23 February 1981. Quoted in Yu, Science and Technology Policy, 12-13.

[4] Chinese Technology Transfer in the 1990's, eds. Charles Feinstein and Christopher Howe (Lyme, New Hampshire: Edward Elgar Pub., 1997).

[5] "China Continues to Absorb Foreign Direct Investment," People's Daily, 26 September 2000.

[6] Alex Trotman, former Charirman of Ford, stated "I did not want to go out as the chairman who lost China." Quoted in "Ford misses out again," The Economist, 21 September 2000.

[7] "Taiwan chip firms begin slow march to China," South China Morning Post, 25 November 2000.

[8] Dr. Robert Yung, "Smart Computing for the Future", 11 November 1999, part of US-Japan Technology Management Center seminar series on "The Transformation of R&D in East Asia and Japan".

[9] All education statistics taken from the China Statistical Yearbook 1999 available online at: http://www.stats.gov.cn/

[10] Data on Huawei is compiled from several sources: a visit by the author to Huawei America, San Jose in December 2000; "Huawei Technologies", a company information brochure; and online at: http://www.huawei.com.

[11] Grahame Lynch, "Telecom Planet: Sino' the times", America's Network, 1 October 2000.

[12] "China adopts the chaebol," The Economist, 5 June 1997.

[13] Linda Yeung, "Internet plan to increase learners," South China Morning Post, 16 December 2000.

[14] Polly Hui, "IT lessons on the way in China," South China Morning Post, 25 November 2000.

[15] Economic Information Daily cited by Raymond Li, "Telecom giants discuss made-in-China tech," South China Morning Post, 13 December 2000.