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CHINA IS RAPIDLY BECOMING A LEADING INNOVATOR IN ADVANCED INDUSTRIES

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There may be no more important question for the West's competitive position in advanced industries than whether China is becoming a rival innovator. While the evidence suggests it hasn't yet taken the overall lead, it has pulled ahead in certain areas, and in many others Chinese firms will likely equal or surpass Western firms within a decade or so.

KEY TAKEAWAYS

- China has reached a new stage in its economic development, with much greater innovation capabilities in its universities and domestic companies—and on many innovation indicators, China now leads the United States.
- China leads or is on par with global leaders in commercial nuclear power and electric vehicles and batteries. It lags behind for now in other key sectors, including robotics, biopharmaceuticals, chemicals, and AI. But it is making rapid progress.
- The combination of low costs and growing innovation capability make an increasing number of Chinese companies formidable global competitors.
- This rapid innovation progress stems from the Chinese Communist Party's determined effort to dominate global markets in a host of advanced industries.
- While the Chinese innovation system is not perfect, it is much stronger than previously understood—and there are many aspects of it the United States should emulate.
- To enable those policies, America should embrace a "national power capitalism" suited to the current existential competition for power. Government must identify key sectors that are critical for national power and invest adequately to win the techno-economic war.
- To do so, America should create five industrial research institutes, a "competitiveness DARPA," and an industrial development bank; triple the research and experimentation tax credit; and institute a seven-year, 25 percent credit for capital equipment.

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INTRODUCTION

Perhaps the most critical question for the United States vis-à-vis China's economic and technology challenge is whether China can become a real innovator. If China has difficulty becoming an innovator and remains largely a copier, then the threat to the United States and other allied technology economies is less. In this case, as long as the United States (and allies) can innovate at a robust-enough rate, they can likely maintain the lead on advanced technologies, even if China quickly copies foreign innovations. But if China can develop new-to-the-world innovations ahead of, or at the nearly the same time as, the United States and allied nations, its potential to displace U.S. (and allied) technology-based companies and capabilities becomes much more likely, especially because China benefits from significant economies of scale and a government laser focused on global best-in-class science and technology policy for competitiveness.

To date, this issue has been widely discussed, but, with the exception of analysis of a variety of innovation input indicators (e.g., research article citations, research and development (R&D) personnel, patents, etc.), it has not been rigorously examined. To remedy that, the Information Technology and Innovation Foundation (ITIF), with the support of the Smith Richardson Foundation, has conducted an analysis of the extent to which Chinese companies are innovating and already possess the capabilities to be global innovation leaders.

Overall, we find that, for the most part, while Chinese firms and industries are not as innovative as the global leaders in Western nations (defined as developed, democratic nations), they are catching up, in many cases at an extremely rapid pace—and the scale of their efforts is massive.[1] As the China Institutes of Contemporary International Relations wrote somewhat modestly in 2021, "China still has a not insignificant gap to close with the United States in the fields of science and technology, but the [Chinese] growth rate is rapid and there is potential for development."[2] To use an analogy, it's as if we were to look out at the ocean and see calm waves, but over the horizon is a tsunami of hundreds of strong, innovative, and lower-cost Chinese firms in dozens of industries seeking to grab global market share from established leaders.

For the most part, while Chinese firms and industries are not as innovative as the global leaders in Western nations, they are catching up, in many cases at an extremely rapid pace—and the scale of their efforts is massive.

These research findings suggest that it's time to reject the often ideologically based view that "China can't innovate." While China is ruled by a communist party, China is not the Soviet Union, and its firms have considerable degrees of freedom to act, as long as they are working to achieve the goal of making China the world innovation leader. The reality is that China is much more akin to where the Asian Tigers (Hong Kong, South Korea, Singapore, and Taiwan) were 20 years ago, only in this case, China is not a tiger, but rather a fire-breathing dragon on government-provided steroids.

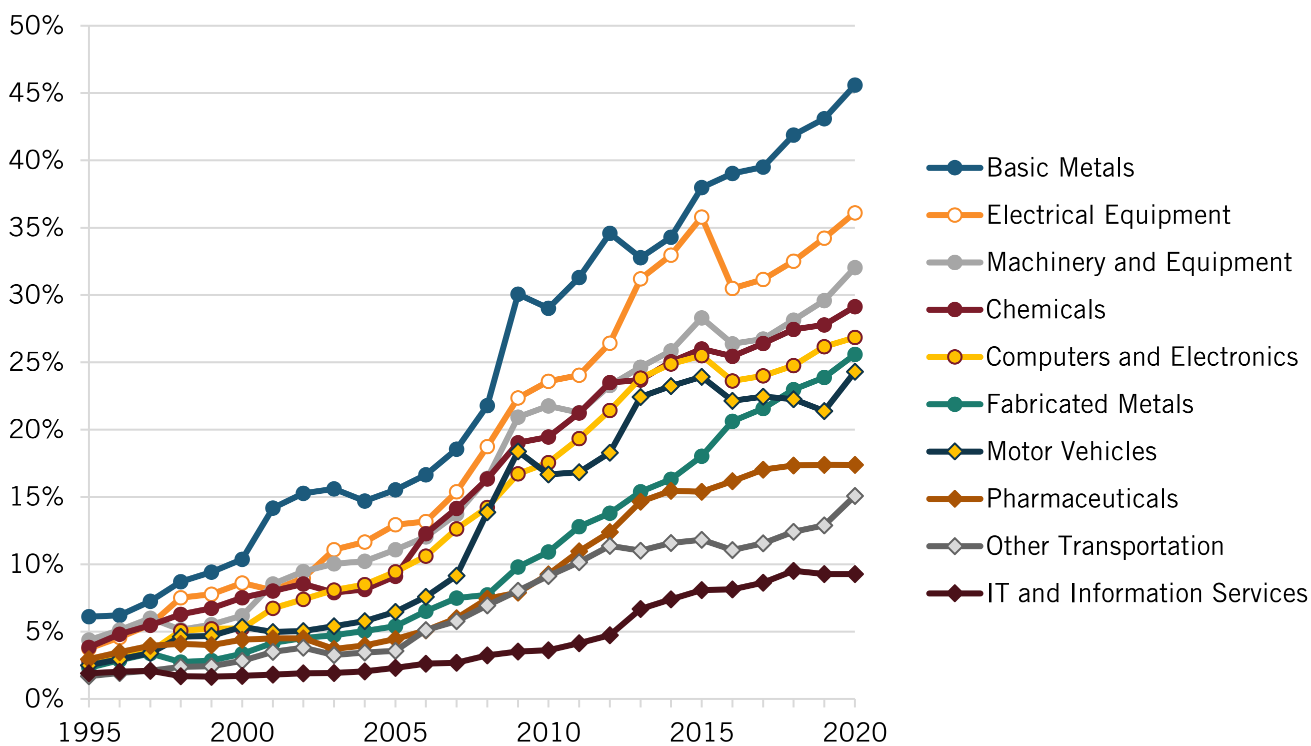
WHY THIS MATTERS

China became the world's manufacturing workshop on the basis of a combination of low costs, a large and rapidly growing domestic market, and aggressive efforts to recruit foreign manufacturers. While that process led to considerable manufacturing decline in the United States, most of it (with the exception of consumer electronics) was in more traditional industries such as plastics, metals, textiles and apparel, toys, and furniture.[3] While this was hard on the U.S. workers and communities that lost to China, it did not mean a significant weakening of U.S. techno-economic strength and dual-use (civilian and military) capabilities, particularly in U.S.-headquartered firms. And it certainly did not mean a high level of strategic dependency on China. If a conflict came, the worst that could happen would be no more McDonald's Happy Meal toys.

China is much more akin to where the Asian Tigers were 20 years ago, only in this case, China is not a tiger, but rather a fire-breathing dragon on government-provided steroids.

However, the last decade has shown that China can be a globally competitive producer of technologically complex goods, such as telecom equipment, machine tools, computers, solar panels, high-speed rail, ships, drones, satellites, heavy equipment, and pharmaceuticals. In all these industries, China has gained significant global market share—and it is making rapid strides in emerging industries such as robotics, AI, quantum computing and biotech. Indeed, as ITIF's *Hamilton Index* shows, China's global share of advanced industries has grown dramatically over the last 25 years. (See figure 1.)

Figure 1: China's global market shares in advanced industries



In most of these industries, China has been able to gain market share through the advantages of scale economies in its often-protected home market, combined with significant subsidies to Chinese firms. This is why, in 2020, in 7 of 10 advanced industries, China led in global production, with the United States leading in only 3. (See table 1.)

Table 1: Hamilton Index industry leaders, 2020

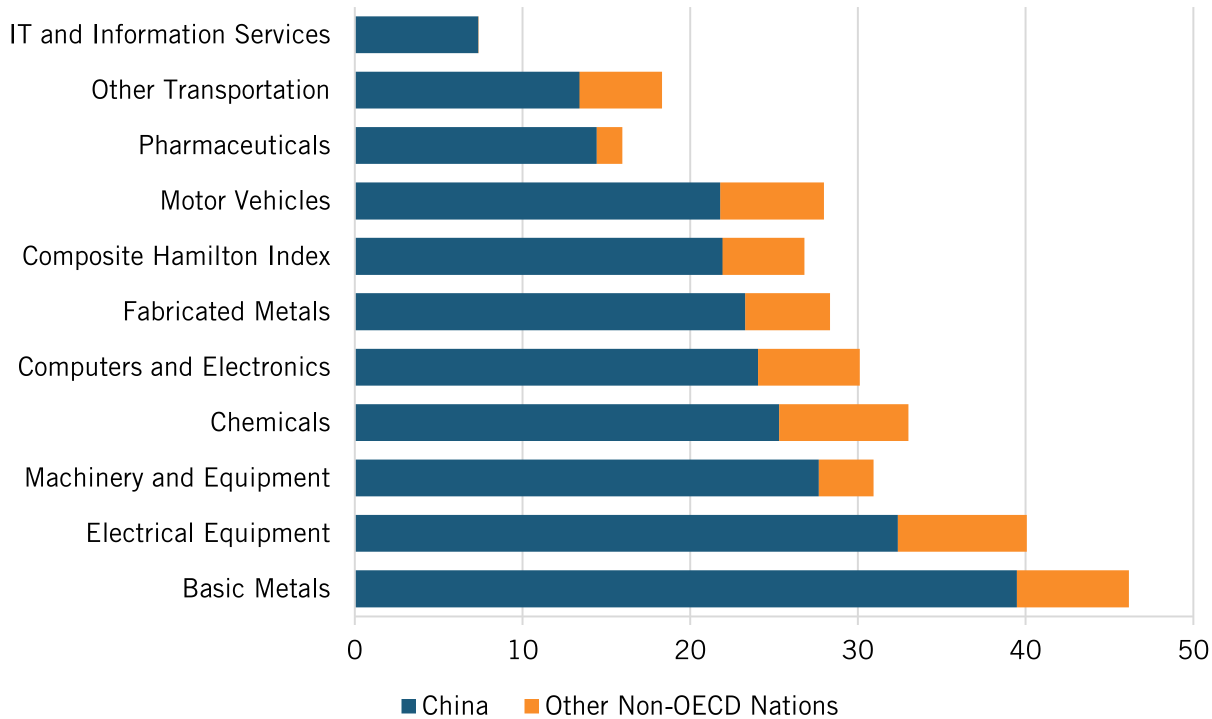
Industry	Global Output (Billions)	Leading Producer	Leader's Share
IT and Information Services	$1,900	USA	36.4%
Computers and Electronics	$1,317	China	26.8%
Chemicals	$1,146	China	29.1%
Machinery and Equipment	$1,135	China	32.0%
Motor Vehicles	$1,093	China	24.3%
Basic Metals	$976	China	45.6%
Fabricated Metals	$846	China	25.6%
Pharmaceuticals	$696	USA	28.4%
Electrical Equipment	$602	China	36.1%
Other Transportation	$386	USA	34.5%
Composite Hamilton Index	$10,097	China	25.3%

On many measures, China already leads the United States and can be considered a co-equal economic superpower. It's gross domestic product (GDP) is more or less equivalent, it has significantly more exports, and its manufacturing sector is vastly larger. But with all that strength, China still lacks two things: high productivity and the ability to outcompete innovative leaders.

China's productivity will no doubt continue to grow faster than the United States' over the next three decades, probably at least until it gets to about 80 percent of U.S. levels. But that will come about almost entirely through domestic-serving industries (e.g., agriculture, utilities, logistics, business services, retail trade, finance, etc.) using more technology and getting more productive. When that happens, China's GDP will easily be double if not triple that of the United States. There is little the United States and allies can do to slow China's productivity growth, because, for the most part, that growth does not depend on any chokepoint technologies controlled by allied nations. Moreover, that growth could have some benefits for the United States and allied advanced industries not only by boosting Chinese demand but also by creating a vast Chinese middle class that may seek more democratic rights, as was the case in countries such as Japan, South Korea, and Taiwan.

It is China's progress on innovation that poses the more-significant challenge to the United States and its democratic allies. To date, much of China's growth has come from copying the leaders and producing products that, while not as high quality, are priced more competitively. This has helped China gain market share, particularly in less-developed countries where price is a more important differentiating factor. This is one reason why China has taken almost all the growth in these industries from nations outside the Organization for Economic Cooperation and Development (OECD). (See figure 2.)

Figure 2: Non-OECD change in global market shares (percentage-point difference, 1995–2020)



However, going forward, if China can combine its cost advantage with an innovation advantage, or at least innovation parity, the challenge to innovative industries in Western nations will become much more significant. As such, a key question for these nations is to what extent China has become or will soon become an innovation leader, or at least on par with innovation leaders. If China can become an innovation leader, that development poses a significant threat to Western nations and their firms because China will be able to combine quality, innovation, and price.

This is a key reason why the threat from an innovative China is so significant. Historically, low- and middle-income countries were generally not innovators, and they competed either in more routine, older industries (e.g., textiles, commodity metal products, low-end electronics, assembly of goods, etc.) or in advanced industries by copying and being a generation or two behind the leaders and competing on lower-cost labor. And in this latter case, this was almost always through branch plant operations of firms in higher-income nations. As such, the knowledge diffusion to the host country was somewhat limited, and its domestic capabilities for competitiveness grew slowly, usually at around the same pace as the leaders.

In this sense, there was a global division of labor, with high-income nations (e.g., the United States, Commonwealth nations, the European Union, and, more recently, Japan, South Korea, Singapore, and Taiwan) specializing in industries and products that other countries did not have the technical capabilities to make.[4] This was one reason why they could sustain their cost disadvantage. But if China can compete across the board in an array of complex industries and produce new-to-the-world products, while also enjoying a significant cost advantage (Chinese labor costs around 25 to 30 percent of U.S. costs), that will be a major competitive threat to leading global innovation-based companies, and the economies that host them. And without these companies producing in the United States and other advanced economies, these nations' techno-economic power will decline relatively, as there is simply no way for domestic (and often smaller) firms to take up the slack when multinationals lose significant market share.

If China can compete in an array of complex industries, while also enjoying a significant cost advantage, that will be a major competitive threat to leading global innovation-based companies, and the economies that host them.

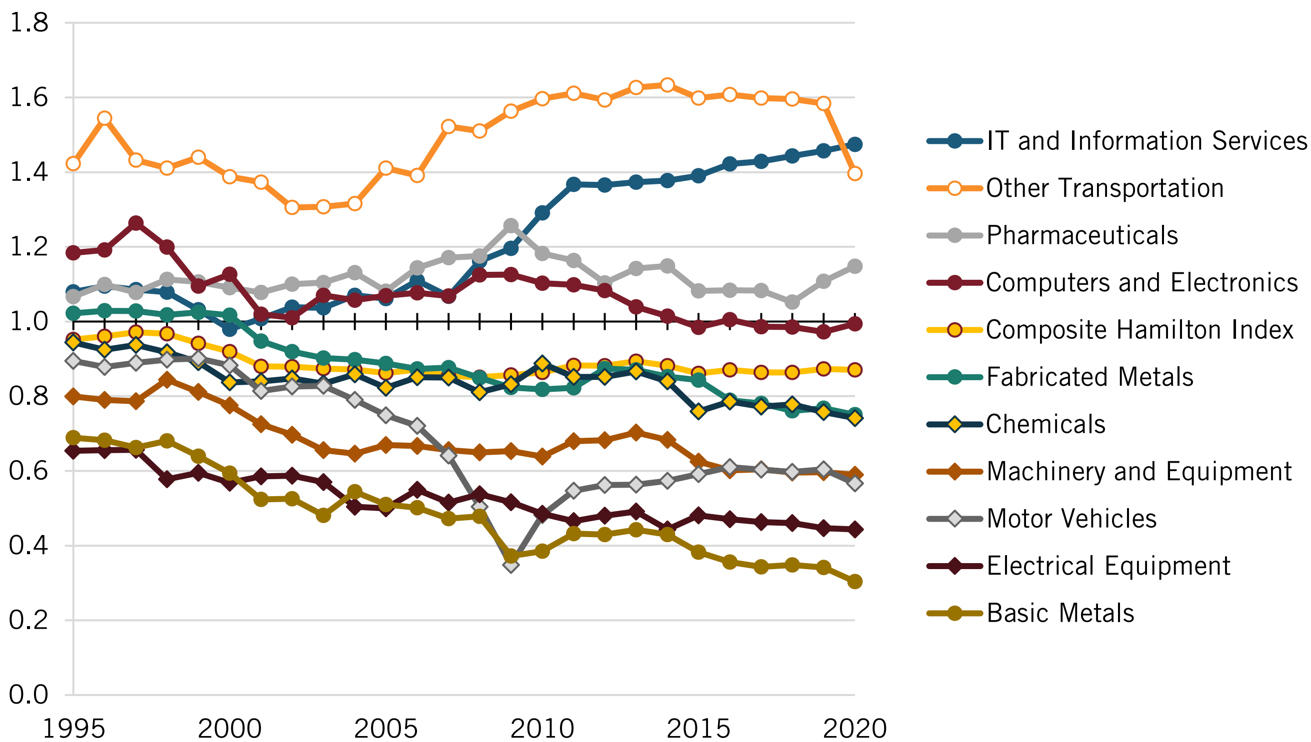
China achieving innovation parity would have two major effects, one in China, and one in Western nations. First, it would mean that China would be much more self-sufficient in advanced industries and much less vulnerable to Western sanctions and other trade tools used in an attempt to discipline China. At the same time, it would also boost Chinese military capabilities even more, as civil-military fusion becomes stronger, and weapons systems companies could rely on cutting-edge technologies across a range of industries. Just as importantly, this commercial technology strength would also equate to increased power in foreign affairs, just as America dominated the globe for more than a half century after WWII, as its firms were the unalloyed leaders. It is China that might decide to impose export controls on the allied nations as punishment.

The Fisher Body Plant in Detroit, Michigan, manufactured automobiles from 1919 to 1984.[5]

It is these foreign effects, particular on the United States (and other Western nations) that are potentially most important. If China can become an innovative leader in robotics, electric vehicles (EVs), airplanes, semiconductors, drugs, and more, it can dominate the global economy.

If China makes serious inroads into the market share of current technology leaders (e.g., ABB in robotics, GM in cars, Boeing in airplanes, Intel in chips, Merck in drugs, etc.), the fundamental nature of the global economy shifts. The 200 year-long development of advanced industry in capitalist, democratic nations—first in the United Kingdom and Western Europe, and then in America, and then Japan, South Korea and Taiwan joining the "club"—could radically change. The West could very well become what Australia, Canada, the United Kingdom and parts of Europe (e.g.. Greece, Italy, Portugal, and Spain) have already become: largely hollowed-out economies with little advanced manufacturing, a weak technology sector, and an economy propped up by tourism, finance, agriculture, and natural resources.[6] This is the trend for the United States as the U.S. location quotient (the industry output as a share of the U.S. economy over the industry output as a share of the global economy) has fallen. (See figure 3.) With any kind of foresight, it's easy to see the same fate befalling the United States if China can be an innovation peer.

Figure 3: America's relative historical performance in Hamilton Index industries (LQ trends)



It is impossible to overstate the implications of this potential development, as it would entail a massive switch in the center of global economic power and innovation from a geopoint somewhere in the Atlantic Ocean to somewhere in China. To be sure, just as the United Kingdom still has some tech capabilities and firms after its half century of industrial decline, the allied nations will not completely become, as Alexander Hamilton warned, a hewer of water and drawer of wood, dependent on the innovation leader of the time, the United Kingdom. But if China can move to the frontier of global innovation—a destination all forces in China are pulling toward—the world economy and relative national power will be fundamentally transformed.

THE NATURE OF INNOVATION INDUSTRIES AND COMPETITIVE POSITIONING

Such a change could be gradual, but if it happens, it would more likely be quite sudden (i.e., within a decade or two). The reason is because of the unique nature of innovation industries. These almost always have high fixed costs (e.g., R&D, product design, tooling setup) and lower marginal costs, where losing sales can lead to a death spiral of less revenue, less investment, and less innovation and then less revenue. The opposite is true for firms that are gaining revenue. Chinese innovation scholar Yin Li noted that "building these organizational capabilities inevitably entails high fixed costs that, for innovation to be successful, must be transformed into low unit costs, through accessing a large share of the market."[7]

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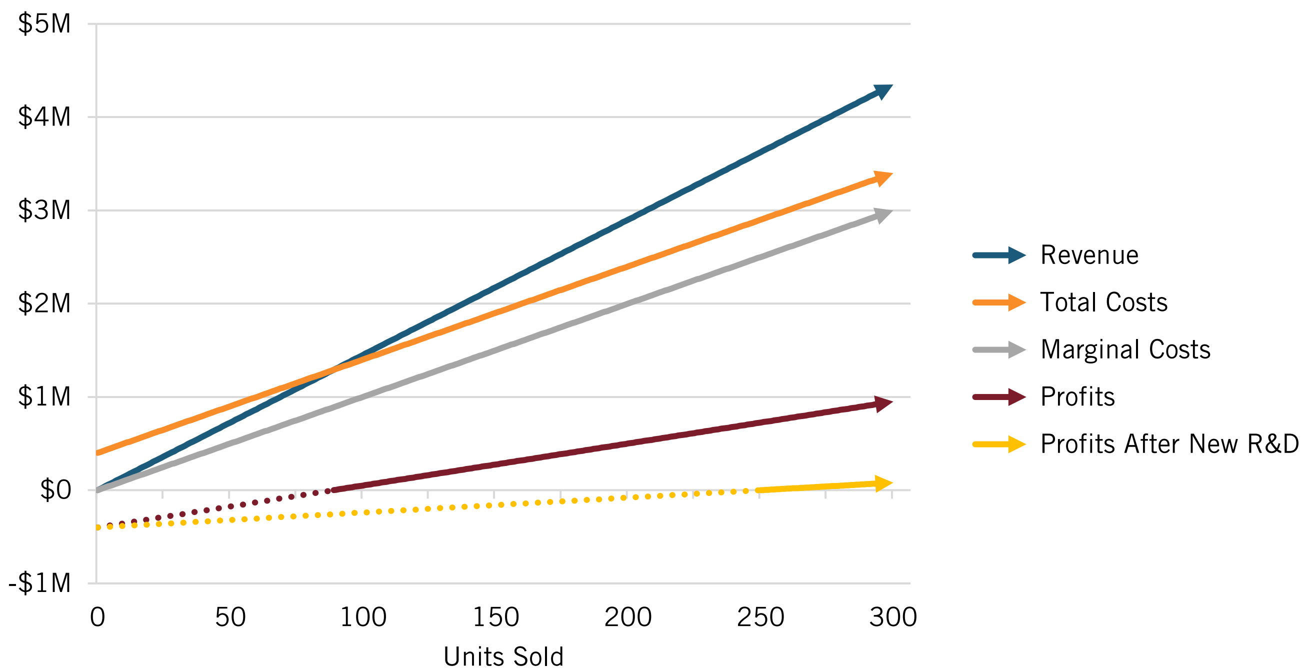
Figure 4 illustrates the cost structure of a hypothetical firm for which fixed costs are 40 times marginal costs—$400,000 and $10,000, respectively. In other words, the company must spend $400,000 on R&D, design, machinery, and other fixed costs before it can produce its first unit. It then costs $10,000 to make each unit in terms of energy, materials, and labor, and the company can sell them for $14,450 per unit. Because of its high fixed costs, the company loses money until it sells at least 88 units. At that point, it makes an increasing profit on each additional unit sold.

Figure 4: Hypothetical firm with fixed costs 40 times greater than marginal costs



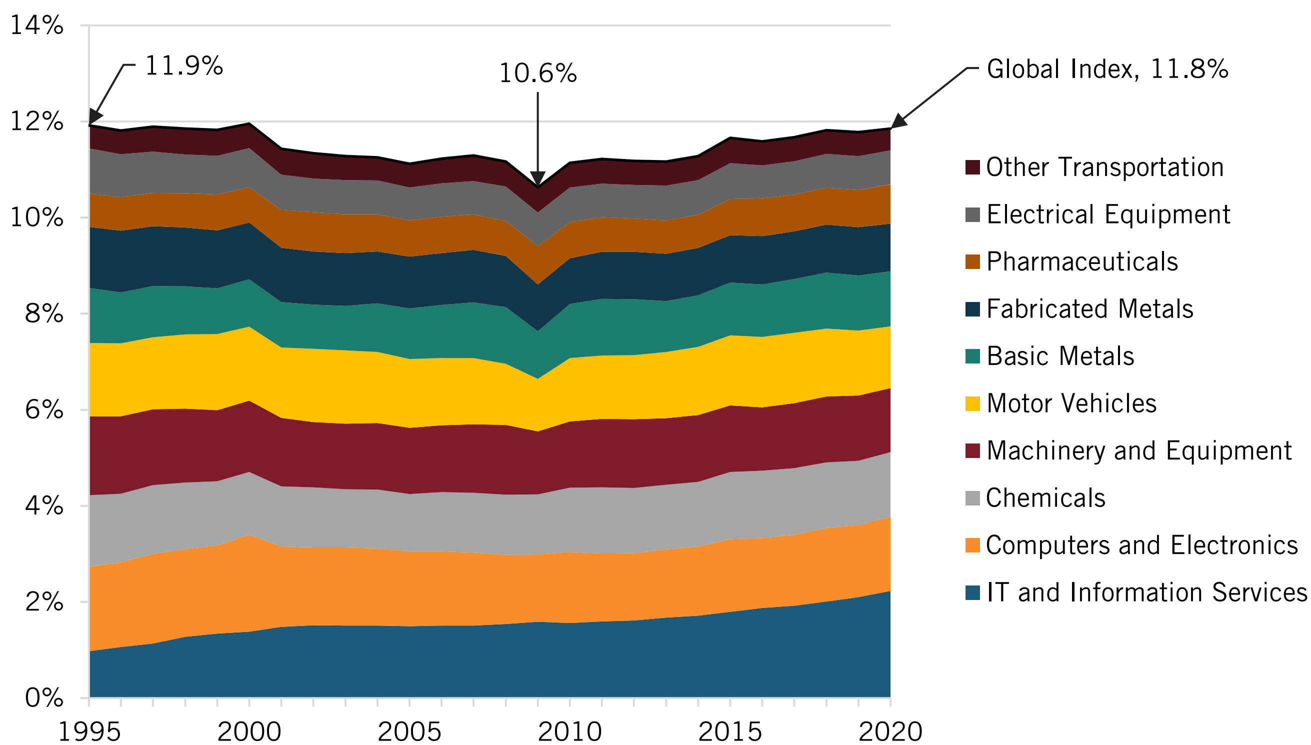
For these industries, scale is everything. Imagine if, because of tougher, subsidized competition from China, sales of the U.S. firm go down to 75 units. In this case, the company would suffer a loss of $62,500. But if it faces less competition from China, then the company could earn a profit of $50,000 after selling 100 units. Meanwhile, whereas the total cost for producing the

75th chip would be $15,333, the total cost for producing the 100th chip would drop to $14,000. Now imagine the company needs to invest 20 percent of its revenues in new R&D to remain competitive. That moves the goalpost; it would require selling more than 250 units to become profitable.

This is why scale is so critical for advanced industries, and why a threat from a robust competitor can be so devastating so fast. Profits fall fast, so R&D and other core value creation capabilities are cut. As a result, the next generation of sales fall, and the downward cycle continues. We have seen this with a number of North American companies facing the China challenge (e.g., Lucent and Nortel) and industries (the U.S. solar panel industry), which fell from dominance astoundingly fast. If China can be an innovative leader and take market share from Western leaders, the latter's ability to keep investing in innovation falls, as do future sales. The increased sales accruing to Chinese firms enables them to gain even more scale, allowing them to sell products for even lower prices and achieve higher profits (or lower levels of government-subsidized losses) to invest in next-generation products.

Some will respond that this exaggerates the threat and paints innovation as a zero-sum game. To be sure, if China develops a cure for cancer (or workable nuclear fusion, etc.) the world and America would benefit. But at the same time, it would mean reduced global market share from U.S. and Western-based drug companies. This is because the market for advanced industry goods is largely fixed as a share of global GDP. As figure 5 shows, 10 advanced industries accounted for 11.9 percent of global value-added output in 1995 and 11.8 percent in 2020. To the extent China captures more of the global sales in these industries, that by definition leads to less market share for non-Chinese firms, and potentially fewer actual sales.

Figure 5: Hamilton industry shares of the global economy



We have already seen such win-lose shifts. ITIF has identified the industries and countries where there was the most nominal decline in output from 2017 to 2020, not counting motor vehicles, which overall saw declines:

- In Austria and Switzerland, the biggest declines were in electrical equipment (declines of $1.15 billion and $115 million, respectively). During this period, China expanded its output by $42 billion.
- The nations where the largest loss was in machinery and equipment were Germany ($16.4 billion), Japan ($14 billion), Italy ($5.0 billion), Brazil ($4.1 billion), Argentina ($1.8 billion), Mexico ($1.5 billion), and the United Kingdom ($1.8 billion). China expanded its output by $69.4 billion.
- In computers and electronics, Denmark's output fell $80 million, Japan's fell $6.5 billion, and South Korea's fell $18 billion. China's output increased by $64.7 billion.
- In chemicals, Brazil's output fell by $8.7 billion, Canada $900 million, Netherlands $1.4 billion, Norway $400 million, Pakistan $600 million, Singapore $5 billion, South Korea $5.6 billion, Germany $5.4 billion, and France $3.8 billion. China's output increased $35.5 billion.
- In basic metals, Japan's output fell $17.2 billion and Turkey's $5.3 billion, while China's increased $86.4 billion.
- In fabricated metals, Germany's output fell by $7.1 billion, South Korea's output fell by $4 billion, France's by $3.4 billion, and Spain and Sweden $1.2 billion, while China's increased $41.8 billion.

It's time to move away from the focus on manufacturing per se and focus instead on advanced industry leadership.

Finally, it is important to clarify that this is not about manufacturing per se. Much of the competitiveness debate in the United State is fixated on manufacturing. The free-market globalists go to great pains to distort the data to show that U.S. manufacturing is healthy (or irrelevant) because they fear that acknowledgement of the truth could lead to an abandonment of their global idealist vision of the world as one large integrated price-mediated market. In contrast, the emerging worker nationalists stress manufacturing jobs—low-tech or high-tech—in part because of their solidarity with labor over capital. But the United States could have a robust manufacturing economy based around low value-added industries (e.g., textiles, metal parts, food products) and still be dependent on China for advanced industries and innovation. As such, it's time to move away from the focus on manufacturing per se and focus instead on advanced industry leadership.

That matters not only for national power writ large—and for holding adversaries in check while increasing their dependence on the United States—but also, critically, for defense capabilities, particularly should the United States be forced into a long and protracted war. As retired U.S. Army Major General John G. Ferrari recently stated, he had "grave concerns" about America's ongoing reliance on China to equip its military and said, "If we were in a war with China and it stopped providing parts, we wouldn't be able to build the planes and weapons we needed."[8]

WHAT IS INNOVATION?

One reason why it has been difficult to answer the question, "How innovative is China?" is that there are multiple definitions of what it means for an economy to be "innovative." Some equate it with doing well in innovation-based industries, even if that output is largely based on copying from leaders in other nations. Others argue it is strong performance in a variety of innovation metrics, such as patents, R&D, and venture capital (VC), even though these metrics are correlated with innovation but are not determinative. Still others argue that it is a nation's firms gaining market share in first-to-the-world (or near-first-to-the-world) products and services. For the purposes of this report, it is this third definition that is most relevant because it is key to determining whether China can do more than copy and because even strong innovation metrics are not necessarily a sign of true innovation performance.

Another factor that can complicate the analysis is whether process or product innovation is the measure. Process innovation—developing and adopting new ways of producing a good or service—is an important factor in increasing labor productivity (e.g., output per labor hour), and that is key to being able to effectively compete with low-wage economies.

Product innovation refers to new and better products (and services). It enables higher-wage economies to compete on the basis of goods that do not compete largely on costs. For example, new pharmaceuticals can be priced higher than older generics if they provide better treatment. New 5-nanometer (nm) computer chips cost more than older 20 nm chips, but because of superior performance will often outcompete the older generations. Patent protection, trade secrets, and other knowledge advantages can provide somewhat sustainable advantages over lower-cost rivals.

However, product innovation is not very important if the innovation cannot be brought to market successfully. This requires adequate quality, a competitive cost structure, and a viable business model. As Clay Christensen pointed out in *The Innovator's Dilemma*, it's not enough to be successful in generating new ideas.[9] Even technological breakthroughs can become a dead end unless they can be translated into working products that are able to be delivered and deployed into the larger marketplace. What we really want to determine is China's innovative capabilities as they relate to being early in bringing new products to widespread market adoption.

Finally, at one end are innovations that are transformative. The invention of nylon, the television, the first transistor, radar, and the personal computer are in this category. At another end are ideas that many other companies are already executing. This is why one factor in innovation is differentiating between breakthrough (sometimes termed exceptional, radical, or disruptive) innovations (e.g., the iPhone) and sustaining innovations (sometimes called incremental or continuous), such as a new generation of semiconductors that has higher performance than the current generation.[10] For example, consider the drivetrain of cars. The development by Tesla of the electric drivetrain was a breakthrough innovation. The development of a better electric motor that uses a small percentage less electricity is an incremental innovation, or what is termed sustaining innovation. Most innovation is sustaining, as companies seek to improve capabilities in existing markets and where they have a clear idea of what problems need to be solved. Disruptive innovations such as the iPhone are relatively rare and often usually relatively quickly enter into a stage of incremental innovation (e.g., better battery life, better displays, better cameras).

Disruptive innovation is perhaps the most threatening to companies. Blackberry did not go out of business because the iPhone was a similar phone with a better physical keyboard; it went out of business because the iPhone and the business model that went along with it (including the app store) was disruptive. The milk glass bottle industry did not go out of business because someone made slightly lighter glass bottles; it went out of business because paperboard cartons and then plastic bottles provided much better value.

In summary, innovation is not invention. It is not science. It is not necessarily entrepreneurship. It is bringing to market new products or services at scale. In addition, while that part of innovation is critical, so is its widespread diffusion and adoption, and so is the process of technology innovation.

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THE ASIAN TIGER PATH

One reason to be on the affirmative side of "can China innovate?" is that it is attempting to follow well-worn paths other developing Asian economies have followed to become innovation leaders. As Linsu Kim wrote in his definitive 1997 history of South Korean innovation upgrading, *Imitation to Innovation: The Dynamics of Korea's Technological Learning*, there are several distinct stages a nation that is catching up to the leaders in innovation usually takes. The first involves the transfer of foreign technology to that nation—sometimes by foreign direct investment (FDI), sometimes by licensing, and often, as in the case of China, by theft or pressure on foreign firms seeking to sell in the market. The second stage involves "the effective diffusion of imported technology within an industry and across industries" which "is a second sequence in upgrading technological capability of an economy."[11] The third stage "involves local efforts to assimilate, adapt, and improve imported technology and eventually to develop one's own technology. These efforts are crucial to augmenting technology transfer and expediting the acquisition of technological capability. Technology may be transferred to a firm from abroad or through local diffusion, but the ability to use it effectively might not be there. This ability can only be acquired through indigenous technological effort."[12]

The final stage is to become a global innovation leader. As Kim wrote:

> Firms in catching-up countries that have successfully acquired, assimilated, and sometimes improved mature foreign technologies may aim to repeat the process with higher-level technologies in the transition stage in advanced countries. Many industries in the first tier of catching-up countries (e.g., Taiwan and [South] Korea) have arrived at this stage. If successful, they may eventually accumulate indigenous technological capability to generate emerging technologies in the fluid stage and challenge firms in the advanced countries.[13]

China is following this recipe/path, with its first step being to attract foreign investment. In the early 1980s, when Deng Xiaoping opened up the Chinese economy to foreign investment, his main economic development strategy sought principally to induce foreign multinationals to shift relatively low- and moderate-value production to China.[14]

China's second step was to attempt to learn from foreign companies, in part by having them train Chinese executives, scientists, and engineers, and also by forced technology transfer, including through joint ventures. In 2015, 6,000 new international joint ventures, amounting to $27.8 billion in FDI inflows, were established in China.[15] And the sophistication and value of the technology the Chinese government has demanded is high. As the United States Trade Representative's (USTR's) Office pointed out in its 2018 Special 301 report on China, pressures on U.S. companies to form joint ventures and transfer technology "is particularly intense."[16]

The third step was to support Chinese companies in their efforts to copy and incorporate foreign technology while building up domestic capabilities. One important marker for the transition from stage two to stage three was the publication in 2006 of the "National Medium- and Long-term Program for Science and Technology Development (2006–2020)," which called on China to master 402 core technologies—everything from intelligent automobiles to integrated circuits and high-performance computers. China moved to a "China Inc." development model of indigenous innovation, which focused on helping Chinese firms, especially those in advanced, innovation-based industries, often at the expense of foreign firms.

The fourth and final step is to enable Chinese firms to become independent innovators—as Japan, Singapore, South Korea, and Taiwan have all become. China is attempting to do this through an array of plans and policies: "13th Five-Year Plan for Science and Technology," "13th Five-Year Plan for National Informatization," "The National Cybersecurity Strategy," and "Made in China 2025 Strategy," and most recently Xi Jinping's call at the 20th Party Congress for "invigorating China through science and education ... for the strategy of innovation-driven development."[17]

The last part of this is to then support these companies "going out" and taking market share in other parts of the world. Unfortunately, for gaining political support for a robust U.S. strategy to respond to China, the United States is among the last places Chinese firms will seek to enter. Rather, they are going after market share in places such as Latin America, Southeast Asia, Africa, and Eastern Europe, the "soft underbelly" of global markets. As their firms gain market share, Western—including U.S.—firms, lose market share, and tipping points can happen quite quickly.

Finally, it's important to note that there are two key factors for innovation success. One is talent, and the other is revenue. More money makes innovation vastly easier. Companies with more money can invest more in R&D. They can acquire talent and technology. They can pay their talent more. And they can achieve scale. This is one of the main differences between the Asian Tigers and China: The Chinese market, and hence revenue, is vastly larger. Because China manages its market and limits foreign sales once its firms get to a certain scale, Chinese firms are blessed with massive, largely secure market revenues, and this does not take into account massive government subsidies.

Related to this is the massive efforts the Chinese government makes to ensure that Chinese society is a lead adopter of advanced and emerging technologies, including high-speed rail, digital and 5G-enabled manufacturing, robotics, smart cities, smart ports, EVs and autonomous vehicles (AVs), digital payments, healthtech, edtech, drones, satellites and space travel, and many more.[18] While China walks the talk when it comes to transforming its society through technology, and in the process creates massive capabilities and revenues for its technology companies, the United States doesn't even slow-walk the talk, as all too often we are walking backward, banning and demonizing technology.[19]

Transitioning from "fast follower" to "global leader" in innovation is not easy, but a number of nations have done it. The United States accomplished this in the early part of the 1900s. Germany and Austria advanced from copying economies in the late 19th century to innovators, building on imports of skilled workers, advanced machinery and blueprints.[20] Japan achieved this by the 1980s, with South Korea, Taiwan, and Singapore doing so two to three decades later. The idea that copiers and followers cannot transition into innovation leaders is just not borne out by history. China is not there yet, at least in many sectors, as this report documents. But that is not for lack of trying and having the same kinds of conditions that other innovation transition economies have had.

The core insight needed to understand the Chinese economic strategy is as follows. China attaining global competitive advantage in virtually all advanced manufacturing industries requires significant "learning," as the production "recipes" to make, for example, a wide-body jet, a computer chip, a genomics sequencer, a robot, or a biotech drug are incredibly complex and cannot be obtained from scholarly journal articles or other widely available sources of technical knowledge.

Because China manages its market and limits foreign sales once its firms get to a certain scale, Chinese firms are blessed with massive, largely secure market revenues—and this does not take into account massive government subsidies.

Even after China has gained global market share in a number of extremely complex, advanced technology industries such as jet aircraft, high-speed rail, solar panels, personal computers, supercomputers, telecommunications equipment, and Internet services, many will still dismiss China's capabilities and assume China will be incapable of even partial success becoming a true innovator. While mastery of some particularly complex technologies such as semiconductor logic circuits remains a challenge for China, Chinese companies have made significant progress in an array of other technologies, including in certain kinds of semiconductors (e.g., chips for Internet-of-Things (IoT) devices). Moreover, the fact that nations such as Japan in the 1960s and 1970s, and Taiwan and South Korea in the 1980s and 1990s, could rapidly progress to become advanced technology economies using similar kinds of approaches (obtaining foreign technology and subsidizing and protecting domestic innovators until they are strong enough to compete on their own), suggests there is nothing inherently keeping China from making similar progress, especially given the massive amount of government support for the effort.[21]

One way to understand Chinese innovation is provided by the McKinsey Global Institute's *The China Effect on Global Innovation*, which separates innovations into four categories: efficiency-driven, customer-focused, engineering-based, and science-based.[22] The report concludes that with its proven ability to produce goods at scale, adapt products to the Chinese market, and develop and adopt digital infrastructures such as mobile payment systems and e-commerce (sometimes even before more-developed economies), China has demonstrated that it is capable of efficiency-driven and customer-focused innovations. The challenge before it, the authors argued, is to catch up in the areas of engineering- and science-based innovations.

CAN CHINA INNOVATE?

As far as can be determined, there have been no thorough studies of China's innovation capabilities. There have been a host of studies, including from ITIF, that examine indicators of innovation, such as R&D spending, scientists and engineers, and patenting.[23] But these do not adequately answer the question of whether China is copying or innovating.

The question of whether China can innovate is a longstanding one, with analysts coming down on both sides. Some argue that China cannot really be innovative because its innovation system is deficient. This includes charges of weak intellectual property (IP) protection, it being too state directed, and having too little creativity due to rote learning and a hierarchical education system. Others argue that China can't be innovative because its economy suffers from low productivity, even though the two factors are related but not codeterminant.[24] Still others embrace the popular narrative that we have reached "peak China" and it's entering into a long, slow phase of decline. Indeed, the conventional wisdom until recently was that China could not innovate; at best, it could be a fast follower.

However, a growing number of analysts have challenged that conventional wisdom, with some arguing that, in certain cases, China is even more innovative than the United States, as exemplified by a 2021 *Harvard Business Review* article "China's New Innovation Advantage."[25] However, this article relies on metrics such as speed of attaining unicorn status. And with the largest population on earth, one would expect a fair number of Chinese unicorns. The authors also talked about how Chinese people like to adopt new technologies. But there is little evidence that this is greater than some other nations, including the United States. Finally, most of the examples given of Chinese innovation success are in a few narrow areas such as 5G (where China's lead is actually much less than most people think), mobile payments, and smart scooters (technologies that are not as important to national power).[26]

China Cannot Innovate

For the most part, scholars studying the Chinese economy broadly, and their innovation capabilities specifically, have until recently largely argued that China is incapable of "true" innovation, at least at the global frontier. In general, the reasons given in support of this view are an education system that encourages rote memorization and represses creative expression, a risk-averse culture centered around a reverence for authority that is not conducive to disruption or drastic change, weak IP protections, and inefficient state involvement in markets. Proponents of these arguments believe that while China's economic rise is impressive, it is bound to be at best a copier of innovations from the West, at least for the foreseeable future.

Examples of such arguments abound. In a 2014 article for *The Diplomat*, Kings College London Professor of Chinese Studies Kerry Brown wrote:

> The Chinese government under Xi can pour all the money they want into vast research and development parks, churning out any number of world class engineers and computer programmers. Even with all of this effort, however, China is likely to produce few world-class innovative companies. The fundamental structural problem is that the role of the state and government in China is still very strong … The system that China currently has still rewards conformity.[27]

Likewise, a 2014 *Harvard Business Review* article titled "Why China Can't Innovate" lists several reasons that explain why "China is largely a land of rule-bound rote learners—a place where R&D is diligently pursued but breakthroughs are rare."[28] It cites the "unprecedented scale of [the Chinese government's] failure to protect intellectual property rights." The article also points out that Chinese schools emphasize test scores too heavily and do not prime students to be creative and design oriented. It goes on to note:

> The Communist Party requires a representative to be present in every company with more than 50 employees. Every firm with more than 100 employees must have a party cell whose leader reports directly to the party in the municipality or province. These requirements compromise the proprietary nature of a firm's strategic direction, operations, and competitive advantage, thus constraining normal competitive behavior, not to mention the incentives that drive founders to grow their own businesses.[29]

It further states that "the freedom to pursue ideas wherever they may lead is a precondition for innovation in universities." Likewise, a recent *Wall Street Journal* op-ed also titled "Why China Can't Innovate" lays the blame on the assertion that "communism is incapable of nurturing the curiosity that leads to innovation."[30]

Others argue, with some justification, that input metrics such as research articles or even patents fail to effectively measure innovation. But then they go on to suggest that China therefore is not leading. A *Defense News* article argues that in America's "thriving open market, a product of the U.S.'s commitment to an open society and the free exchange of ideas, metrics like commercial success, technology adoption and real-world impact become more telling than raw measures."[31] Yet, the author failed to report any of these better metrics. He went on to note, with no real evidence, "The U.S. strives, though imperfectly, to offer opportunities to everyone who desires them, eschewing artificial barriers and quotas and avoiding intellectual conformity. This commitment fuels a dynamic, diverse workforce that is a wellspring of ingenuity and innovation."[32]

In this same vein, an Atlantic Council report states, "China's authoritarian top down political system poses the risk of restraining free thinking and sharing of ideas and information—both domestically and internationally—that are crucial in stimulating scientific research and discoveries."[33] A recent article in *Foreign Affairs* just states it bluntly in the subtitle: "A Statist Economy Can't Foster Creativity."[34] The author went on to write that "an innovation-based industrial strategy may not be transformative if the government is unable to address basic systemic weaknesses such as youth unemployment, frailties in China's banking and financial systems, and weak consumer demand." It's not clear how any of these relate to innovation, or are even true. Yasheng Huang argued in the *Rise and Fall of the EAST* that China's repression, especially under Xi, is deeply problematic for Chinese innovation.[35]

Simon Gao wrote that "there is a bigger reason that China's ambitious technology endeavors are failing: Its communist system stifles innovation.… If China can't cultivate free thinkers, it will always be a follower and never a leader as the West imagines and invents the future."[36]

Others see China as a "peaking power," implying that it will continue to lag behind in innovation.[37] Likewise, a *Washington Post* series featuring experts reflects the new preferred wisdom that China faces a demographic crisis: Its young people are discontent and its economy has hit the wall, in part because of the current banking and real estate challenges; and the Chinese Communist Party (CCP) is only interested in its own power, not innovation.[38]

Studies criticizing China for a rote education system appear to overstate the case. For example, in *China as an Innovation Nation*, Zhou, Lazonick, and Sun argued that claims criticizing the Chinese education system for suppressing creativity are overblown because similar critiques exist of Japan and South Korea, though most regard both to be innovative nations.[39] At times, this view is similar to the view held in the 1960s and 1970s that Japan's postwar economic miracle would never overtake the United States because the Japanese were an "imitative people" who were only capable of creating copies of goods the United States and the West developed (e.g. computers, TVs, automobiles, etc.), which proved disastrously wrong.

How many governments in the world have decided they're going to become major innovation centers? None of them have succeeded. Unless you count Finland, Ireland, Israel, Japan, South Korea, Singapore and Taiwan.

Michael Pettis, a professor at the Guanghua School of Management at Peking University, bluntly stated, "This is not a country we can expect major innovations from. In the West we don't have enough confidence about this. How many governments in the world have decided they're going to become major innovation centers? None of them have succeeded."[40] Unless you count Finland, Ireland, Israel, Japan, South Korea, Singapore and Taiwan. They all committed to becoming innovation centers, and they all succeeded.[41]

Pettis went on to say that China is doomed to stagnate, like he's claimed Japan did, even if it has the best supply-side technology development policies, because of demand-side stagnation, which he's said Japan suffered.[42] First, Japan had no demand-side stagnation, given that its unemployment rate from 1995 to the present was quite low.[43] Second, Chinese firms don't rely just on the Chinese market (the same way Japanese firms didn't); they rely on the growing global market.

Scott Kennedy of CSIS is also skeptical of China's ability to turn willpower and resource allocation into innovation. Citing the lack of growth in China's output score relative to its input score in the World Intellectual Property Organization's (WIPO's) Global Innovation Index between 2009 and 2016, Kennedy dubbed China a "fat tech dragon," since its apparent inability to turn inputs into outputs is analogous to a low metabolism.[44] Kennedy also pointed out that, while plentiful, Chinese patents are of relatively little practical use. Licensing revenues from the use of patents are still minuscule, and the surge in patents filed is a response to government rather than market incentives. Despite these issues, Kennedy acknowledged that China now graduates more scientists and engineers from its universities than does any other country, a higher percentage of bank loans are going to private businesses rather than state-owned enterprises (SOEs), and IP protections are steadily expanding.[45] Nevertheless, Kennedy has argued, innovation appears to be a secondary goal to market expansion overseen by the state.

Others argue that China cannot be innovative because its productivity performance lags behind global leaders. In an article for Australia's Lowy Institute, John West argued that notwithstanding the relatively high rank on global innovation for a number of Chinese companies, overall, China is not innovative because it is not highly productive.[46] But this wrongly equates innovativeness with productivity. China could in fact have highly innovative globally traded companies and still have low productivity, especially if its nontraded sectors lag behind in productivity. This describes Japan to this day, where its leading traded sector industries (e.g., electronics, autos, etc.) are highly productive and innovative, but its nontraded sectors (e.g., healthcare, retail, etc.) are generally not.

Still others now advance the narrative that China's economic slowdown means that it is in the Japan phase of development and the threat has passed. For example, Council on Foreign Relations scholar Zongyuan Zoe Liu has argued that China has been "killed" by failed CCP policies.[47]

One might say that the most important kind of freedom for innovation is the ability to do innovation with generous funding, something that is much easier for Chinese scientists than for Americans, especially given the declining federal funding for R&D.

Finally, it's important to understand the "freedom" argument that democratic freedom is essential to national innovation. China is not the Soviet Union, where Lysenkoism (the rejection of traditional Darwinian genetics because it did not fit with Soviet ideology) reigned supreme. It is not even the United States, where stem cell research using discarded embryos was banned for religious reasons. It is a place that gives its scientists and engineers enormous freedom to innovate, as long as it is in areas seen as in the public interest (as opposed to, for example, education apps that lead to an arms race among parents of one-upmanship) or does not criticize or get ahead of the CCP. Indeed, one might say that the most important kind of freedom for innovation is the ability to do innovation with generous funding, something that is much easier for Chinese scientists than for Americans, especially given the declining federal funding for R&D.

China Can Innovate

More recently, some assessments have argued that China can innovate—if not across the board, then at least in some select key technologies. For example, WIPO's *2022 Global Innovation Index* ranks China 11th most innovative in the world and states, "China stands out for producing innovations that are comparable to those of the high-income group."[48] A recent article by IMD Professor Georges Haour tells us, "Why China is on the way to being a global innovator."[49]

Others have argued that China may be an innovation leader in certain new technology areas, such as quantum computing, fusion, and AI.[50] For example, in the article "Why China will win the global race for complete AI dominance," the author stated that Kai-Fu Lee believes:

> We're in the age of implementation, we're in the age of data, and China has a better set, a larger set of implementers or good AI engineers who get the work done, who make the algorithms run fast, connect to business logic. The West needs to revise its view of Chinese technology companies being copycats of western products, and acknowledge that, in fact, some categories of Chinese technology are best-in-class.[51]

The biggest danger for Silicon Valley, according to Lee, lies in "solipsism and complacency in its own supremacy." Lee also pointed out that China suffers much less from incumbents using their political power to prevent the adoption of new technologies. He also could have just as easily said that "neo-Luddite" forces in China resisting new technologies, such as AI, facial recognition, automation, and other disruptive technologies, are much less than in the United States, and to the extent they exist in China are suppressed by the state.

Likewise, a 2021 report from Harvard's Belfer Center, "The Great Tech Rivalry: China vs the U.S.," argues that China has become a serious competitor in the foundational technologies of the 21st century: AI, 5G, quantum information science (QIS), semiconductors, biotechnology, and green energy. The report notes, "In some races, it has already become No. 1. In others, on current trajectories, it will overtake the U.S. within the next decade."[52] It attributes this to a strong R&D ecosystem as well as the top-performing Chinese universities that continue to improve.

China technology expert Dan Wang has argued:

> China's technological development is considerably more dynamic than the country's image suggests. China remains behind in several critical areas, and some of its most important tech firms face regulatory squeezes—whether from Washington or Beijing itself. Regardless of these challenges, Chinese industries are reaching world-class standards, and the country's science is steadily advancing. Along the way, Chinese firms have begun to make significant innovations of their own, including in strategic areas that the United States has prioritized.[53]

Tim Ruhlig argued that China is innovative and that the role of the CCP has been a plus, not a negative: "Although widely thought to hamper innovation, the role of the party-state should be considered the Fourth Virtue that has made China innovative. It is certainly true that central planning is an obstacle to creativity and thereby to innovation."[54]

Matt Sheen, a fellow at the Carnegie Endowment for International Peace, argued that China is an "innovation powerhouse" because of its "large, semi-protected market; ties with researchers and companies around the world; and waves of financial, human, and physical capital invested in promising fields like AI," all factors promoted by the government.[55]

There are also structural factors that suggest that China could emerge as a global innovation leader. Huang and Sharif argued that three factors will play a key role in making China a technology leader: China's large market (which lets innovative firms drive down marginal costs faster than others), the centralized system of government that enables China to provide significant support to innovative firms, and China's strong role in international markets to acquire advanced technologies while increasing its capacity to undertake advanced R&D, often in partnership with foreign interests seeking access to the Chinese market. They argued that these three factors will make China the global technology leader "over the long term."[56]

A Harvard Belfer Institute study argues that "China's whole-of-society approach is challenging America's traditional advantages in the macro-drivers of the technological competition, including its technology talent pipeline, R&D ecosystem, and national policies."[57]

Finally, as China technology expert Dan Wang wrote:

But amid these serious vulnerabilities, China is making rapid progress in many other technologies. Chinese firms have quickly gained ground against their European and Japanese counterparts in the production of advanced machine tools such as robotic arms, hydraulic pumps, and other equipment. As the iPhone demonstrates, China now rivals Japan, South Korea, and Taiwan in its mastery of the electronics supply chain. And in the digital economy, despite recent efforts by President Xi Jinping to tighten government control of Internet companies such as Alibaba, Tencent, and Didi, China remains strong. Chinese companies can still offer spirited competition to Silicon Valley's tech giants, as ByteDance's TikTok has been doing to Facebook. China leads the world in building modern infrastructure, including ultra-high-voltage transmission lines, high-speed rail, and 5G networks. In 2019, China became the first country to land a rover on the far side of the moon; a year later, Chinese scientists achieved quantum-encrypted communication by satellite, pushing the country closer to creating unbreachable quantum communications. These achievements are emblematic of China's steady effort to master more and more difficult tasks.[58]

INNOVATION ANALYSIS

Determining what to measure depends in large part on what question one wants to answer. Ideally, innovation should be defined as output and market share in new-to-the world products and services. In other words, invention is not a challenge to market leaders; only innovation is, with innovation being defined as successfully bringing a new product or process to market. Nor are innovation inputs and outputs to the innovation process, such as R&D spending and patents, a challenge to market leaders. Those are useful indicators, but ultimately, they are inadequate to truly measure innovation.

Given the lack of adequate Chinese data, it is not possible to measure output and market share for some, if not most, industries and technologies. But it is possible to assess the development of innovative products in many Chinese firms. Chinese-owned companies are the focus, not the Chinese economy, because foreign firm operations in China are much less of a threat to allied economies than Chinese firms are. Foreign firms may move some production and research to China, but their goal is not to displace themselves. In contrast, the goal of many Chinese-owned firms is, like most multinational firms, to win global market share. Moreover, over time, the role of foreign firms in China will continue to shrink as the Chinese government continues its progress with "indigenous innovation" (innovation by Chinese companies). That is why the focus is not on Chinese innovation, but rather on Chinese firm innovation. The notion that "China" can or cannot do something well is of course misleading.

But what do we mean by "new to the world"? Clearly there is a difference between innovation that is new to a firm or even new to a country. For example, surveys asking Chinese firms if they have innovated show similar, if not even higher, rates than firms in more advanced nations. But this only means that Chinese firms are doing something different than they had been doing, even if that means copying foreign innovations and technologies.

Unfortunately, there are no hard and fast definitions of "new-to-the-world" and "leading edge." Moreover, for many products, firms incorporate many existing products and innovations, but also add some components and functions that are new. As a rough rule, ITIF defines "leading-edge innovation" as something a firm does no later than a year after something has been introduced somewhere else in the world. Anything longer risks picking up developments that are based more on copying. And a significant part of the new product must be innovative and new. Clearly assessing these factors involves a judgment call. There is no hard and fast rule as to how much copying a firm engages in would disqualify a technology from being defined as innovative. Almost no firm is a completely original innovator. Even Apple incorporated an array of prior innovations to develop the iPhone. But we define copying as largely and substantially using technology and features that are already in existing non-Chinese products, and innovation as the opposite.

Over time, the role of foreign firms in China will continue to shrink as the Chinese government continues its progress with "indigenous innovation."

Unfortunately, with the exception of drug approvals for the biopharmaceutical industry, there is no readily available data base assessing the number and extent of innovations from Chinese firms. As such, we use three methods to assess Chinese firm innovation. The first, and least useful, is a review of quantitative innovation indicators, such as R&D personnel, patents, and article citations. These are useful, but not determinative.

The second is an analysis of individual Chinese firms. We use as a population of Chinese-headquartered firms listed on the EU R&D 2,500 list (the list of the world's top 2,500 R&D spenders). A total of 679 Chinese companies were on the 2023 list, and we selected, mostly at random, although we tried to ensure broad sector coverage, 44 companies to examine more closely. At one level, this is a biased sample in that it only includes leading R&D spenders. But these are the kinds of companies most likely to be innovative, so to the extent that they are not, this tells us a lot about Chinse innovation capabilities. While we selected at least 2 companies to fit with the 11 in-depth industry/technology case studies, for the rest, we chose randomly. Relying on native Chinese language researchers, we reviewed company annual reports and investment analyst reports to qualitatively assess the product innovations these companies have developed and the extent to which these are or close to new to the world. ITIF experts then independently scored each firm on a scale from 1 to 10 (1 being a complete copier to 10 being at the leading edge of innovation in the world).

Third, we examined nine key industries and technologies important to national security and national economic power: EVS, robotics, semiconductors, chemicals, AI, biotechnology, quantum computing, displays, and commercial nuclear power. Some of these technologies are dual use and important to not only U.S. national security but also its economic security.[59] Others are emerging technologies that help shape technology competition.[60] To do that, we relied on interviews and roundtables with experts on Chinese industries. For the most part, we did not interview experts in China, in part because of current CCP restrictions on sharing information with foreigners, but also because we were not certain we would obtain objective information.

A limit of these methodologies is the extent to which firm studies and industry case study results can be generalized. One way we addressed this was to examine a range of companies and industries. But to be sure, both were samples, and it's possible that the innovation performance of other companies and innovation-based industries is considerably different. Of course, examining even more industries in depth would have been better. But the time cost involved in doing so is extensive. Even with the limitations discussed, the fact that the same general dynamics were found in all 11 industries suggests that the results are likely to be generalizable across virtually all Chinese globally traded industries, especially the ones the Chinese government is targeting.

We also chose not to use some cross-national datasets on firm innovation performance, for two reasons. First, national surveys of firm innovation performance (e.g., asking questions such as what percentage of firm revenue came from new products) do not differentiate between products new to a firm, new to a country, and new to the world. Second, these surveys appear to not be comparable across nations. For example, OECD reports that 80 percent of Canadian firms are innovative, compared with 38 percent of American firms, a lead that most Canadian innovation policy experts would find dubious at best. It also reports that 38 percent of Chinese firms are innovative (from the 2108 Chinese Innovation Survey), equal to the U.S. number, and Chinese manufacturing firms overall are the most innovative in the world. This is likely to be more of a result from survey bias than actual performance, just as it appears that Chinese firms over-report R&D expenditures to the government and seek to inflate their innovation performance.[61] It could also be an indication that the survey only asks the firm if it is innovative compared with what it had been doing.

For the most part, we also chose to focus on product innovations and not on process innovations for several reasons. First, many process innovations are a way for a firm to lower production costs. China can and does that in many ways, including government subsidies, currency manipulation, and others. Second, and more importantly, it is extremely difficult to measure process innovations because, by definition, they are within the firm and not sold in the marketplace. This should not diminish the importance of process innovation. There are innovations that U.S. companies have come up with, but the United States has lacked the processes and skills needed to make them. This broader manufacturing ecosystem, including technical skills and deep supplier networks, is one reason China has been so successful in advanced manufacturing.[62]

One final note on methodology: The goal of this study was not to predict future technological developments. Both private markets, the main determinant, and government policies are themselves highly unpredictable, and the interactions and eventual outcomes among them are even more so. But to use an analogy, if someone observes a sports team with great athletes working out intensely and supported with a massive budget, it's not unreasonable to predict that this team is likely going to be successful. In other words, while it is not possible to predict the course of technology development (will EVs, or hydrogen vehicles, become dominant?), it is possible to assess current positions and momentum, and that should and can inform likely predictions about the future.

Despite the limitations of raw data, the following section examines an array of empirical data sources and studies to assess both trends and levels in Chinese innovation. The overall finding is that, in some areas and industries, China appears to be ahead of the rest of the world, and in most others, it is rapidly catching up.

Empirical Data

Normally, to assess how innovative a country is compared with others, measures should be examined controlling for the size of the economy. Otherwise, an extremely innovative small country would look less innovative than a very large country that is not very innovative. However, when assessing how innovative Chinese industries are, and the threat that poses to other nations' industries, total figures are extremely relevant because firms don't compete against an entire country, but rather against other firms. Therefore, this section examines total figures.

Figure 6 shows the number of total full-time researchers in China relative to the number in the United States. In 2011, China's total number of researchers exceeded 1.3 million, almost 20 percent more than the 1.1 million researchers in the United States. The dashed line represents the total number of researchers in the United States over this same period. By 2021, the gap between China and the United States had increased substantially. The number of researchers in China increased by over 1 million employees to 2.4 million, almost 50 percent more than the total in the United States, 1.6 million.

Figure 6: Number of researchers in China relative to number in the United States[63]

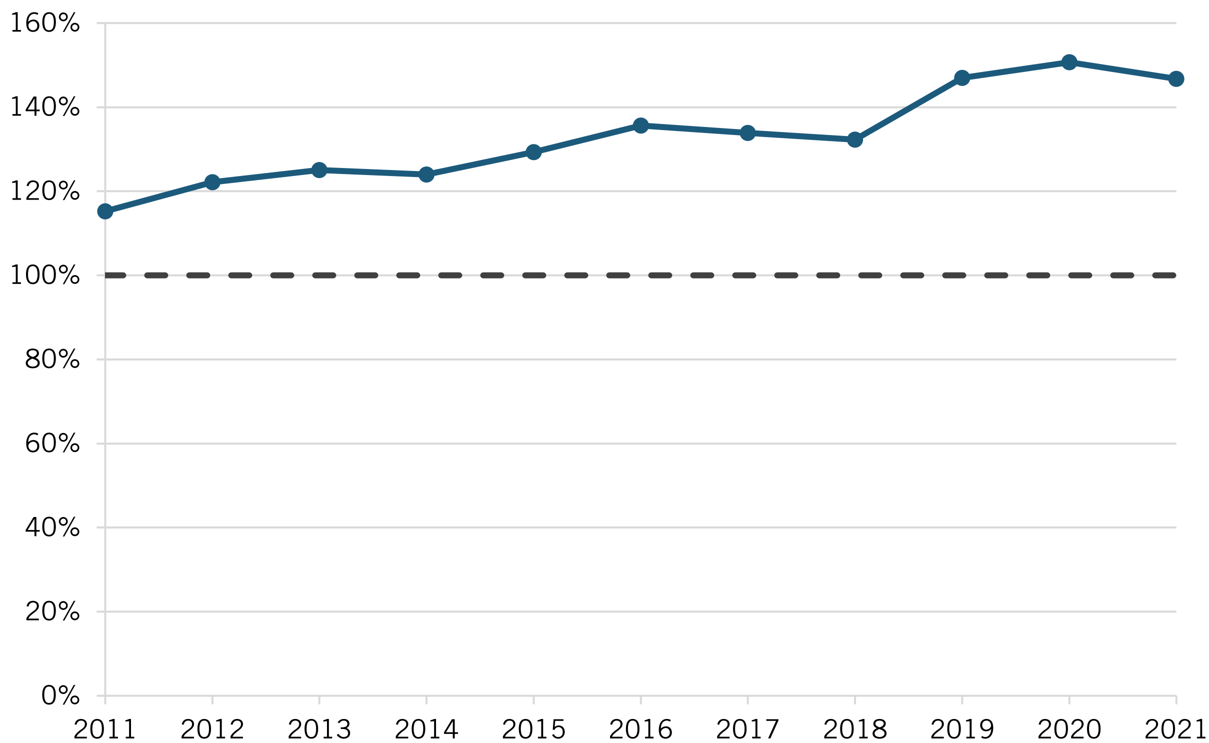


Figure 7 shows the number of researchers employed by private businesses in China as a percentage of all researchers, relative to the United States. In 2011, 62 percent of full-time researchers in China were employed by private business enterprises compared with 74 percent in the United States. Over the decade, the share of business researchers decreased substantially compared with the United States. In 2021, only 58 percent of researchers were employed by private businesses in China, compared with 83 percent in the United States. This trend reveals an increasing concentration of research conducted in the business sector in the United States, while the opposite occurs in China.

Figure 7: China's researchers in the business sector as a share of total researchers, relative to the United States[64]

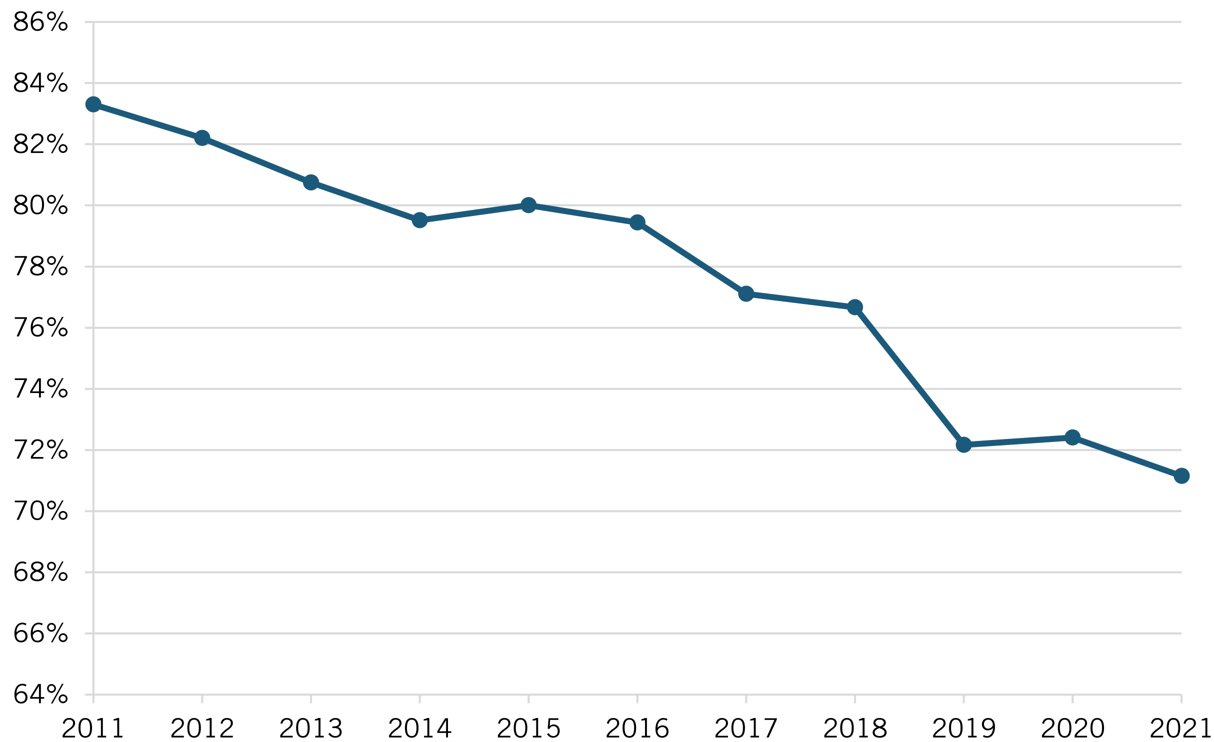


Figure 8 shows gross expenditure on R&D by performing sector in China relative to the spending in the United States from 2011 to 2022. In all sectors and in overall expenditure, China neared the United States in R&D spending. In 2011, China spent $246 billion on research, just 58 percent of the $427 billion spent by the United States that same year. However, 11 years later in 2022, China had crept much closer to the United States, now spending $811 billion, or 88 percent of the $923 billion spent by America. Sectorally, China has also come close to equaling the United States, represented on the graph as the black dotted line. China spent 86 percent of the United States' expenditure on government research, and in the business sector, China's expenditure in R&D was virtually equal to that of the United States; in 2022, China spent $641 billion while the United States spent $646 billion.

Figure 8: China's gross domestic expenditure on R&D by sector, relative to the United States[65]

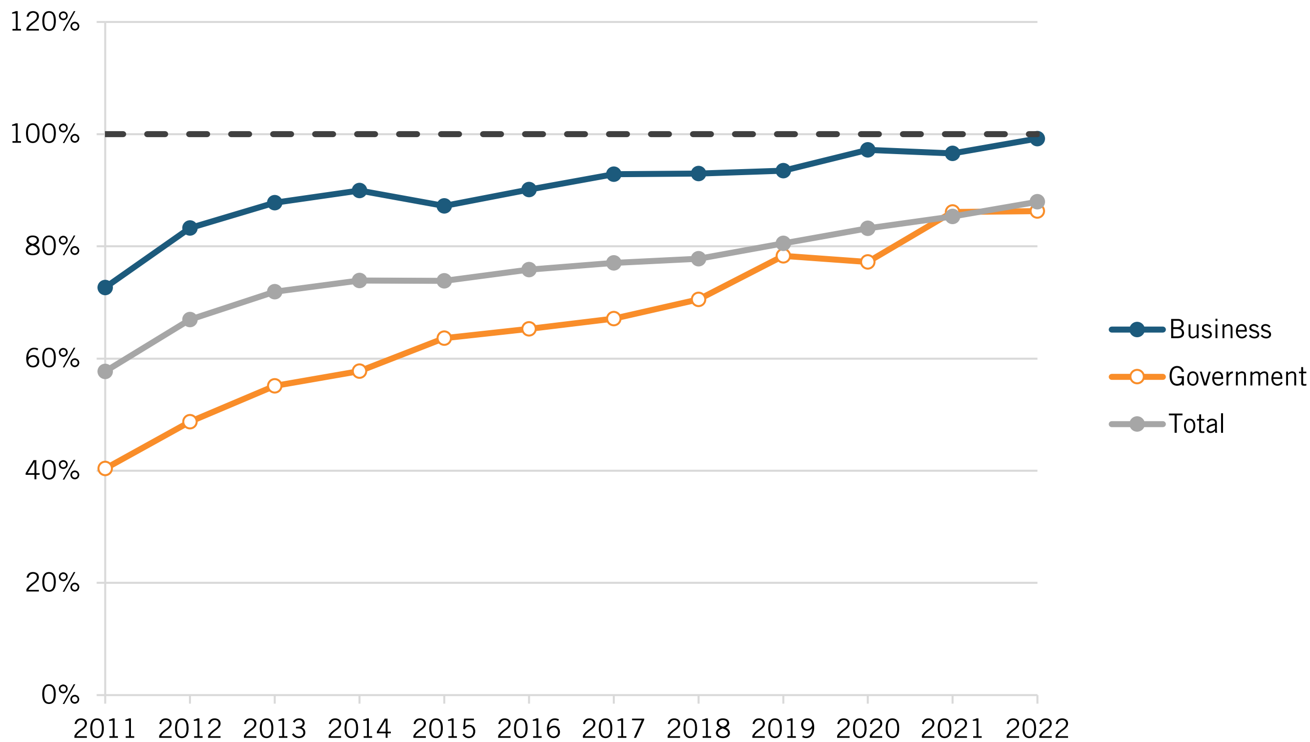
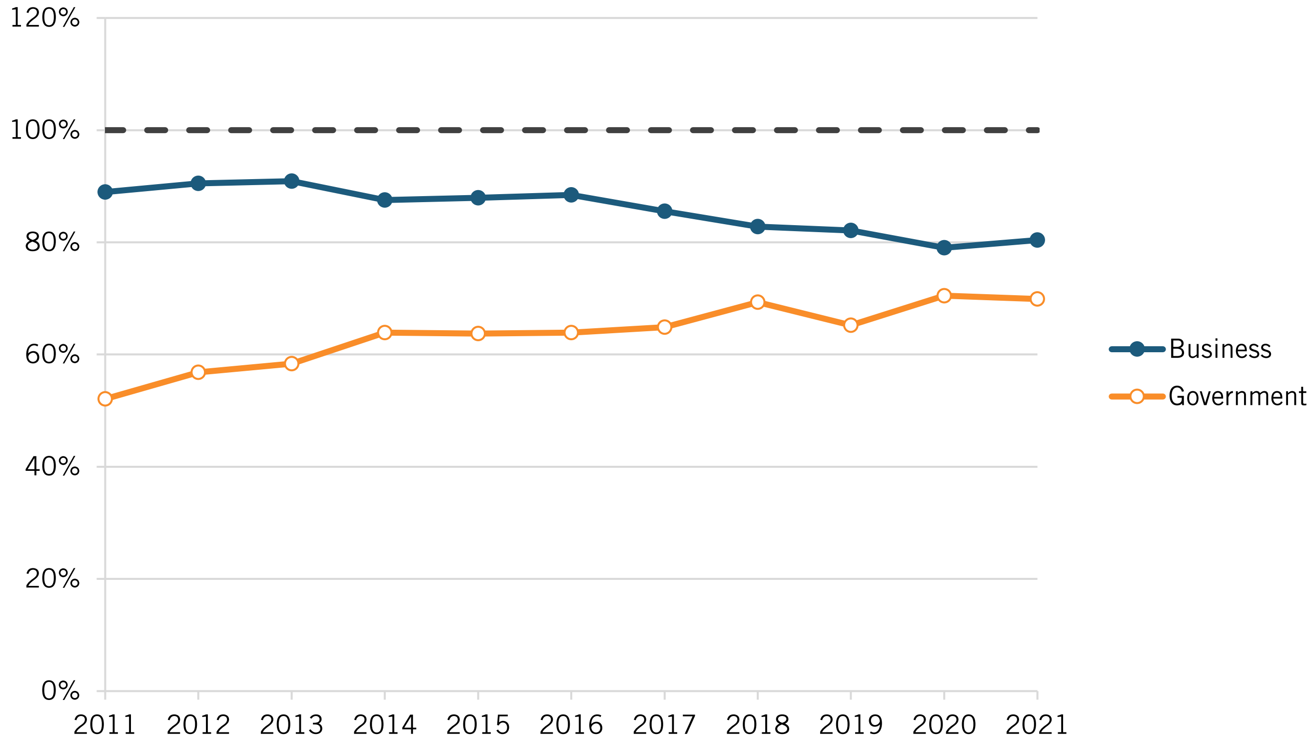


Figure 9 depicts the R&D intensity in China by performing sector, relative to the United States. Between 2012 and 2022, R&D expenditure by private businesses increased in both countries. In 2012, the R&D intensity in China was 1.42 percent or 89 percent of the R&D intensity in the United States. By 2022, the R&D intensity in the business sector in China had declined, while the intensity by government entities increased. Most recent data shows that the R&D intensity in China's business sector has declined to just 80 percent of the United States, while R&D intensity financed by China's government has increased to 70 percent of U.S. levels, an increase of 18 percent over the past decade. The dashed line represents the level at which R&D intensity in China would be equal to the United States.

Figure 9: R&D intensity in China by performing sector relative to the United States[66]



Every year, the European Commission compiles a list of the firms that have invested the greatest amount of money in R&D. Figure 10 shows the number of these firms that were concentrated in the United States and in China. Since 2013, China had made significant gains compared with the United States, represented as the dashed line. In 2013, 658 of the top-R&D-spending firms were located in the United States, almost six times more than the 93 firms located in China. By 2023, the numbers in the United States and China had increased, but not proportionally. China had increased its top R&D firms sevenfold, with 679 firms making the list in 2023. In the United States, 827 firms made the list.

Figure 10: Number of global top R&D investment firms in China relative to the United States[67]

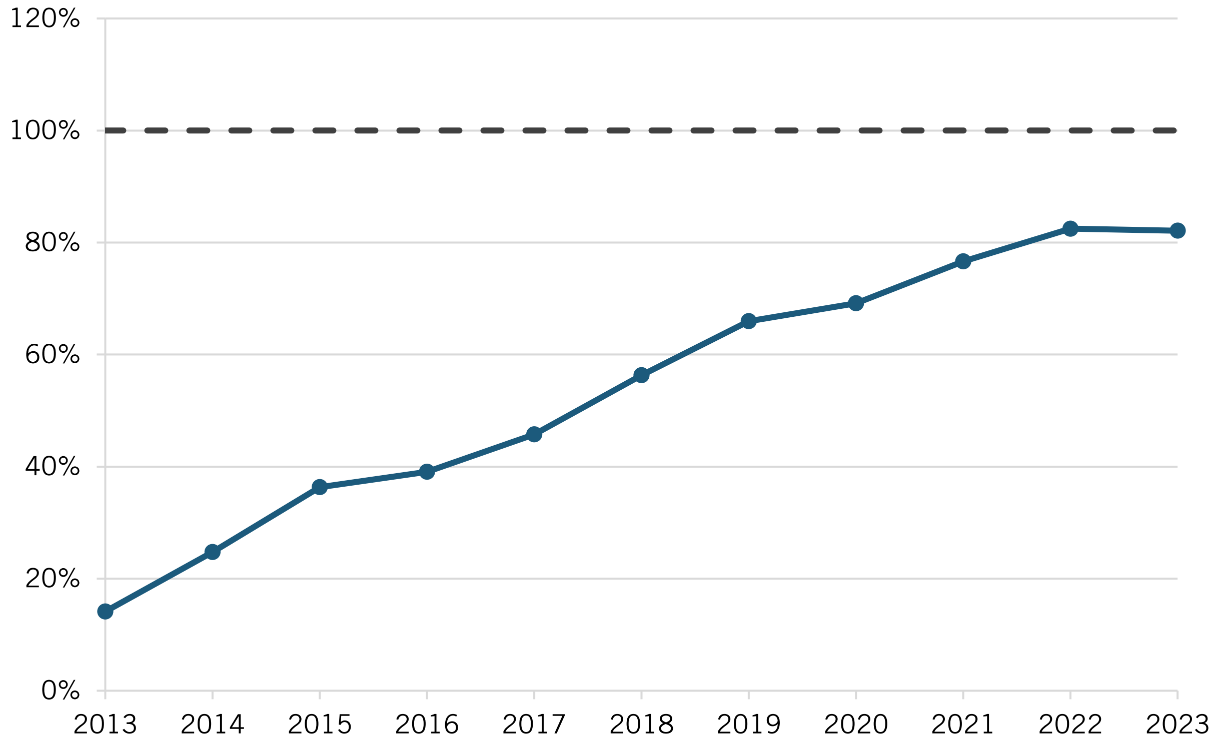
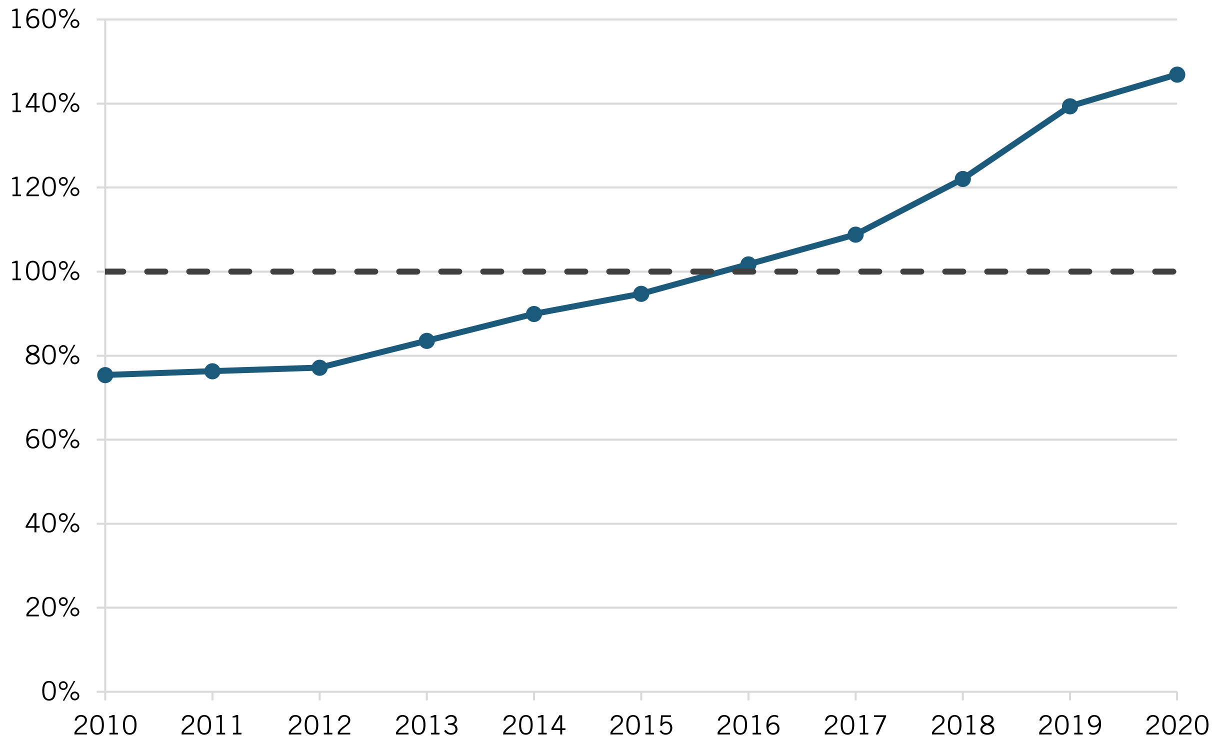


Figure 11 demonstrates the growth in scientific and technical articles published in China relative to the United States from 2010 to 2020. In 2012, about 330,000 articles were published in China, and just 75 percent of the over 430,000 articles were published in the United States that same year. However, by 2016, China had surpassed the United States. The dashed line represents the number of articles the United States publishes annually. Most recent data from 2022 shows that China continues to exceed the United States, publishing almost 900,000 articles, 47 percent more than the 457,000 published in the United States.

Figure 11: Number of science and technical articles published in China relative to the United States



To be sure, some of China's published papers appear to be fraudulent, based on strong incentives to "publish or perish."[68] However, one academic study that controlled for a number of independent measures, including type of journal, finds that China is farther ahead in top-level academic journal publications than is generally believed and that China overtook Europe in 2015 and the United States in 2019. Wagner, Zhang, and Leydesdorff wrote:

> The top-1% analysis using field normalization may have obscured the fact that China is operating at world-leading levels of scientific output in both volume and quality. The increase of the quality of China's scientific output challenges a number of assumptions about the ways or conditions within which nations build scientific capacity. China's science policy has propelled the nation to world-class levels in a very short time period, moving the nation's profile from rapid imitation to levels challenging nations with a longer history of world-leading science.[69]

Clarivate, a data analytics company, produces an annual list of highly cited researchers, or "influential researchers … around the world who have demonstrated significant and broad influence in their field(s) of research." Figure 12 shows the share of these highly cited researchers located in China relative to the United States. In 2018, over 43 percent of highly cited researchers were located in the United States, while only 8 percent were found in China. However, over the next several years, the number of these influential researchers in the United States fell, while in China the opposite occurred. By 2023, the number of highly cited researchers more than doubled there, with 18 percent of all highly cited researchers living in China. Meanwhile, the share of these researchers in the United States fell to 38 percent.

Figure 12: Share of highly cited researchers in China relative to the United States[70]

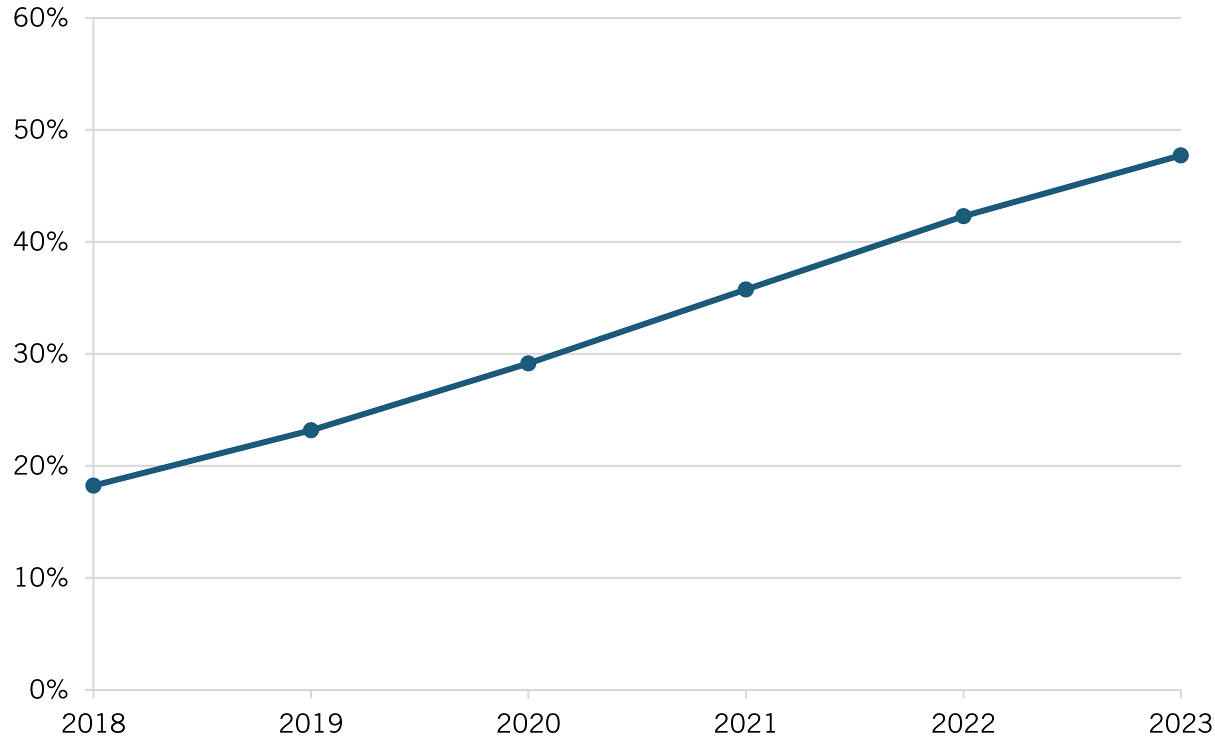


Figure 13 shows the number of top 100 global universities in China relative to the United States from 2013 to 2023. In 2013 through 2015, China had no universities in the top 100 of the Academic Ranking of World Universities, a list published by the Center for World-Class Universities, while the United States had over 50 each year. By 2023, China had increased its number of top universities to 11, 29 percent of the 38 universities the United States had in the top 100.

Figure 13: Number of top 100 universities in China relative to the United States[71]

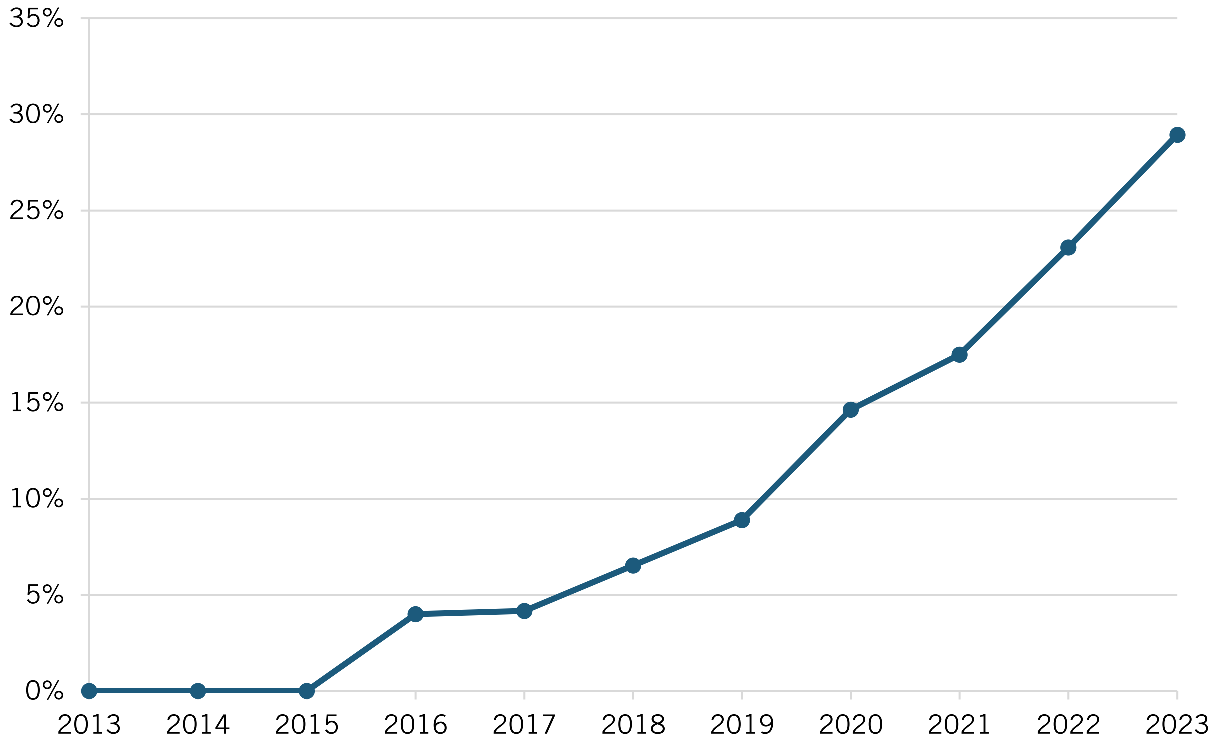


Figure 14 shows the change in gross VC investment in China relative to the United States from 2015 to 2023. Over this period, VC in both countries saw a relative decrease. In 2015, China saw about $53.2 billion in VC investment, 20 percent more than the $43 billion invested in the United States. The difference in VC investment between China and the United States hit its peak in 2018, when China received $123.5 billion. The United States fundraised just $71 billion that same year. After 2018, China faltered in VC investment, losing a substantial amount of fundraising in the several years following. As of 2023, the two countries each raised about $27 billion in VC fundraising.

Figure 14: Gross VC investment in China relative to the United States[72]

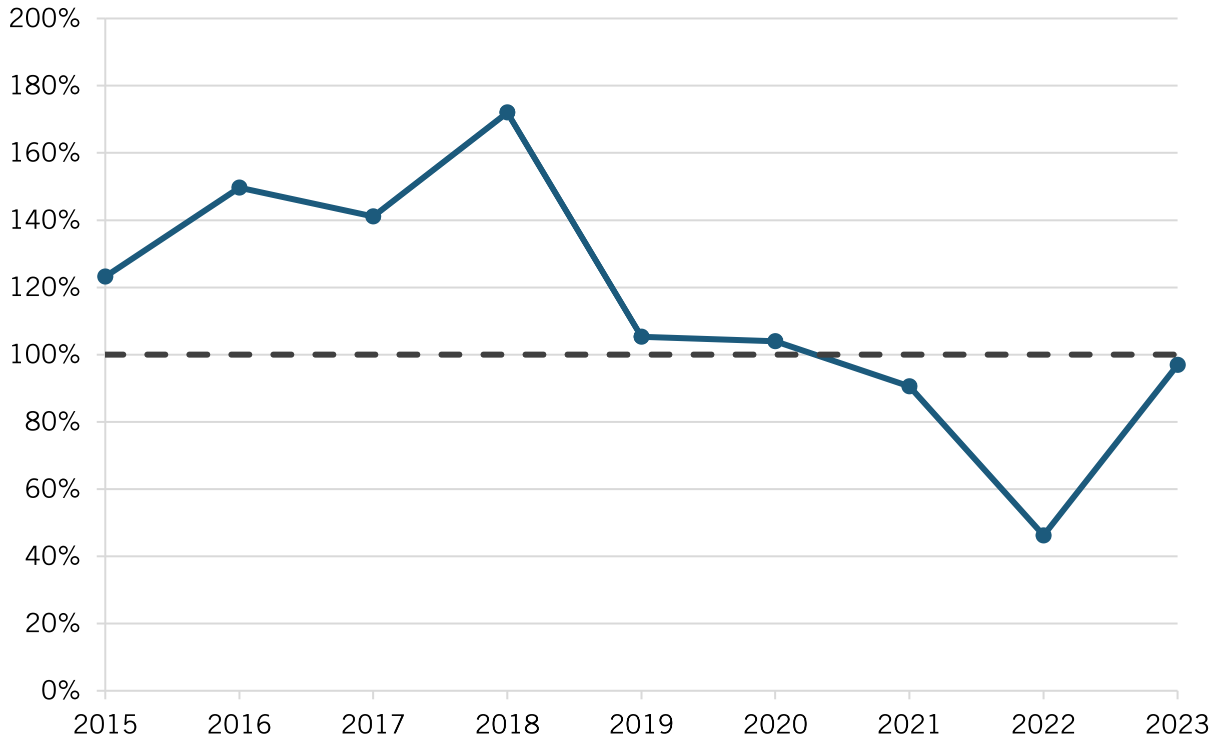
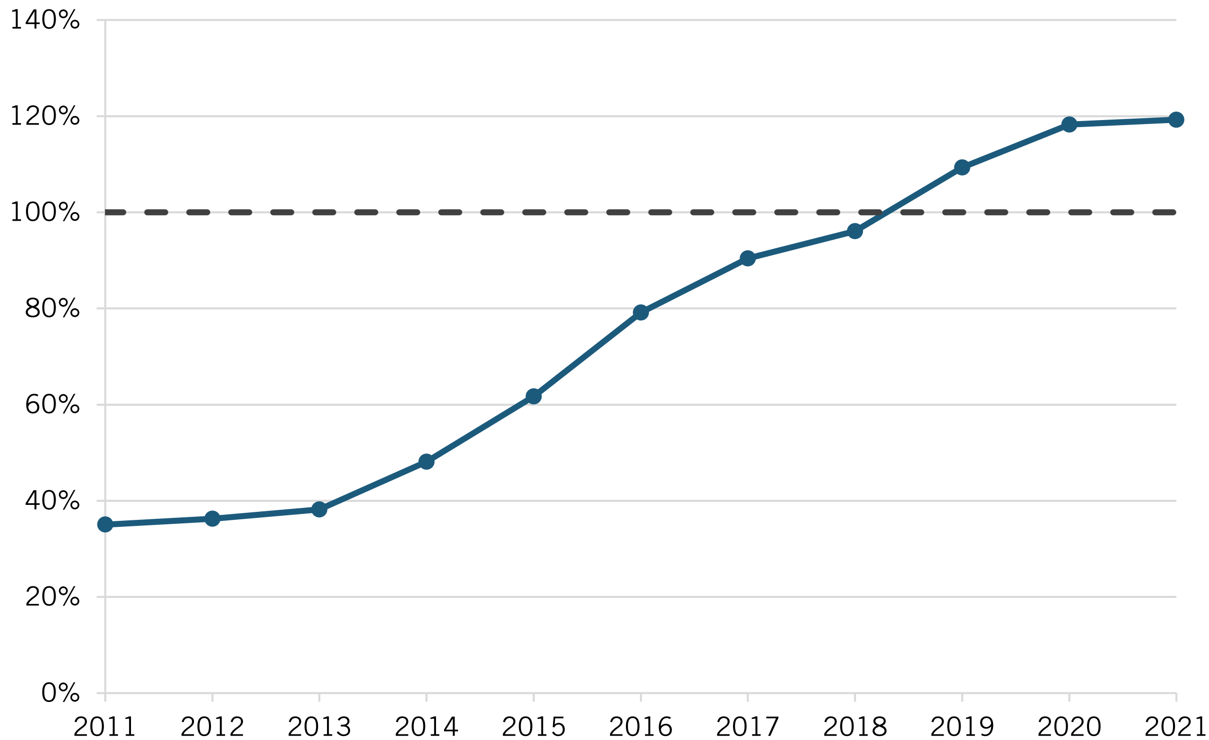


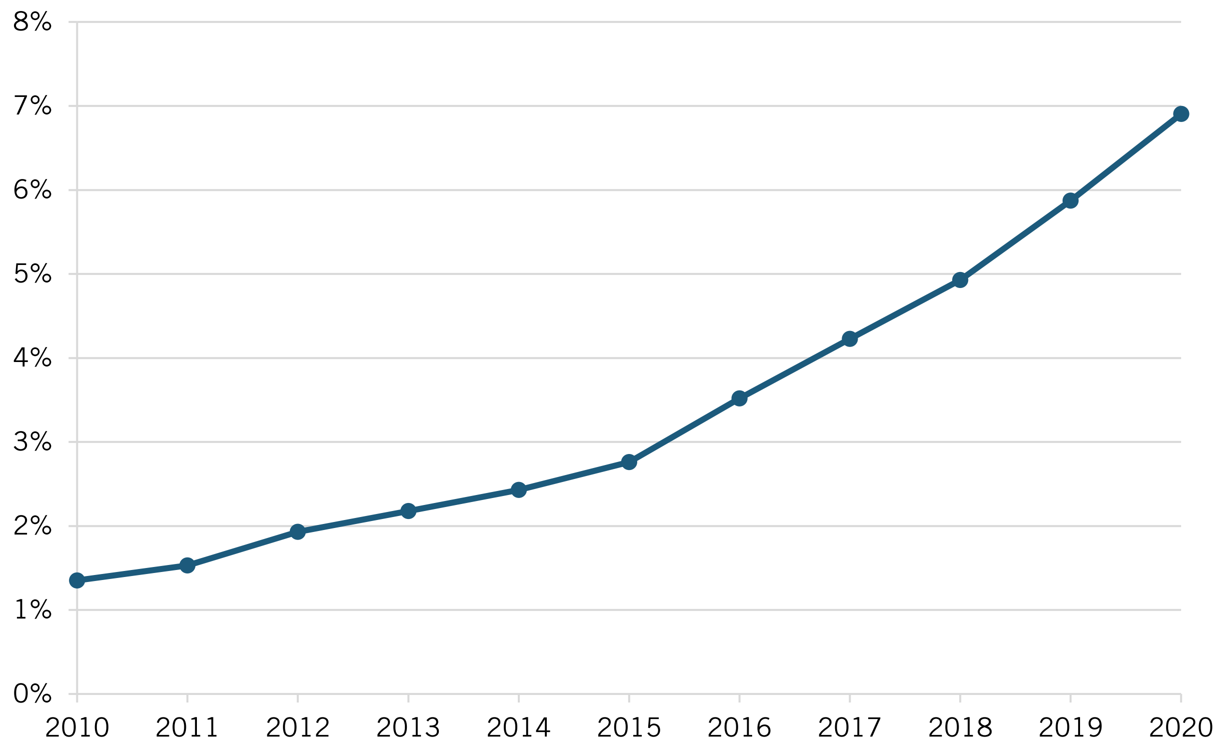
Figure 15 shows the number of Patent Cooperation Treaty (PCT) patent applications for China relative to the number of applications in the United States. From 2011 to 2021, China surpassed the United States, represented by the dashed line, in patent applications. In 2011, Chinese filers applied for just over 17,000 patent applications, only 35 percent of the 49,000 applications from the United States. Over the next decade, both countries increased their patent output; however, China did so faster. In 2019, China officially produced more patents than the United States did for the first time in history, and by 2021, China had produced over 67,000 patent applications per year, 19 percent more than the 56,467 patent applications produced in the United States.

Figure 15: Number of PCT patent applications for China relative to the United States[73]



China has been known to publish a significant number of false or dubious patents, making the number of sheer patent applications misleading. Instead, looking at the number of patents granted by the United States Patent and Trademark Office (USPTO) can provide a more truthful estimate of the number of legitimate patents published by China. Figure 16 shows the share of patent grants awarded by the USPTO to Chinese firms from 2010 to 2020. In 2010, China was granted just 3,303 patents, less than 1 percent of all patents awarded in the United States that year. Yet, by 2020, China's patent grants in the United States increased to almost 27,000, 7 percent of all grants. China had the third-most patents granted by USPTO in 2020, behind only the United States and Japan—evidence that, despite some questionable patents, China is publishing many quality patents.

Figure 16: Share of patent grants awarded to Chinese firms by USPTO[74]



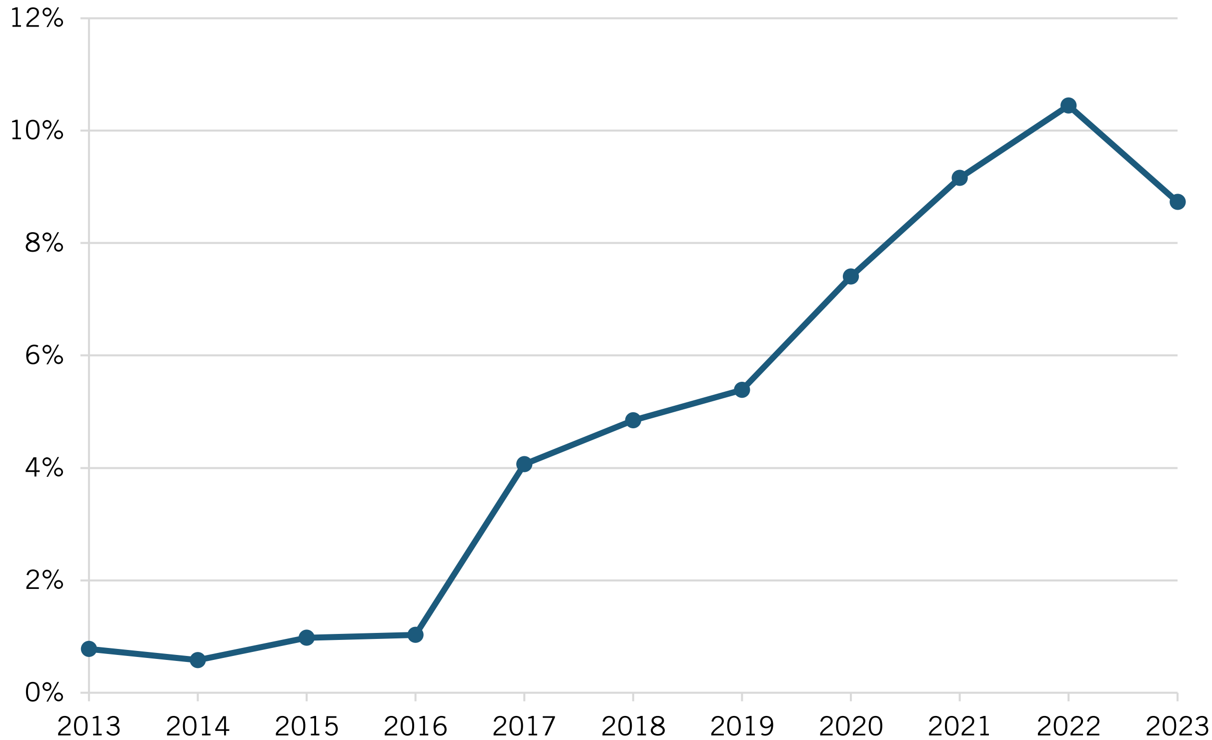
China had the third-most patents granted by USPTO in 2020, behind only the United States and Japan—evidence that, despite some questionable patents, China is publishing many quality patents.

Another study of patenting by Bergeaud and Verluise finds that China's contribution to frontier technology had become quantitatively similar to U.S. levels in the late 2010s while overcoming the European and Japanese contributions, respectively. Although in some ways China still exhibits the hallmarks of a catching-up economy, that veneer has quickly faded. The quality of frontier technology patents published at the Chinese Patent Office has leveled up to the quality of patents published at the European and Japanese patent offices. At the same time, frontier technology patenting at the Chinese Patent Office seems to be increasingly supported by domestic patentees, suggesting the buildup of domestic capabilities.[75]

Another study of Chinese patenting finds that, in the last decade, Chinese patents have become less dependent on foreign knowledge and technology, and the importance of Chinese patents relative to USPTO patents has steadily increased over the last two decades. Moreover, Chinese and foreign patenting have become more similar in terms of specialization across technology classes, suggesting that China is now innovating in areas similar to the global leaders.[76]

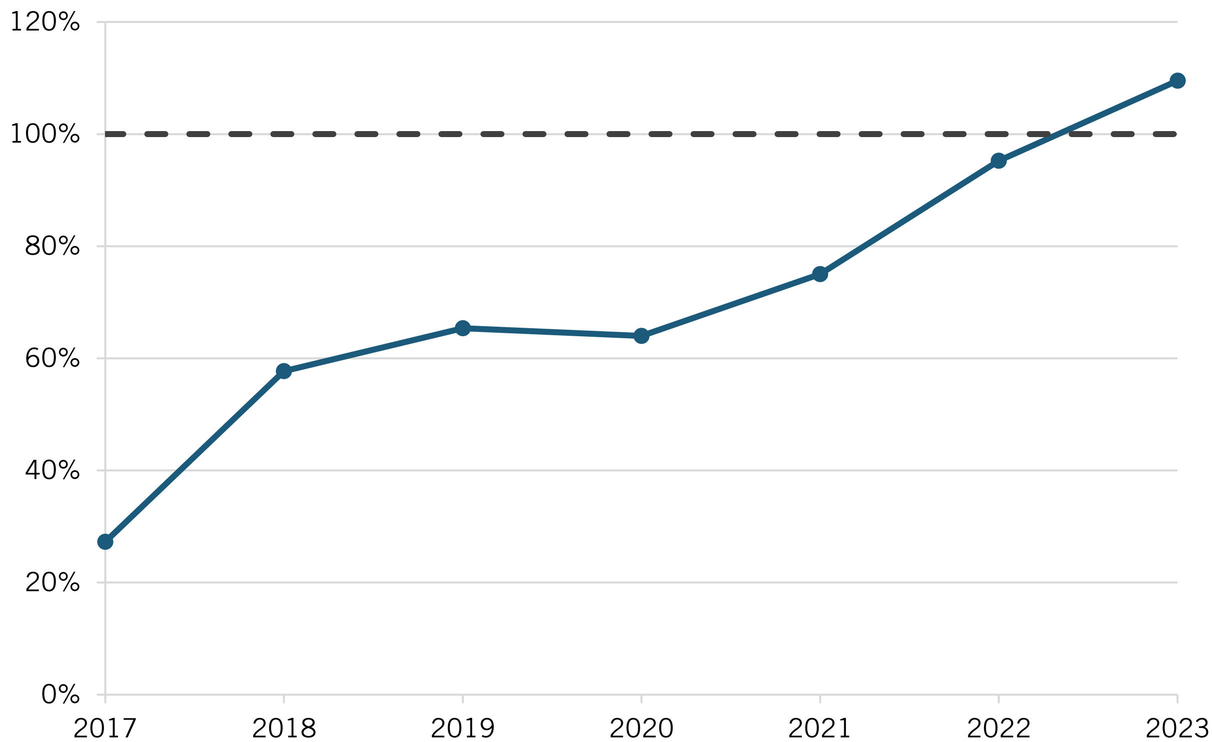
Figure 17 shows the value of IP licensing receipts in China relative to the United States from 2013 to 2023. Over this period, the value of IP licensing receipts in China increased relative to that of the United States. In 2013, IP receipts in China were valued at less than 1 percent of the value in the United States. Yet, by 2023, this value had increased to 9 percent, with a peak of 10 percent in 2022. The United States still maintains a significant lead in the value of IP licensing receipts; however, China has made gains over the past decade.

Figure 17: Value of IP licensing receipts by China relative to the United States[77]



Since 2017, WIPO has produced an annual report ranking the top 100 science and technology clusters, or "local concentrations of world-leading science and technology activity." These clusters are hubs of innovation, with high rates of patent applications, scientific and technical article publication, and great densities of large firms with high rates of R&D investment. Figure 18 shows the number of these hubs that were located in China relative to the United States between 2017 to 2023. Over this time, China rapidly increased its number of clusters, from just six in 2017 to 23 in 2023. At the same time, the United States, represented by the dashed line, stayed relatively stagnant in its number of clusters, with 22 clusters in 2017 and 21 clusters in 2023. As of 2023, China had two more scientific clusters in the global top 100 than the United States did.

Figure 18: Number of WIPO global innovation clusters in China relative to the United States[78]



Unicorns are private start-up companies that have a value of over $1 billion. As of April 2024, there were 1,453 unicorn companies, with many concentrated in the science and technology sector. Figure 19 shows the share of unicorns concentrated in the United States and in China. The United States accounts for most of the world's unicorns at 48 percent, while China holds 23 percent.

Figure 19: Unicorns in the United States and China as a share of total unicorns in 2024[79]

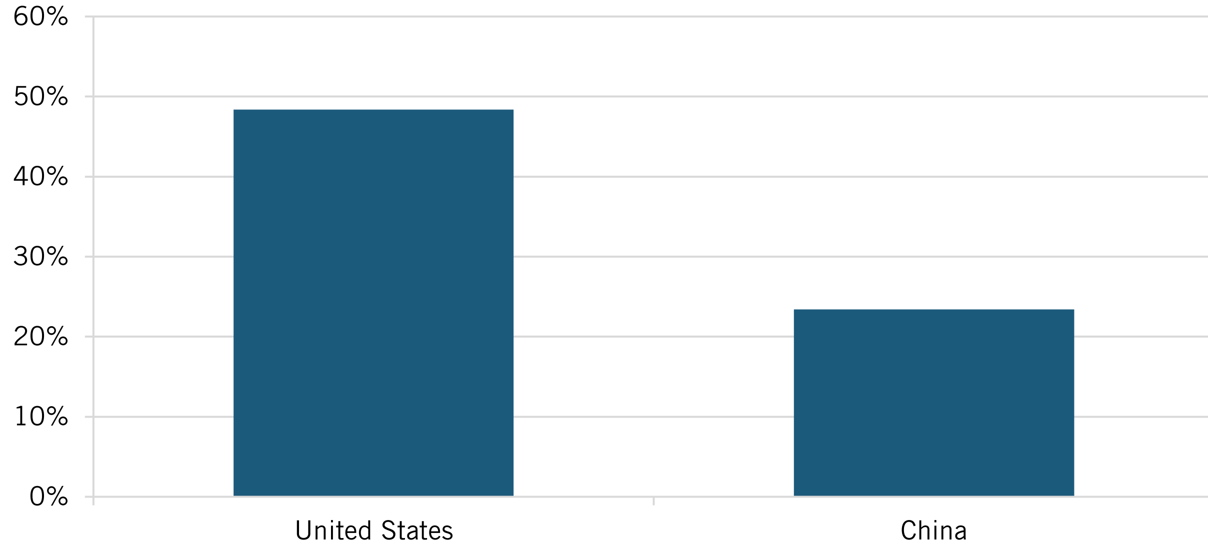
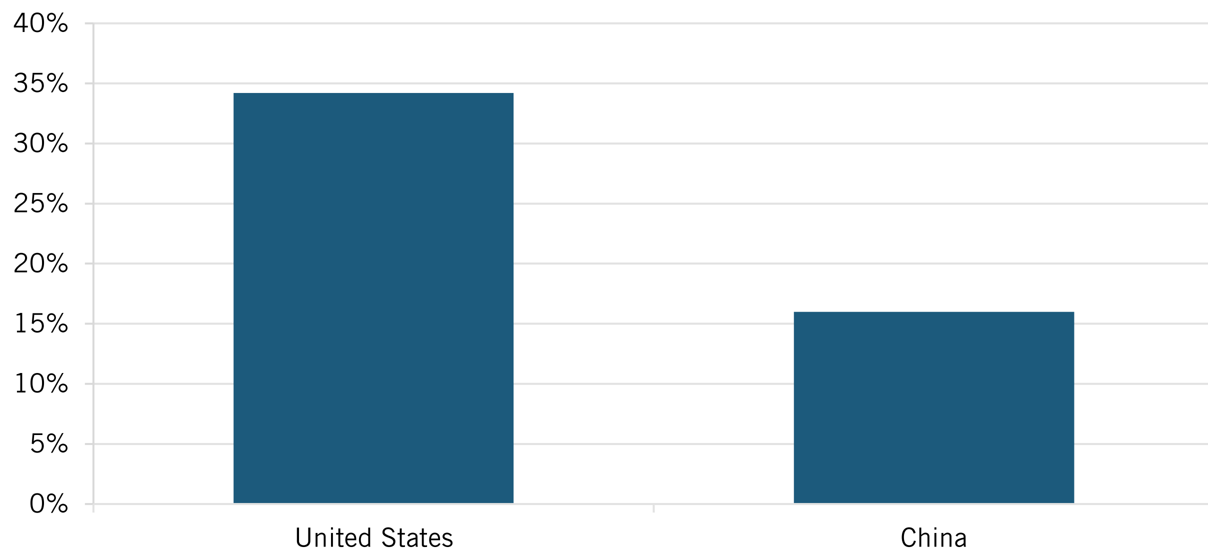


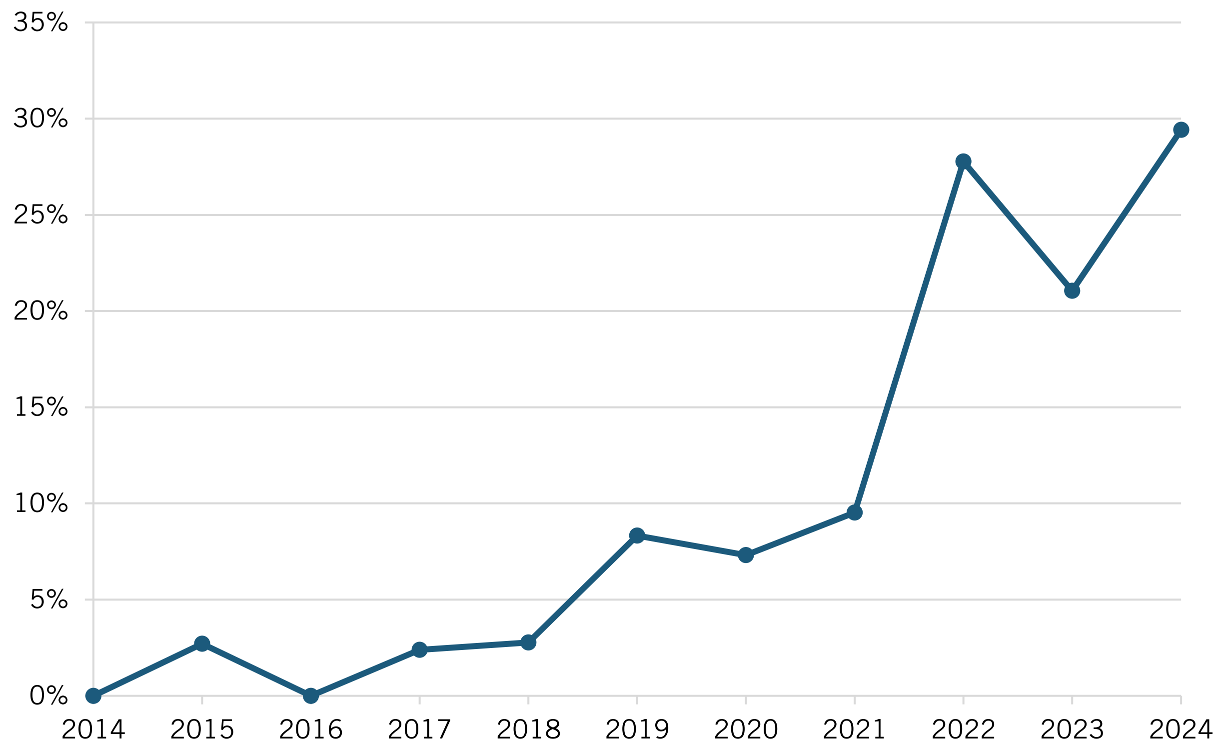
Figure 20 depicts the number of supercomputers located in China and the United States as a share of the top 500 supercomputers in the world. In 2024, the United States housed 171 of the top 500 supercomputers, or 34 percent of the most-powerful supercomputers in the world. China, on the other hand, held just 80 supercomputers, or 16 percent of the top 500 supercomputers in the world.

Figure 20: Share of supercomputers in the top 500 in China and the United States in 2024[80]



Clarivate also produces an annual list of the world's top 100 innovators, including companies and research institutions that produce research and innovation with the most significant interindustry impact. Figure 21 shows the number of these companies located in China relative to the United States from 2014 to 2024. In 2014, 46 of the top 100 innovators were located in the United States, while zero were in China. Over the decade, China has increased the number of companies labeled as top innovators, with five firms making the Clarivate list in 2024. The United States, on the other hand, has seen a substantial number of firms fall from the list. As of 2024, 5 Chinese firms made Clarivate's list of top innovators, 29 percent of the 17 U.S. firms that also received the title.

Figure 21: Number of top 100 innovators in China relative to the United States[81]



Other data sources paint a similar picture. Since 2017, China has exhibited the largest growth in innovation capacity in the world, according to the European Innovation Scorecard, a report prepared by the EU assessing international innovation using criteria such as international investment, R&D expenditures, and business activities. Over the past seven years, there has been a 28.2 percent increase in China's innovativeness, earning it the label of a "global moderate innovator." Other world leaders experienced much more constrained growth, such as the EU and South Korea, which both improved by 10 percent. China has shown significant growth in the areas of R&D expenditure in the business sector, trademark applications, and highly cited scientific and technical articles. In these three categories, China is substantially more innovative than the EU.[82]

The Australian Strategic Policy Institute's (ASPI) Critical Technology Tracker also found that China has become the leader in almost all the critical technologies the tracker covers. The tracker focuses on how innovative countries are in foundational technologies such as energy, the environment, defense, nuclear, quantum computing, and many other critical industries.

Innovativeness is assessed using the top 10 percent of the most highly cited research publications in those industries from the past 21 years. In the most recent report, China leads in 57 out of the 64 critical technologies from 2019 to 2023, up from just 3 out of 64 from 2003 to 2007. Comparatively, the United States, which led in 60 technologies between 2003 to 2007, now leads in just 7. China is also now viewed as "high-risk" for holding a monopoly in research for 24 of the technologies in which it leads.[83]

China has also generally made progress on WIPO's Global Innovation Index. (See table 2.)

Table 2: China's scores on select factors from the Global Innovation Index[84]

Indicator	2017	2023
R&D	17	15
Knowledge workers	1	12
Innovation linkages	62	27
Knowledge absorption	13	14
Knowledge creation	5	3
Intangible assets	2	1
Creative goods and services	29	28

Select Cases

Anecdotes do not make data, but they can tell an interesting story. The following are select cases gleaned from news reports of Chinese innovations.

China has developed a staff-less hotel wherein the guests check in and use elevators based on facial recognition.[85] It has built the world's largest and tallest pig farming facility that is highly automated. It has developed and deployed the world's largest sodium battery unit capable of powering 12,000 homes.[86] It has landed a craft on the dark side of the moon and returned samples.[87] China has developed an innovative stealth fighter that also deploys drones.[88] Chinese scientists have reportedly come up with a new steel that is ultra tough, yet stretchable.[89] It has launched a satellite with a high-power electric drive.[90] Chinese scientists have developed an innovative solar panel technology involving up-conversion of infrared photons.[91] A Chinese company has built and shipped one of the largest tunnel boring machines.[92] China recently set the world record for the fastest hyperloop train.[93] Reportedly, China has developed plasma technology enabling radar invisibility of military aircraft.[94] A Chinese government research institute reports developing a prototype for a thermoacoustic Stirling generator, something NASA has a patent on but has not yet been developed in the United States.[95] Chinese scientists have apparently developed a revolutionary aircraft engine that can propel a plane to 20,000 km/hr.[96]

A government-backed consortium of 40 universities has deployed a 1.2 terabit-per-second network, the fastest in the world, and purportedly is two years ahead of the other nations working on the technology.[97] The Shenzhen library has a fully automated book return system that operates without human intervention.[98] A Chinese research team has developed a high-performance aqueous zinc-ion battery with an ultralong-cycle lifespan in a weak magnetic field.[99] China has tested a maglev train—a train suspended above its tracks via a magnetic field—that operates at speeds of 281 miles per hour.[100] Reportedly, China has developed a fully automated cruise missile production line.[101] In 2024, a Chinese physicist became the first Chinese researcher to win the top U.S. physics prize.[102]

China's lunar probe was sent to the moon in June 2024 and returned to Earth carrying samples.[103]

China has developed a robot that can play piano, a complex technological task.[104] It built and operates the largest and most highly automated seaport in the world.[105] It has made major breakthroughs in fusion energy.[106] Just recently, it made significant independent breakthroughs on chip technology.[107] A Chinese firm is the first to sell recyclable wind turbine blades.[108] It has launched satellites with a powerful electric engine.[109] It has launched robots on satellites that have the ability to hack apart other nations' satellites in space. Chinese scientists have developed lightweight strong steel that is stretchable.[110]

Thanks to government support after designating it a priority industry, China became the world's largest automobile producer in 2009 and is now also the world's largest producer and exporter of EVs.[111] China landed the first probe on the dark side of the moon in 2019. It began launching the components of its Tiangong space station in 2021, and current NASA administrator Bill Nelson recently stated that China may land astronauts on the moon before the United States is itself able to return.[112] China has recently added to the pantheon of tech giants by producing companies such as Alibaba, Baidu, Huawei, and Tencent, and 8 of the 10 fastest companies to reach a one-billion-dollar valuation are Chinese.[113] China is challenging the United States in supercomputers, although the true extent of China's supercomputing capabilities is now unknown because the Chinese government wants to "hide its light" regarding its capabilities.[114]

An additional example of Chinese frontier innovativeness, notably in an area in which China transitioned from a copier to a leader, is high-speed rail. China first developed its high-speed rail network with the help of imports and technology transfers from European and Japanese companies. It opened its first railway—between Beijing and Tianjin—in the summer of 2008 in time to show it off to the world as it hosted that year's Summer Olympics. Since then, China's high-speed rail network has ballooned and is by far the largest in the world with over 23,500 miles of rail.[115] It has also developed the world's fastest autonomous train, capable of speeds up to 217 miles per hour, and one of China's rail producing SOEs, CRRC, has become the world's largest producer of railway vehicles and related technologies. China has recently developed a prototype for a maglev train that it claims is capable of speeds up to 385 miles per hour.[116]

Striking Factoids About Innovation in Key Chinese Industries

- China installed more industrial robots than rest of the world combined in 2023.
- In 2013, the U.S. share of global chemicals industry R&D spending was 30 percent, while China's was 1 percent. By 2022, Chinese chemical companies grew to 16.8 percent, with the U.S. share falling to 18.6 percent.
- China has more nuclear power plants under constuction than the rest of the world combined.
- China will add more chipmaking capacity than the rest of the world combined in 2024, with 1 million more wafers a month than in 2023.
- In 2024, China will account for 62 percent of global EV production.
- Chinese clinical trials grew 146 percent from 1,040 in 2017 to 2,564 in 2021, the highest for any country.

Firm Analysis

To answer the question about China's innovative capabilities, one key is to focus on Chinese company capabilities and performance.

From 679 Chinese firms listed on the EU R&D 2,500 list, we randomly selected 44 firms for deeper analysis. Few were at the global leading edge of innovation, although most appeared to be catching up to the leaders and making rapid progress. On a scale of 1 to 10, where 1 is completely a copier with no real original innovation and 10 means the firm is moderately to significantly ahead of the global leading edge of innovation, the mean score was 6: lagging, perhaps 2 years behind, with some original innovation. The highest-ranking firms were Chinese National Nuclear Power (score of 9), drone maker DJI (8.75), QuantumCTek (8.25), EV maker BYD (8), and AI company Zhipu (8).

Industry Analyses

We relied largely on case study approaches for each industry and supplemented a review of literature and company and analyst reports with roundtable interviews with key experts. Because we sought openness and frankness in the discussion, the participants were anonymous. We also included several in-depth company analysis reports in these industry studies, as well as examined relevant data, such as patents and scholarly research citations. We did not interview Chinese experts, in part because we wanted to ensure objectivity.

There are a number of limitations to this overall approach. First, Chinese companies may overstate their level of innovation in order to improve their reputation with shareholders and the CCP. Other companies may do the opposite, hiding their innovative performance for national security reasons. Second, non-Chinese individuals will by definition have less insight into what is actually happening in China than Chinese citizens working in these institutions. But given the overall limitations, we believe that this research framework can provide usable insights into the question of whether China is innovative.

All but machine tools were published separately as full reports. Table 3 provides an overall summary. Of the 10 industries, we assessed that China is ahead or at par in two, near the lead in four, and lagging behind in four. With the exception of semiconductors, where progress has been somewhat frustrated by export controls on equipment, and quantum, China's rate of progress is striking.

Table 3: Summary of industry studies' results

Industry	Position vs. World Leaders	Pace of Progress
Robotics	Near	Rapid
Chemicals	Lagging	Rapid
Nuclear Power	Ahead	Rapid
Electric Vehicles/Batteries	At Par	Rapid
Machine Tools	Lagging	Rapid
Biopharmaceuticals	Lagging	Rapid
Semiconductors	Lagging	Modest
Artificial Intelligence	Near	Rapid
Quantum	Near	Modest
Display Technology	Near	Rapid

Robotics

While the United States invented robotics, it is now an also-ran, at least in production, with the leading robotics companies located in the engineering powerhouses of Germany, Japan, and Switzerland. However, by volume, both of production and use, China leads the world. And China has significant cost advantages.

The enormous and rapidly growing demand for robotics in China means that most of the major Western robot manufacturers have set up production operations there, that existing Chinese companies have expanded, and that many new start-ups have been created.

In Shanghai, American ABB and Japan's Fanuc have built the largest robot production factories in the world, with facilities even more advanced than what Fanuc has in Japan. Japan's Yaskawa Electric Corporation has built three factories in China that can produce 18,000 units of robots annually. And if recent history is any guide, China is using this foreign investment to capture knowledge and force technology transfer to Chinese robot makers. Even when foreign investors put tight controls on IP theft, there will still be spillover effects in terms of industrial knowledge that will help Chinese firms close the innovation gap.[117]

China has many domestic robotics companies, such as Geek Robotics, Hikvision, and Blue Sword (robots for China's military). In fact, since 2017, there have been over 3,400 robotics start-ups in China, not just industrial robots, but also autonomous mobile robots (AMRs). This was part of China's "100 Million Robot Program." Moreover, China has made very rapid progress in the development of robotics companies in the last year. For example, Tracxn lists 188 Chinese robotics start-ups.[118] Of the top 10, 8 have venture investors from outside China, indicating their innovative potential.[119]

Many of these start-ups are from Songshan Lake, an industrial development zone south of Dongguan China that has hundreds of robotics companies, both start-ups and established.[120] While some of this may be hype, one Hong Kong professor stated that "people here [at Dongguan] can develop a new tech product 5 to 10 times faster than in Silicon Valley or Europe, at one-fifth or one-fourth the cost."[121]

Notwithstanding this growing domestic production, China is still the largest importer of industrial robots, which suggests that it is still relying heavily on foreign technologies.[122] In 2019, 71 percent of new robots in China were sourced from overseas, including from Japan, South Korea, Europe, and the United States. Core components are dominated by Japanese and other firms.[123] For example, Chinese firms hold just 25 percent of market for harmonic gear reducers. Indeed, China is dependent on many imported components. As one Chinese analyst stated, "The value of imported parts is still very high in the robots exported by China."[124] In 2022, China exported just 36 percent of the value of robotics that it imported.[125] Another study looks at three key upstream systems going into industrial robots: robot gear reducers, robot controllers, and robot servo systems.[126] These three key inputs account for almost 70 percent of production costs of industrial robots. In 2020, these were predominantly made by foreign companies, particularly from Japan, Germany, and Switzerland. The study suggests that most of China's industrial robot firms are system integrators, performing lower value-added work.

However, China lags behind in at least two areas. The first is software. A differentiator of robot quality and versatility, about 80 percent of the value of today's robotics is the software. And China still lags behind in industrial software capabilities. As one expert noted, "We see a lot of copycat hardware, but most of what differentiates vehicle warehouse robots, especially in terms of throughput capacity, is driven by the software capabilities, and China is behind there." The second is integrated systems development and robotics as a service as a business model, in which Chinese companies are weaker than Western ones.

Moreover, many Chinese robotics companies are copiers. One expert reported that Japanese robot producer Fanuc found its foundry cast mark on a Chinese competitor's robot. As another example, after Boston Robotics developed its dog-like walkable robot, several years later, Chinese companies copied it.

While Chinese robots generally do not match the quality of the best Western companies, they usually have a price advantage—and for many companies, particularly those not in high-income countries, such a cost-quality tradeoff is one worth making. For these customers, which are less demanding, the low price is attractive. As one expert told us, many Chinese robots are 80 percent as good as the best foreign ones but are much cheaper. This price point drives sales. According to Dr. Anwar Majeed, associate professor at the School of Robotics at XJTLU Entrepreneur College, "It is worth noting that its products are estimated to be 30 percent cheaper than their European and Japanese counterparts, allowing them to be more attractive to rising economies."[127] For example, Chinese firm Humanoid's price point is around $90,000, five times less than that of Western firms. As one article states, Chinese robot producers are currently competing on cost.[128] Indeed, the strategy appears to be to trade quality for price in order to achieve scale. Gain sales at the low and medium end of the market (from the leading players) and then reinvest (along with help from the government) in higher-end, more-innovative offerings.

China is, however, innovating in particular markets. For example, experts have argued that Chinese firms such as Geek and HAI are innovators in the materials handling space. Leader Drive is strong in components. Unitree is a robotics start-up moving fast to close to the gap. Its robots, such as BD, are not quite as good, but they are much cheaper, so they are adopted by universities and other organizations that do not need a high level of quality. China is also making progress in emerging areas of robotics, especially humanoid robots. China's Ministry of Industry and Information Technology (MIIT) has announced plans to dominate this by 2027 and is providing significant state funding to companies for this purpose.[129] Indeed, leaders say it has a plan to mass-produce humanoid robots that can "reshape the world" within two years.[130]

China has also used foreign acquisition to gain capabilities. Most notably, in 2016, Midea Group announced its acquisition of German robot maker KUKA.[131] Likewise, Effort bought or invested in three robotics companies in Italy: Evolut, Robox, and W.F.C Group.[132] Chinese industrial robot maker Estun acquired or invested in several foreign robot companies, including BARRETT (a U.S. exoskeleton drive system company) and fMAi (Germany), while partnering with a leading European robot producer, CLOOS.[133]

Information robot at the Shenzhen Bao'an International Airport in Shenzhen, China[134]

On the whole, it appears that China and Chinese robotic companies recognize that they need to pivot away from being fast followers and copiers to being innovators. One way they are doing this is by focusing on many projects that are cutting edge. Moreover, the government is forcing robotics researchers at universities to rub shoulders with companies. As such, while China is still largely a follower in robotics, it is becoming a fast follower.

However, China has followed this path in other technologies to become innovation leaders. A case in point is DJI, the world's leading drone maker. DJI dominated drones by throwing thousands of engineers and conducting R&D and manufacturing at a scale well beyond anything any other company was doing elsewhere. Similarly, as one study of Chinese robotics argues:

> Upgrading trajectory of industrial robots … is similar to the development of the mobile phone sector in China: at first, the domestic firms provided slightly lower quality but much cheaper alternatives to foreign produced high-end phones; and later on, when the domestic firms accumulated enough resources, they could make significant technological breakthroughs and become internationally competitive.[135]

As such, there are different views of China's innovative capabilities. One expert told ITIF that because of this fast progress, "China is at least on-par, and possibly ahead, of the United States and Europe in robotics. China's firms are strong on the hardware side of robots, especially for automotive."

One participant stated that "the Chinese companies are innovators in the materials handling space. They've launched products we haven't in the United States. HAI Robotics would be a good example. But it appears the domestic Chinese firms are getting the most penetration in the second- and third-tier markets, at least on the autonomous mobile robots and robots for retail applications."

However, another expert told us that in the field of AMRs, "China is deploying a fast follower strategy, but they are rapidly catching up. Right now, their robots aren't as good as ours, but are much cheaper, so are being adopted by educational institutions or the less serious commercial customers. But that gap is closing."

Another expert said that "China will be able to close the gap, just a question of how long it takes."

Overall, one reflection of how China is not leading in terms of innovation (and quality) is the fact that foreign firms probably account for 75 percent of the Chinese robotic market today, with domestic firms accounting for about 25 percent. Core components are dominated by Japanese firms, but Chinese firms are making quite rapid progress.

One reason is the Chinese central government has made global leadership in robotics development, production, and use a top priority—a top industrial priority. China understands that it is behind in robotics and still runs a trade deficit, which is why it has set a goal of moving into higher-end robotics, including humanoid robots, robots to replace workers in dangerous conditions, and high-precision industrial robots. The government has also set national goals for the use of robotics, laying out 11 key areas where it would like more robotic innovation and adoption, including in health care, education, and energy.[136]

Chemicals

For a long time, China was content to produce commodity chemicals with little focus on either process or product innovation. However, after "Made in China 2025," China has focused more on new chemicals for new applications, including in batteries, semiconductors, and solar panels, with strong government support. As professor Seamus Grimes wrote, China's rapid growth in its chemical industry "has increased China's ambition to become a world leader in the chemical industry through innovation and trade and through growing its market share internationally."[137]

Foreign companies still dominate many key areas, but their IP has been eroded over time. Multinationals continue to dominate key parts of the value chain, especially related to high tech and more specialty chemicals. However, the consensus among experts ITIF spoke with is that Chinese companies are beginning to erode the market share of large foreign companies. Part of this has stemmed from Western-company complacency and assumptions that Chinese companies cannot challenge them, and also because of strong Chinese government incentives and support for Chinese chemical companies. And relatively lax chemical industry production regulations help provide China with a competitive advantage.

Moreover, unlike biotechnology or software, chemicals is a relatively mature industry with overall rates of innovation lower than more-advanced, innovation-based industries. There are approximately 300,000 chemicals available, but only around 2,000 or so new chemicals are developed each year, a rate of around just 6 percent.[138] This means that, as a slow-innovation industry, it should be easier for China to catch up to the leaders.

In basic chemicals, China is increasing its position as a net exporter. In very few commodity chemical products is China a net importer. For example, China has overcapacity for polypropylene; however, China runs a trade deficit in specialty chemicals. As a result, China's MIIT is focused on boosting China's capabilities in specialty chemicals, as this will determine global chemical industry leadership. In contrast, the EU-27 runs a trade deficit in basic inorganics and petrochemicals but a trade surplus in specialty chemicals and consumer chemicals.[139]

One advantage for China is that the chemical sector is connected to specific sectors, such as automobiles, electronics, renewable energy, etc. Because Chinese production in many of these products is so large and growing so fast, local chemical companies have an advantage by being close to their customers. Seamus Grimes noted that "a number of R&D managers acknowledged that more recently their innovation in China was being driven by innovative Chinese customers."[140] In addition, because of China's significant coal reserves and a willingness to keep burning coal, China is leading in coal-derived chemicals.

However, China is highly dependent on other countries for high-quality chemical products, high-end equipment in the chemical industry, and leading technology. For example, MIIT stated in 2018 that 32 percent of 130 basic chemicals could not yet be produced in China at all, and more than half of all fine chemical products would still have to be imported.[141]

One way China has closed the gap with world leaders, especially in commodity chemicals, is by relying on foreign producers investing in China, a model it has used in multiple industries. For example, of the top 10 coatings companies in China, 4 are local and 6 are foreign. Moreover, by one estimate, about one-third to half of the top executives at Chinese chemical companies have had significant experience at multinationals. This skill base clearly helps Chinese companies catch up.

Experts also pointed to the fact that domestic companies usually have significant price advantages, in part because some are state-owned and don't have to earn as high a profit as the foreign companies and because multinationals have higher global overhead costs. And many Chinese-owned chemical companies receive government subsidies.

Experts also argued that Western companies are more goal oriented and short term in their orientation. They have specific procedures and slower decision-making models. Chinese companies, in part because they are trying so hard to catch up and because of the encouragement of the state, are more aggressive. For example, if a European chemical company is doing well in China, it may eventually decide to increase capacity by 20 percent. In contrast, a corresponding Chinese company is likely to quickly agree to double its capacity to gain market share. Even when times are not good, many Chinese firms will increase capacity, just as they have done in other industries such as solar and steel. And like in steel and solar, this creates overcapacity. Once this happens, some foreign firms divest to private equity because they see it as a cash-cow business that no longer meets their financial hurdles. Indeed, China has killed or shrunk a number of overseas companies through a superior cost position and economies of scale. Chinese companies are not as deterred by short- to medium-term earnings setbacks.

For foreign companies that stay in the business, they are doing more R&D in China, which will spill over to domestic Chinese companies. Originally, multinational chemical companies did not perform a lot of R&D in China. But now with some of their most important customers in China, more are expanding their R&D spending there. One reason is that of the top 10 metropolitan areas in the world to locate chemical industry R&D facilities ranked in terms of quality of the research, 3 were Chinese (Guangzhou, #1, Shanghai #3, and Beijing #6).[142] Strikingly, no Chinese metro made the top 10 in terms of cost of operating an R&D facility.

China is also investing significant amounts in chemical research capabilities in universities, which has paid off in terms of the number of academic papers. In fact, China has overtaken the United States as the main source of academic papers in the field. However, experts argue that limits on the number of skilled domestic Chinese R&D leadership personnel holds back innovation.

There was a consensus among experts ITIF spoke with that China will, over time, eventually come to dominate the global chemical industry and, absent significant market closures by Western nations, there is little that can be done about it.

In many areas, such as the lithium battery chemistry, initial advances were made in the United States. But U.S. companies haven't followed up on them and instead Chinese firms have innovated ways to manufacture these batteries and materials at scale and lower cost. And, as in solar panels, China has shown an effectiveness at process innovation.

China may be able to make significant strides in innovation with the industry currently facing a global inflection point as it goes through a "greening" process. The Chinese government is focused on helping firms develop chemicals that meet green requirements and are more environmentally friendly. This includes coating materials for transportation equipment, biodegradable materials, and materials in batteries.

Finally, China historically has been a copier of process technology. However, as one article states, "For the past two decades, China has invested heavily in R&D. The research was initially aimed at developing new products, but process development has more recently turned into a major focus."[143] The article goes on to state that "foreign chemical companies start to see China as a source of manufacturing expertise."[144]

A good summary of the Chinese position and trends comes from Chinese chemical industry expert Kai Pflug, who wrote:

> In the past, Chinese pressure on the Western chemical industry came from below—China captured more and more of the market segments with limited innovation and complexity. What is new about the current wave of Chinese domestic investments in chemicals is that these now target precisely the chemical segments that are the most innovative, which tend to also be the fastest growing ones. So far, Western chemical companies survived by out-innovating the Chinese—the latest developments show that this approach is far from certain to work in the future. In a worst-case scenario, this would only leave Western companies with smaller-volume chemicals, in which the scale-oriented Chinese players typically are less interested.[145]

China has long and successfully sought to grow its chemical industry. That success has been mostly in basic, commodity chemicals. However, it is now seeking to achieve the same success in more innovation-based specialty chemicals, with the central government targeting chemical innovation. The 2023 "Guiding Catalog for Industrial Structure Adjustment" advocates for the development of a number of new materials related to the chemical industry, including low-VOC (volatile organic compound) adhesives, water treatment agents, catalysts, electronic chemicals, silicone materials, and fluorine materials.[146] The Chinese government provides significant direct and indirect subsidies to chemical firms.[147] In addition, it is upgrading chemical parks. Under this plan, 10 or so leading companies are to be "cultivated" as "national champions." In addition, as noted, Chinese governments provide a range of financial incentives, including low-interest loans. The government has also set a goal that the share of fine chemicals in total chemical production in China is to be at least 50 percent.

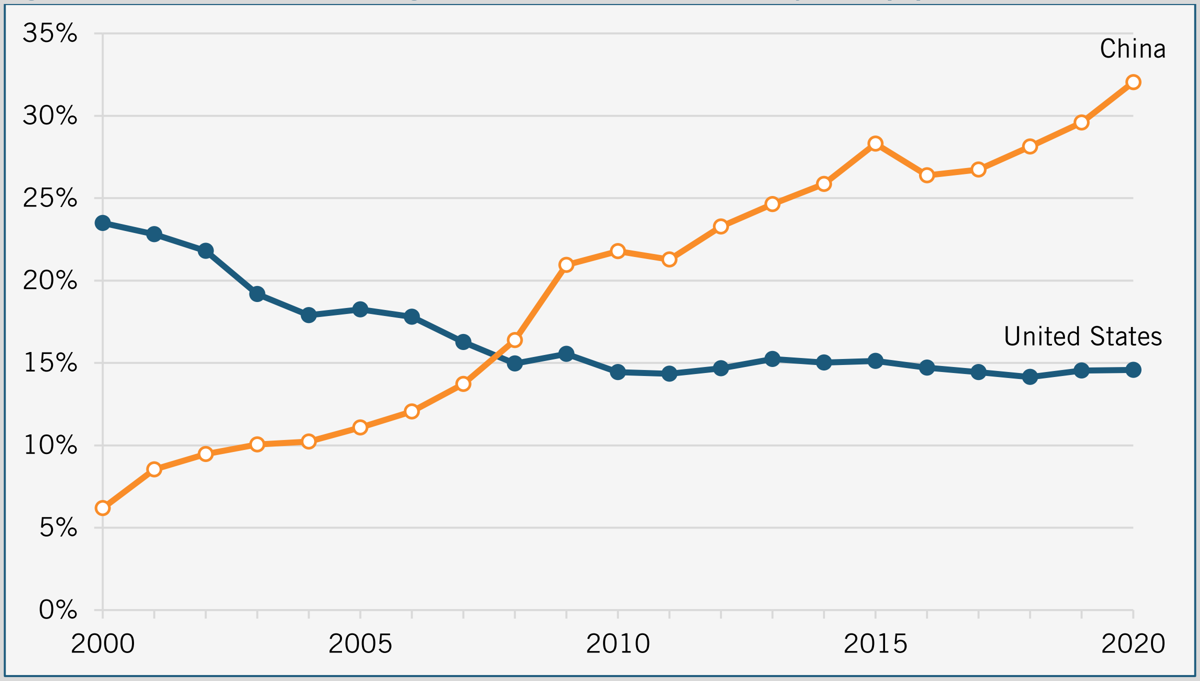
Machine Tools[148]

Machine tools are used to remove or add material from a workpiece.[149] To date, China has largely been a copier. But if China can prove to be a true innovator, American machine tool companies will become vulnerable.

In 1981, the United States was the largest producer of machine tools at $5.1 billion.[150] By 2022, China was the world's leading producer at $27.1 billion per year, while the United States ranked fifth at $5.9 billion.[151] However, even though China's domestic companies produce more than 95 percent of the domestic demand for low-end computer numerical control (CNC) machine tools, over 90 percent of its high-end CNC tools are still imported.[152]

Over time, the U.S. global market share in machinery and equipment has decreased while China's has increased. (See figure 22.)[153] In 2000, the United States held a 23 percent global market share, and China held just 6 percent.[154] By 2020, China had a 32 percent share while the United States only had 15 percent.[155] The United States has witnessed a decline in machine tool manufacturing.[156] Industry output is increasing at a rate slower than GDP. In contrast, China has experienced an upward trend in the metal-cutting machine tools industry, growing at a rate faster than GDP.[157]

Figure 22: U.S. and Chinese firms' global market shares in machinery and equipment[158]



In addition, from 1999 to 2020, U.S. firms filed more machine tool patents than did Chinese firms at the three major offices: European Patent Office, Japan Patent Office, and USPTO.[159] In 1999, the United States filed 258 patents while China filed just 2.[160] But by 2020, the United States filed only 20 patents while China filed 3.[161] However, filing 493 patents in 2019 alone, Japan surpassed the United States and China as the top machine tool patent filer from 1999 to 2020.[162] Germany had a slight lead ahead of the United States with 188 and 120 patents filed in 2019, respectively.[163]

Chinese machine tools are considered low end and low tech.[164] According to the Strategic Study of Chinese Academy of Engineering, China's machine tool industry trails behind advanced international countries by 15 years.[165] For example, fewer than 20 Chinese manufacturers of machine tools have upgraded their production lines to incorporate Industry 4.0 standards, such as IoT technologies and AI, within the high-end CNC market.[166] Consumers of Chinese-made machine tools have also reported product defects, including oil, liquid, and gas leaks.[167] Moreover, China has yet to implement additive manufacturing into the machining process on a large scale due to inadequate development.[168]

In addition, the average time between system failure of Chinese machine tools is 600 to 2,000 hours, while foreign ones have an average time of over 5,000 hours.[169] China's multi-axis machine tools have a utilization rate, which is a measure of the equipment's productivity, of 15–30 percent and an acceleration due to gravity lower than 0.8 g.[170] However, foreign machine tools have a utilization rate of 60–90 percent and a minimum acceleration of 1–1.5 g.[171] In particular, China's ultraprecision machine tools have a submicrometer processing precision, which is worse by one to two orders of magnitude compared with technologically advanced countries.[172]

In an attempt to boost competitiveness, Chinese machine tool companies such as Shenyang Machine Tool have tried to out-innovate the United States by copying American technology. In 2016, the company released the i5M8, the world's first integrated smart machine tool, with a high machining precision of 0.003 mm.[173] Manufacturers can create eight different models of one tool in either three-, four-, or five-axis formats. But Shenyang's i5 series is far from innovative. The operating system is a replica of Apple's iOS and its cloud platform mimics Apple's iCloud.[174] By utilizing Apple's proprietary technology and marketing the product as if China invented the machine, this example exemplifies China's inability to be a true innovator. And up to 2020, the system largely produced two- and three-axis machine tools rather than high-precision four- and five-axis machines the company boasted about.[175]

China's inability to be a true innovator stems from Chinese firms' incapability to produce high-end core components of machine tools, such as rolling components. Rolling components, including ball screws and roller linear guide rails, help to increase machine tool efficiency and accuracy and lower energy dissipation. But more than 90 percent of these critical parts are imported. In addition, the production of high-end precision bearings, another vital component of machine tools, is largely dominated by Japanese, German, Swedish, and American firms, accounting for more than 70 percent of the global bearing market.

Chinese firms are also looking at innovative ways to incorporate automation, robotics, and 3D printing within CNC machines; however, with less than 20 high-end CNC machine producers in China, advanced countries such as Japan and Germany have been able to easily outpace China in terms of the R&D of novel machine tools. Thus, due to the high technical barriers and costs, Chinese firms are hesitant to enter the high-end machine tool market. China's medium- to high-end machine tool industry is heavily reliant on imports from Asian and European countries. In 2020, the largest share of high-end machine tool imports was from Japan ($2.7 billion) and Germany ($1.3 billion), accounting for 62 percent of total imports. And in particular, foreign businesses makes up 70 percent of China's medium-end machine tool industry.

The Chinese government has made a conscious effort to break this pattern. "Made in China 2025" strives to decrease foreign dependence and increase independent innovation capabilities through the R&D of high-end machine tools and key components. It also aims to cut production cycle time and product defects by 50 percent each. While China lags behind overall, there has been some innovation. In 2017, Zhang Haiou at Huazhong University of Science and Technology created the world's first 3D printing CNC machine tool with independent IP rights and simultaneous casting and forging capabilities. HuazhongCNC, a Chinese medium to high-end CNC systems manufacturer, launched the Huazhong CNC 9 series intelligent system, the world's first intelligent CNC system, in 2021.[176] This novel system not only incorporates automation, AI, and Internet of Things, but also has independent learning and decision-making capabilities.

Nuclear Power

China has become an—if not clearly the—global leader in nuclear reactor technology.[177] Francois Morin, China's director of the World Nuclear Association, asserted that China is "ahead of other countries in terms of nuclear technology research and development."[178] Overall, analysts assess that China today likely stands 10 to 15 years ahead of the United States in its ability to deploy fourth-generation nuclear reactors at scale. The country expects to build six to eight new nuclear power plants each year for the foreseeable future, with the average construction time for those reactors averaging about seven years. In total, China intends to build a total of 150 new nuclear reactors between 2020 and 2035.

To be sure, the bulk of the nuclear reactors Chinese firms are currently deploying are based on the Westinghouse Electric-designed AP1000, which became the first Generation III+ reactor to receive final design approval from the Nuclear Regulatory Commission (NRC), in 2004. In 2007, Westinghouse won a China National Nuclear Corporation (CNNC) bid for four AP1000 reactors, although this also included a major technology transfer agreement that significantly accelerated the advancement of China's commercial nuclear power industry, leading to the development of China's CAP1400 reactor. What needed technology China could not get from voluntary tech transfer, it simply stole: In 2010, hackers working with the Chinese military penetrated Westinghouse's computer systems and stole confidential and proprietary technical and design specifications for Westinghouse's AP1000.[179]

While China did not excel at innovating the CAP 1400, it did excel at taking the steps needed to deploy it. In fact, while China was deploying its version of the AP1000 as early as 2017, America's first installation of the Generation III+ reactor only came online in 2023.

This points to China's strengths in systemic and organizational innovation when it comes to nuclear power, and especially refers to the country's coherent national strategy toward nuclear power—at both federal and provincial levels. This strategy entails a range of supportive policies, from low-interest financing, feed-in tariffs, and other subsidies that make nuclear power generation cost competitive to streamlined permitting and regulatory approval (i.e., of safety and environmental impact assessments) to coordinating supply chains in an effective fashion.

Moreover, in the future, China will be deploying Chinese-designed fourth-generation nuclear reactors with 93.4 percent of the materials used in a new $16 billion facility, the Shidaowan 1, domestically sourced.[180]

China has also led construction of the world's first multipurpose small modular reactor (SMR) demonstration project, known as the Linglong One. It was the first SMR to receive approval from the International Atomic Energy Agency.

The Shanghai Institute of Applied Physics is slated to launch the world's first molten salt and thorium nuclear reactor, the TMSR-LF1. While thorium-based reactors are not entirely novel, what differentiates them is their utilization of thorium as a fuel source within a molten salt reactor.[181] In December 2021, China became the third country to develop a floating nuclear reactor, the ACPR50S, which has been designed to endure the equivalent of a once-in-10,000-years weather catastrophe.[182]

Ultimately, the Generation IV International forum—a cooperative international endeavor among 13 countries seeking to develop the research necessary to test the feasibility and performance of fourth-generation nuclear systems and make them available for industrial deployment by 2030—has identified six different reactor types as "Gen IV": the gas-cooled fast reactor (GFR), the lead-cooled fast reactor (LFR), the molten salt reactor (MSR), the sodium-cooled fast reactor (SFR), the supercritical-water-cooled reactor (SCWR), and the very high-temperature reactor (VHTR).[183] Notably, across various projects, China is trying to build reactors of each of these types.[184]

China is also making significant progress in nuclear fusion. In 2024, the Chinese government launched an industrial consortium to promote the development and advancement of fusion.[185] The Chinese government has also launched new fusion education programs in China, with a goal of training 1,000 new plasma physicists to support these initiatives.[186] The government has set a goal of building the first industrial prototype fusion reactor, which it has dubbed an "artificial sun," by 2035, with officials hoping to begin large-scale commercial production of fusion energy by 2050.[187]

Industry analysts ITIF interviewed have observed that China appears to be roughly on par today with U.S. efforts to develop nuclear fusion technologies. However, a July 2024 *Wall Street Journal* article finds that the Chinese government is now nearly doubling the U.S. government's R&D investments in nuclear fusion—roughly $1.5 billion annually for China compared with $790 million for the United States—although these figures did not count private-sector investment. Nevertheless, the *Journal* reported , "Scientists familiar with China's fusion facilities said that if the country continues its current pace of spending and development, it will surpass the U.S. and Europe's magnetic fusion capabilities in three or four years."[188]

When it comes to innovation inputs, China placed 7 of the top 22 enterprises in the "2023 EU Industrial R&D Investment Scoreboard" for their R&D investment intensity toward nuclear innovation. China's performance was stronger with regard to scientific publications and patents in nuclear engineering. As of 2022, China ranked third in terms of nations with citations among the top 10 percent of highly cited publications in nuclear science and engineering, with 339 such publications, compared with EU-27 nations with 457 such publications and American ones with 399. China's number of such publications increased fourfold between 2008 and 2021. China is a leader not only in the quantity of nuclear energy publications, but also in "high-quality" publications.

China has surpassed the United States in its deployment of the current generation of nuclear reactors and in the development and deployment of fourth-generation nuclear reactors. Chinese firms are developing indigenous innovation capabilities in the sector, and China's growth in high-impact scientific publications and increased share of global patents awarded in the sector suggest that Chinese enterprises will only become more competitive in the civilian nuclear energy industry in the future.

Semiconductors

China's government has prioritized semiconductors, investing hundreds of billions of dollars to catalyze the development of an indigenous semiconductor ecosystem and ideally cultivate globally competitive semiconductor firms across virtually all segments, from semiconductor design and fabrication to semiconductor manufacturing equipment to assembly, test, and packaging (ATP).

Thus far, however, those efforts have met with uneven success. With regard to the fabrication of leading-edge logic semiconductor chips, China's flagship competitor, the Semiconductor Manufacturing International Corporation (SMIC) likely stands about five years behind global leaders such as the Taiwan Semiconductor Manufacturing Company (TSMC).[189] Chinese competitors are even further behind with regard to semiconductor manufacturing equipment, such as the lithography tools that make semiconductors. One commentator noted that Chinese firms might be as many as five generations behind in this field.[190] As another analyst explained, "The best machinery a Chinese company can produce makes chips that are 28 nm wide; the industry's cutting-edge equipment can make 2 nm chips."[191] That said, Chinese semiconductor firms appear to be catching up in certain pockets.

Manufacturing semiconductors starts by designing them, making electronic design automation (EDA) software that assists in the definition, planning, design, implementation, verification, and subsequent manufacturing of semiconductors vitally important. Historically, EDA has "constitute[d] a weak link in the PRC's efforts to build a leading domestic semiconductor value chain."[192] However, in March 2023, Huawei announced that it had achieved a number of breakthroughs in the development of EDA software, which it suggested would free China's industry from reliance on foreign suppliers of those tools when producing semiconductors of 14 nm or more.[193] Still, Chinese firms clearly lag behind global leaders in the EDA space.

EDA represents a key input to designing semiconductors, and China's weakness there has historically hampered its semiconductor design firms. Chinese design firms accounted for only 8 percent of global design revenue in 2022, with no Chinese firms among the top 25 global design firms.[194] Nevertheless, as one report notes, "China's design industry has rapidly increased in size since 2015, driven by factors such as the widespread availability of capital (including from both the government and private sector), government support, a desire to localize the industry, demand growth, the acquisition of foreign firms, and downstream users designing their own semiconductors."[195] In fact, from 2010 to 2022, the number of semiconductor design firms in China increased nearly sixfold, from 582 to 3,243.[196]

When it comes to designing and manufacturing advanced logic semiconductor chips, Chinese enterprises have caught up in pockets, but overall remain well behind global leaders. The real bottleneck comes with regard to the capability to manufacture advanced process node (i.e., sub-7 nm) chips. While China's flagship fabricator, SMIC, is manufacturing at 7 nm, it's generally with more expensive, time-consuming, and lower-yield processes; in other words, while SMIC can do high-volume, high-yield manufacturing at 28 nm, it has yet to master the practice at 7 nm, let alone sub-7 nm levels, and leaders such as Intel and TSMC continue to push leading-edge semiconductor manufacturing down to the sub-2 nm level.

To be sure, Chinese firms have recorded some successes in advanced logic chips. For instance, in August 2023, Huawei released the Mate 60 Pro smartphone, which deployed the 7 nm Kirin 9000S chip (which Huawei's HiSilicon design arm architected) and was manufactured by SMIC using its SMIC N+2 process technology "with capabilities that shocked the world in terms of its performance."[197] As Dylan Patel of *SemiAnalysis* commented, "Put simply, [the] Kirin 9000S is a better designed chip than the West realizes. It has solid power and performance. Even with the lackluster export controls, this is a leading-edge chip that would be near the front of the pack in 2021…. We cannot overstate how scary this is."[198] However, the process SMIC uses to make the chip is time-consuming and expensive, making it difficult to manufacture using this process at volume scale, explaining why analysts expected Huawei to ship only 7 million of the MatePro phones in 2023, and perhaps 40 million in 2024.

Elsewhere, a plethora of Chinese competitors, including Huawei (with its Ascend chip), Biren, Tencent, Alibaba, Baidu, and MetaX, are designing AI chips. Patel asserted that these firms "will soon be able to deliver on chips that are on par with Nvidia's A100 [using] SMIC 7nm in two years at significant volumes."[199] Commenting on Huawei's Ascend GPU chips, one observer noted that Huawei's highest-end product is likely comparable to an NVIDIA H800 in most features save for energy efficiency. Biren's BR100 processor competes in the market against NVIDIA's H100, delivering powerful performance speeds, but industry observers noted that

NVIDIA's CUDA ecosystem, which tightly integrates hardware and software, is likely more attractive than Biren's competing offering.

Legacy (or "larger" or "mature") node chips represent those manufactured using 28 nm or greater process technologies. China has become an ever-more-significant player in this sector of the market, but its basis for competitive advantage here is likely to be more predicated on a large scale (supported by massive, state-driven industrial subsidization) that facilitates price-driven, not innovation-driven, competition.[200]

China will account for the most significant share of new semiconductor capacity coming online over the next several years. Indeed, analysts expect that China will add more chipmaking capacity than the rest of the world combined in 2024, with 1 million more wafers a month than in 2023.

The semiconductor memory industry has long been a strategic priority for China's economic development.[201] Yangtze Memory Technologies (YMTC), China's leading NAND maker, represents a Chinese state-controlled joint venture launched by the National Integrated Circuit Industry Investment Fund, supported by $24 billion in initial government funding allocated for its initial Wuhan factory alone.[202] ChangXin Memory Technologies (CMXT) is another Chinese-government-created semiconductor manufacturer, focusing on DRAM technology.

YMTC got off to a hot start, "mov[ing] rapidly up the NAND manufacturing curve, producing 128-layer NAND and moving rapidly toward more advanced processes, at 232 layers and above."[203] A *TechInsights* article finds that YMTC introduced "the first 200+ layer 3D NAND Flash" on the market, ahead of rivals Samsung, SK Hynix, and Micron.[204] In 2022, Apple considered acquiring YMTC's NAND memory chips for use in iPhones and iPads to be sold in China, and reportedly wanted to increase the order up to 40 percent of the chips required for all iPhones.[205] As one observer noted, "YMTC's products are as good as anyone else's." However, when the U.S. Department of Commerce's (DOC's) Bureau of Industry Security added YMTC to its "Entity List" in December 2022, it significantly impeded YMTC's expanse, resulting in YMTC laying off 10 percent of its staff.[206]

For its part, CXMT has become the workhorse DRAM company in China, but "the company faces significant challenges in the execution of its roadmap," and analysts don't regard it as competing at the leading edge.[207] As Paul Triolo wrote, "[K]ey players like memory makers YMTC and CXMT [are] hobbled by lack of access to cutting-edge tools, but still capable of producing useable memory."[208]

Lithography represents a crucial step in the chipmaking process, wherein a chip wafer gets inserted into a lithography machine and exposed to deep ultraviolet or extreme ultraviolet light and a pattern is printed onto a chip's resist layer through a photomask. As such, catching up in lithography has long been a central focus of China's chip aspirations, with the efforts going back to China's "Project 02," launched in 2008. Shanghai Micro Electronics Equipment Group (SMEE), China's leading lithography developer, claimed in December 2023 to have successfully developed a 28 nm lithography machine, the SSA/800-10W.[209] However, analysts question SMEE's ability to produce 28 nm lithography equipment at scale. Overall, the domestic market share of Chinese producers of wafer-fabrication tools rose from 4 percent in 2019 to 14 percent in 2023.

Lastly, ATP represents the final step in semiconductor manufacturing. As of 2021, China accounted for 27 percent (134) of the world's 484 ATP facilities. By August 2023, Chinese ATP firms commanded 38 percent of the market, with the five largest OSAT players—JCET, HT-Tech, TF, LCSP, and Chippacking—all being Chinese.[210] However, while Chinese firms are cost competitive in the ATP sector, industry observers at an ITIF roundtable contended that "while China has made some progress … it really doesn't have that capability on the leading edge" of semiconductor ATP.[211]

With regard to innovation inputs, China's semiconductor industry is not nearly as R&D-intensive as other leading nations' semiconductor sectors. In 2022, its semiconductor-sector R&D intensity of 7.6 percent was just 40 percent of America's 18.8 percent, and well below the EU-country average of 15 percent, or Taiwan's 11 percent.

Chinese researchers have also made impressive strides in the number and quality of their scientific publications in semiconductors. Considering the h-index, a measure of the productivity and citation impact of scientific publications, China counts seven institutions in the global top-20 research institutions releasing advanced integrated circuit and design publications.[212]

Ultimately, Chinese enterprises are innovating as rapidly as they're able to in this industry—and they have made some notable achievements and advancements—but overall, they remain behind global leaders in the semiconductor industry.

Electric Vehicle and Battery Industries

The more than 200 EV manufacturers operating in China will produce an estimated 10 million EV units in 2024. In 2022, China accounted for 62 percent of global EV production (though this figure also counts Western manufacturers such as Tesla operating in China) and 59 percent of global EV sales.[213] Similarly, China's battery manufacturing capacity in 2022 stood at 0.9 terawatt hours, roughly 77 percent of the global share.[214] China's two largest EV battery producers—CATL and FDB—alone account for over one-half of global EV battery production.

The Chinese government—at both the federal and provincial levels—has made EV competitiveness a national priority. But while China's EV industry has certainly benefitted from intense government support, Chinese EV and EV battery enterprises have become increasingly innovative in their own right across a number of dimensions of product innovation, process innovation, business model innovation, and even customer experience innovation. Collectively, Chinese EV and EV battery enterprises have at least equaled—and in some cases surpassed—their Western peers in innovation capacity and product quality.

Indeed, as one report observes, many contend that "China is the epicenter of EV innovation."[215] As commentators at the ITIF roundtable of experts on China's EV industry observed, "Chinese enterprises are very innovative, especially in EVs" and "China is doing really remarkable, innovative work in the vehicle electrification space."[216] Overall, research firm Bernstein estimates that Chinese EVs can cost half as much to make as European ones, even while they can boast of better technology.[217]

Chinese enterprises have made critically important breakthroughs in EV battery chemistry. As Zeyi Yang wrote in *MIT Technology Review*, "Just a few years ago, LFP [Lithium iron phosphate] batteries were considered an obsolete technology that would never rival NMC [nickel manganese cobalt batteries] in energy density."[218] But today, LFP batteries account for about 40 percent of the global market for EVs, and as Yang wrote, "It was Chinese companies, particularly CATL, that changed this consensus through advanced research."[219]

Chinese EV battery makers such as CATL and WeLion now sell LFP EV batteries with a 1,000 km (621-mile) range off a single charge.[220] And some Chinese EV battery start-ups are now working to develop EV batteries they assert will have a 2,000 km (1,300-mile) range.[221] As another commentator explained, this is "purely down to the innovation within Chinese cell makers. And that has brought Chinese EV battery [companies] to the front line, the tier one companies."[222]

Chinese EV makers are also leading in other aspects of vehicle technology, from innovative vehicle suspension systems to the incorporation of a range of novel digital features, including such features as autonomous driving and interactive voice controls to multiple touch screens that enable everything from watching movies to singing karaoke.

Retail showroom for BYD electric vehicles in Shanghai, China[223]

Chinese firms are also aggressively innovating vehicle production processes, from robotic automation to digital production systems (i.e., digitalized manufacturing execution systems) to innovative aluminum diecasting processes. For example, Chinese EV maker Xiaomi has made important innovations on the diecasting process Tesla pioneered, such as building an AI program that uses a method known as deep learning to simulate how different materials behave when placed inside a die-cast machine.[224]

Process innovations such as these have enabled Chinese EV manufacturers to accelerate the pace of product innovation. One assessment finds that Chinese EV companies are 30 percent faster in developing and releasing a new car model than "legacy" American, European, and

Japanese carmakers are. In fact, Chinese EV makers offer models for sale for an average of only 1.3 years before they are updated or refreshed, compared with 4.2 years for foreign brands.[225]

In terms of automotive companies' levels of R&D investments, as reported in the "2023 EU Industrial R&D Investment Scoreboard," China placed 8 of the top 15 companies in the study. Nio and XPeng were the leading Chinese companies, with an R&D intensity of about 21.3 percent of its revenue. That is ahead of well-known automotive manufacturers including Ferrari and Aston Martin.

Chinese EV enterprises are backed by an increasingly capable support ecosystem, including everything from the quality of the R&D conducted at Chinese universities and research institutions to a deep local supplier base. In particular, the number and quality of Chinese scientific publications pertaining to EVs and EV batteries has increased markedly in recent years. For instance, the Australian Strategic Policy Institute (ASPI) found that Chinese institutions account for 65.4 percent of the high-impact publications for electric batteries, substantially outpacing the United States' 11.9 percent. And, as ASPI wrote, "The Chinese Academy of Sciences is a stand-out performer in the *Critical Technology Tracker* datasets. It leads in six of the eight energy and environment technologies [and is] no. 1 globally for electric batteries."[226] Meanwhile, Chinese entities' global share of patents in the field of electric propulsion increased 11-fold from 2.4 percent in 2010 to 26.9 percent in 2020.

While certainly the highest-end Western firms such as BMW and Tesla remain at the forefront of the global EV market, Chinese firms such as BYD, Xiaomi, and Li Auto are competing effectively at the luxury EV level, while in the mid-market, BYD, JiYue, Nio, and others are excelling at delivering attractive, cost-competitive EVs. China's leadership in EVs certainly began as a result of intentional industrial policy and guidance, especially through market-making activities such as intensive industrial subsidization. However, from that base, Chinese EV players have become increasingly capable, innovative, and competitive in their own right.

Artificial Intelligence

The United States has long led in AI, thanks to cutting-edge research and a strong private sector, but China's relentless, state-driven approach is closing the gap fast. The outdated narrative of China as merely a copier is being replaced by evidence of its strong academic institutions and innovative research, which have produced most of China's leading AI start-ups. U.S. efforts to slow China down are unlikely to work in the long run, so if America doesn't ensure that it stays ahead, it could find itself outpaced by a rival that's advancing with impressive speed and focus.

China's ascent in AI is marked by a series of strategic moves that have transformed its research landscape. For years, China has been churning out AI research at an impressive volume, although it is often perceived as lagging behind in quality compared with that from the United States. This narrative is changing. Today, China and America are neck and neck in generative AI research output, each contributing thousands of papers that push the boundaries of what AI can achieve. However, where U.S. research tends to lead in impact—evidenced by higher citation counts and more significant involvement from private companies—China's research is rapidly gaining recognition, especially in fields in which it directly competes with American efforts.

At the heart of China's AI revolution is Tsinghua University, a powerhouse of academic innovation that has become the breeding ground for some of the country's most promising AI start-ups.

Companies such as Zhipu AI, Baichuan AI, Moonshot AI, and MiniMax—collectively dubbed the "AI tigers"—are not merely replicating Western technologies but are also carving out their niches in the global AI landscape. These firms, often led by Tsinghua alumni, are at the forefront of developing large language models (LLMs), some of which now outperform their U.S. counterparts in bilingual benchmarks. This is no small feat, considering the complexity of training AI systems to operate effectively in multiple languages.

China's approach to AI is deeply intertwined with its broader economic and industrial strategies, and the country has identified AI as a critical component of its future growth, integrating it into key sectors such as manufacturing and healthcare. The Chinese government's support for AI extends beyond mere rhetoric; it is manifest in substantial financial backing, through both direct state funding and the creation of favorable conditions for private investment. This support is particularly evident in regions where private capital has traditionally been scarce, allowing high-potential firms to flourish in areas that might otherwise be overlooked.

Yet, while China's AI ecosystem is rapidly maturing, it still faces significant challenges. In terms of private AI investment, the United States continues to dwarf China, with American firms attracting far more VC and producing a greater number of groundbreaking AI models. However, this gap may begin to close as foreign investors, including significant players such as Saudi Arabia's Aramco, begin to see the potential in China's AI sector. Moreover, China is also leading the world in generative AI patents, dominating the top 20 slots globally, which is a strong indicator of its growing innovation capabilities.

One of the most striking aspects of China's AI strategy is its open source LLM ecosystem, which is advancing at a pace that has caught the attention of global AI communities. Models such as Alibaba's Qwen 1.5 and Zhipu AI's ChatGLM3 are not only competitive, but are also starting to set benchmarks in various applications. This is complemented by China's aggressive pursuit of a national data strategy designed to enhance the availability and quality of data, which is crucial for training advanced AI models.

However, the question remains: Can China sustain this momentum and translate its research prowess into global leadership in AI? While China's progress is undeniable, the United States still leads in key areas, particularly in the commercialization of AI technologies and the development of foundational models that underpin a wide range of AI applications. The U.S. private sector's deep integration with academic research continues to give it an edge in producing AI that is both innovative and practical.

China's rapid advancements in AI reflect a nation that is no longer content with being a follower. Through a combination of strategic state intervention, robust academic output, and increasing private investment, China has positioned itself as a serious competitor in the global AI race. Whether it can overtake the United States remains to be seen, but one thing is clear: American dominance in AI should not be taken for granted.

Displays

Electronic displays have become an integral part of the modern global digital economy, representing the key visual and tactile (via touchscreens) human interface for a wide variety of consumer electronics from televisions, computers, mobile phones, tablets, and vehicles to a range of other applications, such as medical devices and refrigerators. Displays also play vital roles in national defense capabilities, from the heads-up displays in fighter jet cockpits to the combat information centers on navy ships.

Analysts estimate that the global display market will generate $182 billion in sales in 2024 and more than double in size over the next decade to become a $372 billion market by 2034.[227] And while Chinese enterprises used to be bit players in an industry once dominated largely by South Korean firms, China's share of global liquid-crystal display (LCD) production has reached 72 percent, while its share of organic light-emitting diode (OLED) production exceeds 50 percent. Chinese players surpassed South Korean ones for the first time in Q1 2024 as the leading producer of OLED panels.[228] Moreover, China's prowess in displays is increasingly driving the competitiveness of its TV manufacturers.

China's aggressive subsidization of the display industry has driven down prices and led to overcapacity, thus depressing profitability for foreign competitors that have to earn market-based rates of return to persist in the industry. In the LCD sector, this approach has succeeded in driving most foreign competitors out of the industry—Japanese companies stopped investing in the sector wholesale around 2010—or precluded other would-be competitors from entering the industry.

While Chinese display makers such as BOE, TCL, Tianma, and Visionox certainly started behind leading peers (notably Japan's Sharp, South Korea's LG, and Samsing Display), they are increasingly developing innovative products in their own right, as reflected by BOE and TCL increasingly winning prestigious awards in the field, such as at the Consumer Electronics Show (CES). For instance, at the 2023 CES, TCL-CSOT (China Star Optoelectronics Technology Co., Ltd., which is TCL's display subsidiary) won the "Innovation Award for MiniLED Display of the Year." BOE has developed innovative flexible OLED screens and what it claimed to be the world's largest 95-inch 8K OLED screen when the company launched it. BOE's display manufacturing facilities are among the world's most sophisticated and are extensively automated.[229] BOE has also worked assiduously to develop its patent portfolio; it has been a top 10 global patent filer over each of the past six years (and the fifth-leading patent filer globally in 2023).

In summary, China has clearly wrested leadership in the global LCD industry away from other players: In 2004, China accounted for 0 percent of global LCD production, but by 2024 its share had reached 72 percent (as strong a case of "comparative advantage" being effectively artificially manufactured through industrial policy as there ever could be). Likewise, China's market share in OLEDs has increased from less than 1 percent in 2014 to over half today; and if current trends continue, then competitors in that segment of the market will be hard-pressed to persist as well. (Indeed, the only route for Korean or Japanese players will be to out-innovate on the front end to develop the next-generation of MinilLED and MicroLED solutions.)

Moreover, it turns out that the manufacturing process similarities between fabricating displays and semiconductors are close to 70 percent, meaning that as Chinese firms develop capabilities in display technologies, these may increasingly spill over into semiconductor capabilities, further powering the competitiveness of China's semiconductor firms.[230]

Quantum Computing

China dominates in quantum communications, lags behind in quantum computing, and roughly matches the United States in quantum sensing. While the United States has historically led the field of quantum information science (QIS), which harnesses the principles of quantum mechanics to process and transmit information in fundamentally new ways, China has rapidly advanced its capabilities through aggressive state-driven investments and strategic focus—and some of these advancements outstrip the United States in scale and scope, making U.S. leadership in quantum far from assured. Quantum technologies are not only important for national security, but they also have the potential to exert a transformative influence on the economy and society.

In quantum communications, China has secured global leadership, as demonstrated by the development of the world's longest quantum key distribution (QKD) network—the 1,200-mile Beijing-Shanghai backbone. This achievement is complemented by the Micius satellite, which extends quantum communication over even greater distances, solidifying China's position at the forefront of secure, long-distance quantum communication. However, despite its leadership in quantum communications, this particular field represents a smaller slice of the overall quantum technology landscape compared with computing, particularly in terms of economic impact. Quantum computing, with its vast potential across industries such as pharmaceuticals, finance, and cryptography, is expected to dominate the quantum economy, capturing the lion's share of market value by 2040.

In quantum computing, China lags significantly behind the United States, particularly in hardware development and the practical implementation of quantum systems. Despite substantial state investment and focused efforts, Chinese companies and research institutions have not yet reached the level of breakthroughs achieved by their U.S. counterparts, particularly in areas such as qubit coherence, error correction, and the development of scalable quantum processors. The United States leads in quantum computing by consistently achieving breakthroughs in scalable systems and practical applications, supported by a dynamic collaboration between academia and industry.

In quantum sensing, the competition is more balanced, with China leading in certain areas while the United States maintains an edge in others. China's strengths lie in the rapid commercialization and application of quantum sensing technologies, particularly in sectors such as defense and healthcare, where these technologies are already making significant impacts. The United States, on the other hand, leads in the quality of research of cutting-edge sensing applications, maintaining a slight advantage in the most innovative and high-impact areas of this technology.

This contrast—China's leadership in the more market-ready quantum sensing and quantum communications versus its lag in the less mature quantum computing—illustrates its strength in swiftly refining and applying existing research, as well as its limitations in foundational innovation. China's strategic focus on near-term, commercially viable technologies reflects a pragmatic approach to innovation, prioritizing immediate gains over the deeper, longer-term breakthroughs that are expected to drive the future of the quantum economy.

China is fully aware of its strengths and plays to them. The Chinese government has proposed investments exceeding $15 billion, far outpacing the United States, which has allocated around

$3.8 billion. At the core of China's quantum innovation strategy is a relentless focus on translating cutting-edge research into practical, commercial applications. Government initiatives have created specialized hubs such as Hefei's "Quantum Avenue," where academic research is seamlessly converted into market-ready technologies. These hubs not only foster innovation, but also ensure that technological advancements align with China's broader strategic goals, particularly in enhancing national security and economic competitiveness.

Biopharmaceuticals

The United States remains the world's biotechnology leader, with the highest level of new drug development. But this leadership position is at risk, particularly from China. The Chinese government has prioritized the development of the biopharmaceutical industry.

China's biopharmaceutical industry is starting to show signs of innovation, including a surge in the volume and quality of biotech-related scientific publications, a rise in the number of novel Chinese drugs and out-licensing deals from Chinese biotech companies, particularly in oncology, and an increase in clinical trials taking place in China.[231]

Chinese institutions are producing an increasing number of top-cited biotechnology-related publications. In 2012, they published 139 biotech papers in the top 10 percent of most-cited publications. By 2022, that number had surged to 671 top-cited papers, an increase of more than 382 percent.[232]

China has also made significant strides in turning its scientific publications into biotechnology patents. The PCT, which entered force in 1978, allows innovators to seek protection for an invention simultaneously in each of a large number of countries through an "international" patent application.[233] From 2013 to 2023, the number of biotech PCT patents awarded to Chinese entities increased by more than 720 percent, from 266 to 1,920, exceeding the European Union's annual number starting in 2021.[234]

China's biopharmaceutical industry is starting to show signs of innovation, including a surge in the volume and quality of biotech-related scientific publications, a rise in the number of novel Chinese drugs and out-licensing deals from Chinese biotech companies.

According to a November 2023 McKinsey BioCentury report, China evinces increasing numbers of out-licensing deals, suggesting multinational corporations have growing confidence in the quality of Chinese biotech products. This number more than doubled from 15 in 2019 to 33 in 2023.[235] The largest rise has been in oncology, which experienced a nearly fourfold increase from 7 out-licensing deals in 2019 to 27 in 2023.[236]

In 2023, China had five first-in-class domestic drug approvals, a sign that domestic innovation is increasing. The five drugs approved were Glumetinib (Haihe Biopharma), Leritrelvir (Raynovent), Anaprazole (Xuanzhu Biopharma), Pegol-Sihematide (Hansoh Pharma), and Zuberitamab (BioRay Biopharmaceutical).[237] Also in 2023, the U.S. Food and Drug Administration (FDA) approved three new Chinese drugs: Loqtorzi (toripalimab), the first FDA-approved drug for nasopharyngeal cancer, Fruzaqla (fruquintinib) for metastatic colorectal cancer, and Ryzneuta (efbemalenograstim) for the treatment of chemotherapy-associated neutropenia.[238] In recent years, China has focused on developing novel drug types, including monoclonal and CAR-T cell products, which show promise in cancer immunotherapy.

Beyond drugs, the industry is also making advances in multi-cancer early detection (MCED) tests, which involve the application of genome sequencing techniques to detect common cancer features in the blood. Through the Chinese government's support, MCED developers can access state capital, academic biobanks, and other resources. This gives them an advantage over their American counterparts, which do not have access to the same resources and thus have to rely heavily on private sector investment to obtain them.

China's biopharmaceutical industry is starting to show signs of innovation.[239]

The Chinese biotech industry's focus on oncology—as evidenced by its novel drugs, out-licensing deals, and diagnostic tests in this therapeutic area—is relatively new, and motivated in large part by China's aging population and the rising incidence of cancer. Previously, its domestic biopharmaceutical industry focused on bringing down infectious disease rates, leading China to become the global leader in penicillin. As the mortality rates from infectious diseases fell, China's focus shifted to chronic diseases, such as cancer, seizing an opportunity to develop treatments for these diseases at lower cost structures.[240]

But despite China's biotechnology advances, the country still faces several challenges. Many Chinese start-ups have been and continue to be founded by scientists, which presents difficulties for commercialization, as scientific research ability is very different from commercial transformation ability. Reflecting on the state of technology entrepreneurship in China, Marina

Tue Zhang, Mark Dodgson, and David M. Gann wrote in their 2021 book, *Demystifying China's Innovation Machine*:

> There is a long distance from lab to hospital and pharmacy. Supportive policy, capital, and experienced managers are needed to make it, which also depend on mature ecosystems that China does not possess. The United States, on the other hand, has a sophisticated biopharmaceutical ecosystem, not only in life science R&D but also in the commercialization of biotechnology and bioengineering breakthroughs, and in strong IP protection.[241]

For China to become a global biotech leader, it will be critical for it to build comprehensive ecosystems, which include greater enforcement of IP rights, the ethical use of technologies such as gene editing, and technology transfer from research to industry to enhance commercialization capabilities.[242]

THE CONTRASTING WESTERN AND CHINESE ECONOMIC MODELS

Economist Larry Summers once stated, "The laws of economics are like the laws of engineering. One set of laws works everywhere."[243] It is this widely held notion that has led many experts and policymakers to dismiss the threat from Chinese techno-economic policies. For them, since there is only one law of economics, China must be like us—or at least working to become so, especially if we teach them—and so China will eventually structure its economic policy to focus on consumer welfare generated through free markets. To the extent China now violates those universal laws, it's China's economy that suffers, not ours'. Because the Chinese economic and innovation system does not comport to the U.S. system, it's easy for so many to dismiss the China challenge. Experts endlessly repeat such statements as China is wasting money; China's growth is not sustainable; and, of course, China is not innovative. The first two are irrelevant, and the last is false.

China's Dream: Techno-Economic Leadership

If China were trying to achieve the Western economics goal of allocation efficiency (the market-based allocation of goods, services, and investments), Western economies would have little to worry about, because as a rising economy, its innovation capabilities would be limited. Chinese leaders and experts do understand the Western economic model and know that, according to it, China should accept developing-nation status. China's economists have read *The Wealth of Nations*. They attend conferences where neoclassical economists tout the importance of free markets and consumer welfare. But they don't care because the CCP wants something completely different. Chinese leaders are not seeking to maximize short-term consumer welfare or even to provide good jobs for Chinese workers. The CCP, especially under President Xi Jinping's leadership, is focused first and foremost on maximizing global techno-economic power, including through an array of predatory mercantilist policies whose principal focus is on growing China's advanced economy at the expense of the rest of the global economy, especially Western technology leaders.

As the China Institutes of Contemporary International Relations, a branch of the Ministry of State Security, stated, "Economic growth is a prerequisite to and a necessary foundation for the rise of a great power."[244] But it is not just any kind of economic growth China is seeking; it is advanced manufacturing. As a Chinese report titled "General Laws of the Rise of Great Powers" states, “Manufacturing can Rejuvenate a Nation … For a modern economy to be prosperous and strong it requires a powerful, diversified, and creative manufacturing industry…. Becoming a major manufacturing power provides crucial security for the goal of realizing the Great Rejuvenation of the Chinese Nation.”[245]

Similarly, Wen Yi, a professor at Tsinghua University, has argued, “So long as a nation steps out onto the road of Industrial Revolution and becomes the factory of the world, it has the possibility of becoming the world leader in technological innovation. But if an industrialized nation abandons its manufacturing industry, it will very likely come by degrees to lose its technological advantage and capacity for innovation.”[246]

Similarly, the China Institutes of Contemporary International Relations wrote, “The state that esteems industry will increase in wisdom day by day.”[247] The opposite is also true, as we see in the United States. The state that is indifferent to or even dismissive of industry will decrease in wisdom day by day.[248]

As Tanner Greer and Nancy Yu wrote:

> Xi explained the logic behind [this] to a gathering of Chinese scientists held [in 2016]… He argued that “historical experience shows that [these] technological revolutions profoundly change the global development pattern.” … Some states “seize” this “rare opportunity.” Others do not. Those who recognize the revolution before them and actively take advantage of it “rapidly increase their economic strength, scientific and technological strength, and defense capabilities, thereby quickly enhancing their composite national strength.”[249]

As such, China’s economic, trade, and technology policy is all about gaining relative global power through advanced industry leadership. Chinese economic policy, unlike American, does not privilege consumer welfare. And it is OK with wasting money; efficiency is not its top goal. Likewise, Chinese leaders do not care about “distorting the market”; in fact, the only way China can become the global leader is to distort the market, because otherwise market forces would suggest that China remain a low-wage manufacturer for many decades to come.

China is focused first and foremost on maximizing global techno-economic power through an array of predatory mercantilist policies whose principal focus is on growing its advanced economy at the expense of the rest of the global economy, especially the technology leaders.

Consider the term “domination.” For China, domination does not come from cooperation or global market specialization along Ricardian lines (i.e., nations prospering by leveraging their distinct comparative advantages); it comes from battle. As such, Yi Changliang, a leading official of China’s NDRC, wrote, “At a time when this new round of techno-scientific revolution and industrial transformation has not yet gained its [full] momentum, there are grand expectations for artificial intelligence, big data, and cloud computing and [these areas] have become the main battlefield for innovation.”[250]

In other words, the CCP sees economics, trade, and technology as a battlefield on which to fight for dominance. This is so vastly far from how Western economics views international economics that very few economists, policymakers, or elected officials understand it or take it seriously. After all, they believe what Larry Summers believes.[251]

And as China advances, the CCP sees and hopes that America is retreating. As Xie Tao, dean of the School of International Relations and Diplomacy at Beijing Foreign Studies University, wrote, "All tides that rise must fall. All living men must age, sicken, and die. Therefore, the United States must accept that the day will come where it too will fall into decline."[252]

China is focused first and foremost on maximizing global techno-economic power.[253]

Likewise, the China Institutes of Contemporary International Relations wrote about the United States turning its back on globalization: "The reversal of the open-door policy is another step down the road to America losing its status as a great power."[254]

China is engaged in a battle to win the war for global techno-economic power. An article by Suchodolski, Harrison, Heiden talks about "innovation warfare":

> Improving the living conditions of one's citizens is a justifiable and laudable goal. However, especially savvy nation states, such as China, also pursue such ends as a mechanism to influence or diminish the national security and geopolitical power of the United States. These actions also threaten the post-WWII liberal economic order and worldwide peace and security. There is no need to inflict upon the world the carnage of war if geopolitical aims can be achieved via alternative competitive means.[255]

Finally, it's important to come back to the Chinese term "Great Rejuvenation of the Chinese Nation," which President Xi Jinping regularly touts. Is this just increasing per capita income growth, or something more? As the Center for Strategic Translation has argued, one aim associated with China's National Rejuvenation is for "China's return to national greatness as a process of 'advancing toward the center for the world stage.'" They quoted an official *Xinhua* commentary on the 19th Congress of what this advance entails:

> China has stood up, grown rich and become strong. It will advance toward center stage and make greater contributions for mankind. By 2050, two centuries after the Opium Wars, which plunged the "Middle Kingdom" into a period of hurt and shame, China is set to regain its might and re-ascend to the top of the world.... China's success proves that socialism can prevail and be a path for other developing countries to emulate and achieve modernization. China is now strong enough, willing, and able to contribute more for mankind. The new world order cannot be just dominated by capitalism and the West, and the time will come for a change.[256]

At the very least, Western policymakers should take seriously the possibility that China is seeking not just growth, not just gradual development, and not just technological advancement according to Ricardian principles; but rather global dominance in advanced industries, which it sees as a source of power.

The CCP sees economics, trade, and technology as a battlefield on which to fight for dominance. This is so vastly far from how Western economics views international economics that very few economists, policymakers, or elected officials understand it or take it seriously.

American Neglect

Unfortunately, few in America recognize that the United States is even in such a competition. To the extent U.S. leaders pay attention, they myopically focus on limiting Chinese military capabilities, thinking that is the main threat to American global leadership, and go out of their way to assure CCP leaders that export controls and other limitations are only for weapons systems. Even worse, many leaders in Europe selfishly portray this as a trade war between China and the United States, which the United States instigated to keep its power; not a conflict between China and the West that China instigated. This way, EU governments hope their firms can sweep in and take U.S. market share as it kowtows to Beijing.

One reason for this lassitude is most U.S. (and EU) economists and international trade think tanks see economic interchange as a win-win, based on Ricardian comparative advantage and specialization generated by market forces. Not China. It sees this as a war wherein there will be winners and losers, and they intend to be the winner and make the West into the loser. To be sure, this framing as techno-economic war is seen as extremist in the West because of just how deeply engrained the 200-year-old economics of trade and market-based allocation focus has become. Indeed, U.S. economic pundits have long scoffed at the very notion that America even competes with other nations. For them, only economic illiterates believe this. Indeed, as one DOC official stated during the Obama Administration when talking to an expert group to advise DOC on developing a national competitiveness strategy, "It seems wrong for us to try to compete with other nations. After all, we don't want to hurt them."[257] To paraphrase Trotsky, you may not be interested in techno-econ war, but techno-econ war is interested in you.

Imagine going to war when thinking that the enemy is both fighting and wanting to cooperate—and to the extent they are not cooperating, you think that it is they who will suffer. That is the idea that dominates too much of American and European thinking.

Even if some recognize that China has a different set of goals than Western nations do, many fail to take China seriously because they have bought into the increasingly fashionable claim that China's techno-economic policies are now simply to achieve self-sufficiency in the face of U.S. export controls and other measures to restrict China's access to technology.[258] Of course, China is seeking to reduce dependence in the short run, but its goal for many years before export controls has been to reverse dependence and make the Western nations dependent on China.

It is the failure to recognize that Summers is wrong and there are two very different economic systems with different rules that is the core problem for the West. The West sees national economies as not in conflict, but rather with specialization based on comparative advantage generating win-win outcomes. China sees competition as akin to war. As Xi Jinping stated, "Technological innovation has become the main battleground of the global playing field, and competition for tech dominance will grow unprecedentedly fierce."[259]

It is the failure to recognize that there are two completely different economic systems with different rules that is the core problem for the West.

Thus, the key issue is not about whether the Chinese system fits the Western system or even if the Western system can be improved within its intellectual confines. The key issue is whether the Western or Chinese system is superior. Surprisingly, Xi Jinping admitted as much when he stated to a CCP gathering, "Institutional/System advantage is a country's greatest advantage, institutional/system competition is the most fundamental competition between countries."[260] We should take him at his word. When Chinese officials talk to the West about win-win, moving to consumer-led growth, how the United States is trying to hold back China, or how it was the United States that started the trade war, we should not take them seriously. And it is amazing that so many outside China do. They are spinning propaganda. But when Xi talks about system competition, we do need to take him deadly seriously. He means it. He is arguing that the very techno-economic system China has constructed is their main advantage against the West—and in many ways he is correct.

Rather than reflectively dismiss the Chinese system as ineffective or even harmful, or to judge it on the basis of U.S. goals (allocation efficiency), the real question to ask is, "What system is superior when it comes to winning the global techno-economic war?" In China's conception, there are winners and losers, and the CCP wants to be the winner. And the way to win is to build up weapons (globally leading firms) and use them to destroy one's enemies (Western nations' advanced industry firms). At minimum, it is time for Western nations' experts and policymakers to open their minds and at least have a considered dialogue and debate about this point, rather than hide their heads in the sand and ignore China's aims and fall back on the inherent superiority of Adam Smith's and David Ricardo's classical economics model for free markets and free trade, especially the notion of all countries gaining from trade based on their comparative advantage.

Chinese and U.S. Economic Systems

As such, the U.S. (and Western) systems and China's are fundamentally different. (see Table 1). Most Western nations' comparative advantage is based on market forces. If the United States loses an industry, such as telecom equipment, it's because we no longer have natural comparative advantage and have moved on to other, inherently superior, activities. Indeed, no loss of technologies and industries can be problematic, because, by definition, their loss is always ordained by market forces and replaced by something superior. In contrast, China, as noted, seeks to win the global war for advanced technology leadership by supporting key firms in key industries, while attempting to reduce the market share of foreign competitors.

For most Western nations, especially outside Asia, the goal is consumer and taxpayer welfare. For example, tariffs are decried because they raise prices for consumers—a cardinal sin. For China, closed markets are a key industrial policy tool. In the United States, because they might waste taxpayer dollars, subsidies are decried, unless they are for "green industries." For China, they are just a cost of doing business. American experts favor a strong dollar because it is good for U.S. consumers (but bad for producers). The CCP favors a weak RMB because it's good for their producers and bad for foreign producers. In China, large firms are supported because they can win the global battle, even if higher prices domestically might result. In the United States, competition, and now "antimonopoly" (a reflective anticorporate doctrine) is privileged because today's consumers and workers might benefit.

Rather than reflectively dismiss the Chinese system as ineffective or even harmful, or to judge it on the basis of U.S. goals (allocation efficiency), the real question to ask is, "What system is superior when it comes to winning the global techno-economic war?"

Because most U.S. economists and pundits look at China through the American free market lens, they fail to see what China is actually doing. They look at China's overcapacity (producing more than a short-term, profit-maximizing firm would produce) as a failure of Chinese economic policy, something Chinese policymakers would fix if only they better understood economics. As former director of President Biden's National Economic Council, Brian Deese, wrote:

> China confronts an economic dilemma of lagging growth, low consumption and an elevated savings rate. This is partly the result of its highly unequal economy, in which workers are paid a smaller share of what they produce than in most maturing economies. A shift toward policies that support domestic demand, such as expanding the social safety net or even direct payments to households alongside more progressive taxation, could reduce inequality, increase consumption and support more sustainable economic growth. But instead, Beijing announced at its National Party Congress last month that it would ramp up investment in advanced manufacturing to export products overseas.[261]

Deese, like so many, is judging China's economic policies through a Western lens. China sees greater domestic demand and consumer spending as reducing needed investment. It sees increased exports as an important weapon for having its firms lead the world. Exported overcapacity is a weapon, equivalent to a cruise missile launched to destroy an enemy installation.

For the West, free trade is ideal and any deviation from it is a problem. It is ideal because it is only though market processes that optimal exchanges can take place, which by definition benefit buyer and seller. In contrast, China practices "power trade," wherein it uses trade policy to strengthen its own producers and weaken foreign ones, and thereby create foreign dependencies on China.[262]

When it comes to advancing technological innovation, the West's model is a linear one, in which the only appropriate role for government is investing in basic research that academics are interested in, an area economists argue the private sector will largely neglect. But this is the kind of research that has the most global spillovers, including to China. The Chinese model is to fund whatever research will help Chinese firms gain competitive advantage, especially applied R&D, which is more easily retained in China. As Yi Changliang noted, "[We must] guide scientific research institutions and universities to focus closely on the major scientific research tasks [prioritized by the government] and effectively integrate and optimize scientific research resources."[263]

The West's economic system is built around consumption, perhaps because of the almost permanent legacy of the trauma of the Great Depression and the imbedded, but faulty, Keynesian thinking that economies naturally gravitate to underconsumption. This is why almost all government spending and tax cuts are justified by claiming they will boost jobs (even when the economy is at full employment) and why automation is opposed by so many. U.S. policy is focused on jobs; Chinese policy is focused on creating globally powerful firms.

For China, the fact that consumer spending constitutes a much smaller share of its GDP is seen as a sacrifice that Chinese consumers make to ensure that the economy grows and becomes powerful.

But Macroeconomics 101 teaches that more spending does not create jobs unless the economy is in recession, which it usually is not. China doesn't care about consumption. It cares about investment; spending that generates a larger economy a decade from when it is made. For China, the fact that consumer spending constitutes a much smaller share of its GDP is seen as a sacrifice that Chinese consumers must make to ensure that the economy grows and becomes powerful. In the United States, there is alarm and finger pointing if the share of GDP going to consumers drops even 1 percentage point, because all that matters is short-term individual welfare, not the greater good of the nation in the medium and long term.

Moreover, there is no direction for Western economies, with perhaps the exception of getting larger (or smaller if you listen to the growing number of climate activists who tout "degrowth"). The very idea that the state would have interest in moving the economy in a certain direction is scoffed at. What could a bunch of pointy-headed bureaucrats know about the economy compared with the tens of millions of consumers and businesses making decisions on a minute-by-minute basis on what to buy and sell? Whatever structure of the economy emerges from this almost magical and holy process is the optimal one, albeit nowadays with the one exception now of climate pollution. But even for this, their answer is carbon taxes so economic actors' decisions take carbon pollution into account. In contrast, the CCP knows the direction it wants its economy to move in. It wants to be more innovative, and it wants a greater global share of advanced technology production in key industries (e.g., AI, aerospace, robotics, etc.) even if this is "inefficient." Building aircraft carriers and fighter jets is also inefficient, but Western nations do it because they know they need to for national power.

This relates to the issue of industrial policy and "picking winners." In the West, and especially in Anglo-American countries, it is *verboten* to argue that an industry is more important than any other, except perhaps nowadays with green tech industries and computer chips (the latter only because China might invade Taiwan).[264] This is why the notion of "computers chips, potato chips—what's the difference?" is still held by most economists. And this is why when the former head of a leading international trade think tank was asked how much manufacturing America could lose and still be OK, he said, "All of it."[265] No reason to have manufacturing. Services are fine. Yet, in China, power comes not only from the end of a gun but from the end of an assembly line. The last thing China would want is to evolve into a services economy, even if doing so somehow led to higher living standards.

China looks at investing in advanced technology industries the way the West looks at investing in military weapons systems. Economic returns are not the goal; power and security are.

The two systems also differ in their orientation to capital investment. The Western model is to not invest unless the net present value return of an investment equals or exceeds the cost of capital, especially in the short term. In this model, the risk of overinvestment is as serious as the risk of underinvestment.[266] There are some exceptions to this, particularly spending for national defense. Yet, few, if any, judge military weapons spending on the basis of overall economic rate of return. Rather, policymakers invest in weapons based on the amount needed to keep the nation secure. China looks at investing in advanced technology industries the way the West looks at investing in military weapons systems. Economic returns are not the goal; power and security are.

Finally, politics. The U.S. political system has always been, since its founding, one in which various interests and factions press to advance their interests. But it has also always been a system in which factions, under determined and visionary leadership, can and do regularly coalesce around the national interest, suppressing at least to some extent and some degree parochial interests.

America did that most recently throughout the Cold War. Alas, those days appear to be long gone. With the threat of Soviet domination long in the rear-view mirror, replaced with a triumphalist "end of history" view, America now appears to be nothing more than warring factions and tribes, each one proclaiming their goodness and others' villainy, and with neither side focused on international advanced industry competitiveness.

In the United States, individual interests vie for benefit. Unions want better jobs and more worker voice. Consumer groups want cheaper prices today. Small business wants lower taxes and fewer regulations. Wall Street wants a strong dollar and an even more financialized economy. Civil society groups want more followers and foundation money. The legal profession wants more litigation. Environmental groups want less pollution. Who wants a strong nation, especially if that requires giving up something? Can you imagine a president stating that U.S. trade policy will deemphasize industries not related to U.S. strategic interests, such as agriculture, financial services, low-wage manufacturing, and natural resources, and instead give priority to advanced industries? Hard to imagine. Not only would the economics pundits scream that potato chips are equal to computer chips, but Congress would immediately intervene to defend local industry interests.

In China, parochial interests are relegated to the CCP's overall goal of advancing technologically and winning the techno-economic war. The July 2024 "Resolution of the Central Committee of the Communist Party of China on Further Deepening of Reform to Comprehensively Advanced Chinese Modernization" states that it will establish mechanisms for major industrial investment funds to be "challenged to our country's *strategic needs*" (emphasis added).[267]

With the threat of Soviet domination long in the rear-view mirror, replaced with a triumphalist "end of history" view, America now appears to be nothing more than warring factions and tribes ... with neither side focused on growth and competitiveness.

Imagine during WWII if the United States had put consumer interests first and not imposed gas or tire rationing because consumers complained. Or if Ford and GM lobbied successfully to not convert to weapons production. Or if unions were told they could engage in unlimited strikes. America's leaders did not do that, and most interests accepted that because they understood that the national interest to defeat the Axis powers trumped self-interest. That is the spirit we need to have today in America to win the techno-economic war with China.

Business used to be able to speak with one voice in the 1960s and 1970s, with groups such as the Business Roundtable and business statesmen such as Irving Shapiro of Dupont and Reg Jones of GE speaking not only for their own companies but for the U.S. capitalist system and the overall nation. We seldom see that anymore. In his book *Doing Capitalism in the Innovation Economy*, Bill Janeway discussed how America had national missions from its founding: the Hamiltonian mission of building the country to be independent of England; the mission from Lincoln to FDR to become a great world power and ty the country together; and the post-World War II Soviet containment mission.[268] But today, America no longer has a unifying national mission that interests can rally around other than freedom for the Right, equity and redistribution for the Left (and the so-called "new Right"), and fighting climate change for many. Self-interest not only runs amok, but has become the new civic religion.

China has a national mission: to make China the most powerful country in the world. The CCP works to align most activities to make that happen. And that gives China an advantage in catching up. Before we hear the cries that ITIF wants to turn the United States into an authoritarian dictatorship: No, we do not. But we do believe that there is a middle ground between the CCP's authoritarianism and the every-person-for-themself principle that now characterizes U.S. politics and society. We used to be able to attain that balance, but we have lost it. Table 4 compares the Chinese and U.S. systems.

Table 4: U.S. and Chinese economic systems

	U.S. System	Chinese System
Overarching goal	Enable comparative advantage based on market forces	Win the global war for advanced technology leadership
Immediate goal	Consumer welfare (or worker welfare for the Left)	National power
Process	Allocation efficiency	Dynamic and productive efficiency
Types of trade	Free trade (or protectionism for the Left and new Republicans)	Power trade
Tool for tech progress	Fund basic science	Fund indigenous technology advancement
Rationale for investment	Invest for rate of return	Invest for market share
Means	Consumption (to keep full employment)	Investment
Technology	No direction	To lead in advanced technology
Focus on industry	Sectoral indifference	Strategic interests
Politics	Aggregation of competing private interests	National interests

There is a middle ground between CCP's authoritarianism and the every-person-for-themself principle that now characterizes U.S. politics and society. We used to be able to attain that balance, but we have lost it.

To be sure, the U.S. government has moved somewhat in this direction, particularly with the passage of the CHIPS Act. But that is best seen as a one-off effort, largely justified on national security grounds. It does not appear that this is a precursor to a more robust national industrial strategy to ensure continued U.S. global power, given both the unwillingness to cut spending and raise taxes to support true investment and because of the failure of U.S. leadership to embrace a new, "producerist" economic policy doctrine.

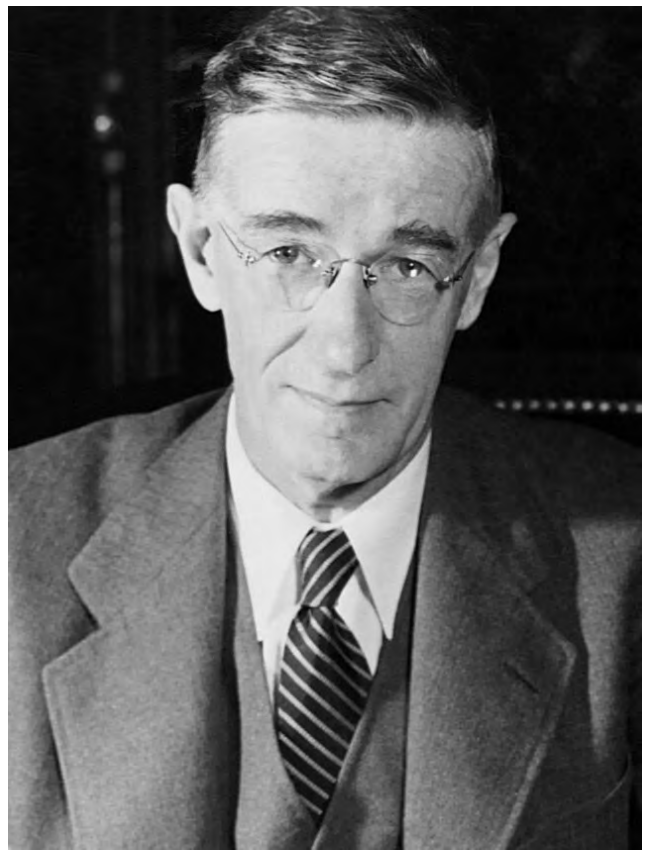
Contrasting Innovation Policy Systems

To achieve its goal of techno-economic power, China has built a different kind of innovation system, perhaps the first of its kind in the world. Most in the West, particularly the Anglo-American sphere, remain in denial of this reality, holding onto a historically unique conception of innovation, one which, when pared against the new Chinese model, is now seriously deficient. Just as the United States put in place a new innovation model beginning in the late 1940s (and adapted it in the 1980s and early 1990s to respond to the Japanese challenge), it is time to do this again, adopting what we call a "national power capitalism" model of innovation and production, wherein the role of the state is much more active and supportive of winning the techno-economic war with China.

The U.S. Innovation System

The U.S. archetypal model of innovation, first articulated in 1945 by MIT engineer and president Vannevar Bush, is the following: Government invests in basic science at universities and government labs, with the research projects selected by principal investigators following their own interests or by agencies pursuing national interests such as defense, space exploration, health, or energy.[269] At some point, through some undescribed process, the knowledge generated is used by entrepreneurs located in the United States.

Vannevar Bush



These entrepreneurs, while not plentiful, constitute a core part of the American system because U.S. culture, education, and immigration policy support individuals who think outside the box and want to take risks to disrupt industries. These heroic and creative individuals—such as Bill Gates, Steve Jobs, Jeff Bezos, Larry Page, Mark Zuckerberg, and Elon Musk—blend scientific results with other ingredients to develop something brand new (the PC operating system, the smartphone, e-commerce, the search engine, social networks, EVs, etc.).

And because of our free markets, limited taxation, and robust IP protection system, they can reap the rewards of their innovations while their products are able to compete fairly in the marketplace. For over at least 75 years, that has been the story Americans have told themselves about the U.S. innovation system—and because the United States has largely succeeded, at least until the last couple decades, few question that mythic narrative. Indeed, it is still held by most to be the archetypal innovation system, with all others being pale substitutes at best. As we will discuss, it is that intellectual commitment to the current U.S. national innovation system that is one of the biggest barriers that need to change. To be clear, the above, including robust IP protections, are a strength, but they are no longer enough.

In fact, this a very appealing and comforting story, and one that plays to America's strengths. We do have the best research universities in the world, even if funding levels have stagnated and China is gaining. We do have perhaps the most entrepreneurial workforce, and a high level of creativity and individuality. And compared with most economies, we do have free markets, light-touch regulation (at least until recently), and not onerously high business taxes.

Given that we have the best innovation system in the world—or at least we tell ourselves that we do—America should be dominating other nations on innovation, especially a communist, Confucian, conformist nation such as China, whose basic science is relatively weak, although improving. China squashes, rather than supports, free thinking. And it does not let markets alone drive development.

Yet, we are not dominating, at least not as much as we did. As noted, in 2020, China had a higher share of advanced industry output as a share of GDP in 7 of 10 industries than the United States did, with the United States leading in only biopharmaceuticals, other transportation (e.g., aerospace), and software and information services. And China runs a trade surplus in advanced technology products, while the United States runs a large trade deficit.[270]

And as this report shows, China leads or is on par with the United States in innovation in a few industries, including EVs and nuclear power; is making significantly faster progress in a host of other industries, including robotics, chemicals, and biotechnology; and is making progress in AI, quantum, and semiconductors. In many industries, we can expect China to catch up in innovation within just a decade or so.

Just as the United States put in place a new innovation model beginning in the late 1940s (and adapted it in the 1980s and early 1990s), it is time to do this again, adopting a "national power capitalism" model of innovation and production.

According to the U.S. conception of innovation, this should not be possible. At best, China should be a copier, regularly a generation or two behind the Western leaders, copying products and services, and gaining market share on the basis of lower prices. To be sure, that was the Chinese model for decades, but what most fail to realize is that this has not been the stated model for China since 2006 when China set its sights on becoming a robust innovator, first on par with the Western nations and then ultimately to lead.

Given that, according to the Western innovation playbook, America should be leading and China lagging behind, how can its system succeed when it is not structured like ours? Perhaps a better question is how can our system succeed given the strengths of the Chinese model, as enumerated ahead?

The U.S. system is based on generating scientific discoveries, but those are a public good that now are relatively easily copied and incorporated around the world. A half century ago, U.S. science was of almost no value to China because it had few scientists and engineers who could use such knowledge. Almost all the value went to the United States. But today, China has many more scientists than America does. Moreover, before the Internet, scientific information was hard to access. Today it is easy.

Our system is based on inventions by heroic entrepreneurs, but invention is also easily copied. Once an original, even radical idea is in the marketplace, it can be copied and reverse engineered, especially by a system that does not respect IP rights. Take nuclear power. Virtually every system the Chinese are building and improving on is based on inventions the United States made in the 1950s and 1960s but abandoned because of the lack of will to invest in building nuclear power plants. And these technologies were relatively easy to learn. Chinese nuclear scientists could read U.S. government reports from the era. They could and did visit our labs. Indeed, remarkably, Chinese researchers formed the largest category of international visitors to Oak Ridge national lab from 2007 to 2015.[271] This was something the U.S. Department of Energy astonishingly encouraged because they wanted the Chinese to have commercial nuclear power.

What the U.S. model fails to fully incorporate is just how much work, improvement, and innovation must be achieved to take an invention to full production. It's a bit like an iceberg: 90 percent of the work is underwater and comes after the headline-making invention. The United States excels at the 10 percent of invention, but often lags behind at the 90 percent of innovation and production. The reality is that much innovation is about iterative experimenting and tweaking. Edison understood this when he said, "Genius is 1 percent inspiration and 99 percent perspiration." James Bessen wrote in *Learning by Doing* that "knowledge and a long string of improvements follow for decades after the invention, continually altering the technology and skills needed."[272] In this sense, the U.S. model focuses on invention; the Chinese on continuous innovation and production.

The U.S. system is based on generating scientific discoveries, but those are a public good that now are easily copied and incorporated around the world.

The U.S. system is based on incentives for entrepreneurs and free markets in which they can sell their products. But incentives to make money cut both ways. The strongest incentives in the U.S. system are for the best and brightest to become glorified casino operators: financial traders who make a fortune manipulating markets and getting a millisecond edge on other traders, all the while adding virtually no value to the economy. And even when the incentives align to create something of real value, the incentives are often for discovery, not production. Witness the number of U.S. tech entrepreneurs more than happy to cash out by selling their companies to deep-pocketed Chinese companies. Moreover, there is plenty of money to be made in tech areas only tangentially related to national power and strength, such as cryptocurrency. The incentives for investing in deep tech (high-tech innovation in engineering or significant scientific advances) or hard tech (innovations in atom-based industries) are much weaker. This is one of the reasons for the establishment by the Pentagon of the Defense Innovation Unit to support entrepreneurial companies working in areas beyond software.

Finally, the U.S. system is based on a linear model based on the following: discover → invent → innovate → produce → go offshore, go bankrupt, or hopefully continue until broken up by trust busters → new discovery, new invention → invent, etc. (See figure 23.) Scientists discover knowledge, which can sometimes lead to something being invented if the knowledge is actually useable and transferred over the first "valley of death" to a domestic entrepreneur or business. That company must be able to move from prototype to full production (getting over the second valley of death). Once it does that, it hopefully expands production in the United States.

But all too often, if these technologies make it over the valleys of death, they are produced overseas. Or if they do enter production in the United States, they often fail to achieve commercial success, either because of foreign competition, often unfair in nature, or because of equity market pressures for companies to go “asset-light” and achieve short-term returns that limit adequate capitalization to achieve globally competitive scale and cost competitiveness. Or, as has been the regular practice for over 75 years, overly zealous U.S. antitrust officials bludgeon successful companies into small bits, later to die from lack of scale vis-à-vis foreign competitors—as they did with RCA, Xerox, AT&T, and IBM—and now are trying to do with leading tech companies such as Google.[273] But not to worry, we are told: The new cycle repeats itself. In fact, for some, such as Federal Trade Commission (FTC) Chair Lina Kahn, the faster we get rid of the large innovators, the faster U.S. innovation will be. If this were not such a tragic framing, it would be laughable.

The strongest incentives in the U.S. system are for the best and brightest to become glorified casino operators: financial traders who make a fortune manipulating markets and getting a millisecond edge on other traders, all the while adding virtually no value to the economy.

Fundamentally, the U.S. innovation system is a process-based one. Support antitrust enforcement and privilege competition. Support research funding. Support light-touch regulation. Support high-skill immigration. Build more infrastructure. If these processes are robust, the results will be robust. While this is no longer true, even if it were, the results do not guarantee that the United States will maintain the needed strengths in the key areas China is targeting for dominance, such as semiconductors, biotech, and aerospace.

Moreover, this ingrained belief in the superiority of the U.S. system is why most U.S. technology policy proposals focus not on changing this linear process, but rather on optimizing it. Not enough discovery? Fund more science. But scientists and engineers in many countries now attend international academic conferences at which U.S. scientists appear and read the scientific journals they publish in. Science is now a much more public (i.e., international) good than it was when Vannevar Bush advised President Truman to establish the National Science Foundation (NSF).

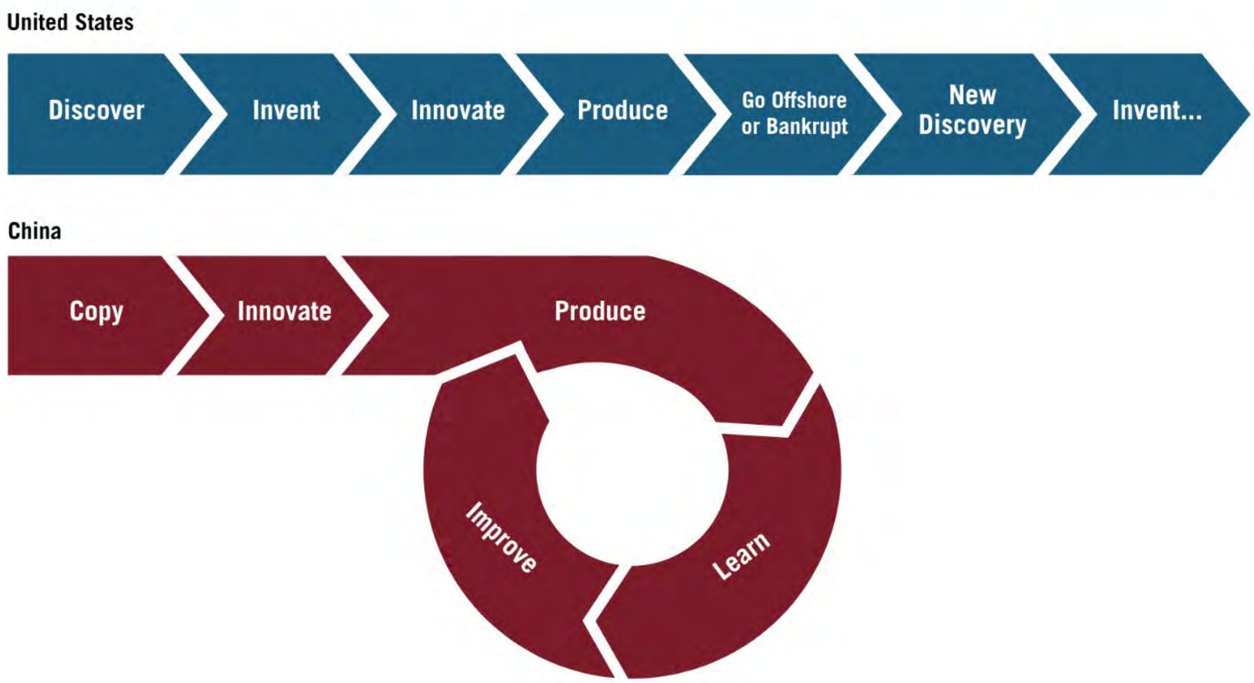
Not enough transfer of discoveries over the first valley of death? Provide more incentives to universities and federal labs to transfer and commercialize the results of their research while making it easier for entrepreneurs to utilize this research (e.g., provide R&D tax credits for start-ups, support seed and venture capital, etc.) And while you are at it, train more science, technology, education, and mathematics (STEM) workers and let more foreign STEM workers live in the United States. Support more entrepreneurs, including nontraditional ones. Ensure that entrepreneurs are free to commercialize and are not squashed by unfair competition from large companies. All good ideas, but none really address the issue of scale-up and economically sustainable production globally in the key industries China is targeting.

The U.S. innovation system has also evolved over the last 30 to 40 years into an overwhelmingly top-down system, focused on the end product and the customer experience/demand, long ago abandoning many lower levels of the value chain. To be sure, in many tech areas, the end customer is the most profitable value chain segment. However, a robust national innovation system requires competencies up and down the value chain—and it is far more difficult for the United States to move down the value chain than for China to move up. China engaged in a classic Clay Christensen attack from below and too many American companies succumbed by ignoring the bottom only for the top. Indeed, this is the essence of America's strategic dilemma, since innovation must occur at every level of the value chain, not just cutting-edge science and high-value customer-facing segments.

The current model of U.S. invents-China produces at scale is no longer sustainable if America does not want a technologically hollowed out economy.

To be sure, if invention is the goal, then it very well could be true that entrepreneurial market capitalism is the superior system. But if innovation at scale in key industries is the goal, then national power capitalism appears to be superior. The current model of U.S. invents-China produces at scale is no longer sustainable if America does not want a technologically hollowed out economy.

Figure 23: The U.S. and Chinese innovation systems



The Chinese Innovation System

While the post-war U.S. national innovation model was never optimal, it was mostly effective—until it came head-to-head with the new Chinese innovation model. China's model is fundamentally different than the U.S. model because it is based on a different goal—gaining advantage while at the same time degrading the advantage of competitors—leading to a virtuous cycle for its companies and a vicious cycle for their competitors. In particular, the advantage it seeks is not principally higher GDP per capita. It is relative national techno-economic strength. As China tech analyst Bill Wyman wrote, "China is most focused on hard technology with national security implications."[274]

Similarly, U.C. San Diego Chinese tech policy experts Naughton, Xiao, and Xu wrote, "Chinese economic policy under Xi Jinping shifts the ultimate objective of technology and industry policies from economics to security."[275]

An article in Qiushi, the website of the CCP Central Commitment Bimonthly, states:

> By seizing the rare opportunities offered by technological revolution and industrial transformation, some countries were able to rapidly build up their composite national strength and become world powers in one leap. At present, a new round of technological revolution and industrial transformation is gathering momentum, with key disruptive technological innovations giving rise to new industries and new forms of business.[276]

China seeks to attain that goal with a fundamentally different innovation model: rather than being linear from birth to death, and then a new birth, China's model is more circular. It starts with an injection of an innovation from an established source. For China, this can involve direct stealing of foreign plans and data (either by cyber or physical spying), copying and reverse engineering foreign technology, forced technology transfer from companies seeking Chinese market access, and sometimes licensing of technology from the leaders.

If invention is the goal, then it very well could be true that entrepreneurial market capitalism is the superior system. But if innovation at scale is the goal, then national power capitalism appears to be superior.

Once that technology enters the Chinese system, a positive cycle begins. (See figure 23.) Chinese companies (often many more companies than will end up surviving) start to produce the innovation, usually at a lower level of quality and lower price point. But because of robust levels of state support, as well as an often protected domestic market, at least some firms expand production. As they do, the more successful firms usually engage in rigorous, continuous incremental product improvement. This is often coupled with deep process innovation (changes in how the product is made), again often supported by government. As sales expand, and weaker firms go out of business, in part because of reduction in government support and a tougher economic environment, economies of scale increase, leading to a virtuous cycle of reduced costs and more R&D. At the same time, the large Chinese market enables more customer feedback, which leads to more changes, leading to more sales, and more profits, etc.

Profits are then reinvested in R&D (product and process) to help the companies attack more market segments where Western companies lead. All the while, the Chinese entrants erode sales of their foreign competitors (often the most profitable incremental sales where product development and production costs are fully amortized) leading the latter to often cut back on R&D or simply exit some segments, telling themselves that these are mature and "dogs" (in the vernacular of the Boston Consulting Group matrix).[277] No need to slog it out in this production war; just exit and move to high-value-added services and branding. Even better, sell out to the Chinese at a hefty premium (e.g., GE Appliances and Haier, Ingram Micro and HNA Group, Motorola Mobility and Huawei, IBM PCs and Lenovo, and Lexmark and Apex Technology). The short-term focus on U.S. equity markets, coupled with the intense pressure to only be in highmargin businesses, makes the Chinese strategy of buying foreign advanced tech firms at a price premium particularly effective.

China's model is based on gaining advantage and degrading the advantage of competitors.[278]

While this model of innovation might not get to radical "Schumpeterian" inventions, it can get to industry leadership in innovation and continuous improvement and increased global market share, which often weakens more innovative competitors.

In contrast, the American/Western linear model of innovation depends largely on good science, risk-taking entrepreneurs, and global market access. This is why both large and small countries can be successful with it. But even with all the spending on research, there are not really all that many fundamental breakthroughs such as gene editing, quantum computing, or deep learning AI models. Breakthroughs are rare. Scaling up and incremental innovation are not. Moreover, breakthrough leaders do not always end up being the ultimate leaders. There is a long history of the market winners being the second and third entrants.[279]

The Chinese circular model of innovation involves factors of success that are different from the U.S. model. These can be called the "10 S's":

1. **S**cience and Engineering Capabilities
2. Head **S**tart
3. Market **S**ize
4. **S**peed
5. Local **S**uppliers

6. **S**ubsidies
7. Firm **S**ize
8. **S**pecialization
9. **S**pace
10. **S**trategy

Let's examine each one in the context of China.

1. Science and Engineering Capabilities

Without strong science and engineering talent, it would be very difficult for China to "absorb and redigest" foreign innovations. Having a massive number of scientists and engineers lets Chinese companies throw talent at the problem of continuous improvement. Unlike the United States, which focuses on producing Ph.D. talent to generate new discoveries, China focuses on producing a large share of bachelor's and master's degree science and engineering talent, which can work in companies to help incrementally improve innovation. As Chinese scholar Wang Xiaodong wrote, "The key variable for determining the course of China's future development is thus the massive number of talented technical and scientific workers."[280]

For every U.S. R&D worker supported by $100,000 of R&D spend, a Chinese firm spending $100,000 on R&D can throw 2.3 workers at the problem.

One reason for this is the cost of Chinese technical talent is significantly lower than in the United States, allowing Chinese companies to put many more researchers and engineers on problems than U.S. companies can. In this case, quantity has its own quality. Using EU R&D 2,500 data, we can see that the number of R&D workers per million dollars of R&D spend is much higher in China than in the United States.[281] For example, in a random sample of 16 Chinese and U.S. firms, the R&D-to-sales ratio is about the same, but the R&D-to-employee ratio is 2.3 times higher for Chinese firms than for U.S. firms. In other words, for every U.S. R&D worker supported by $100,000 of R&D spend, a Chinese firm spending $100,000 on R&D can throw 2.3 workers at the problem.

Even as China has built up its own domestic capabilities, it continues to seek R&D capabilities from overseas, especially by attracting advanced industry and R&D facilities to China. The Chinese Ministry of Science and Technology recently wrote:

> Whether innovative resources can be efficiently allocated is an important consideration for foreign investors to set up R&D centers in China. Several measures are proposed to actively absorb qualified foreign R&D center science and technology experts into the national science and technology expert database and relevant local science and technology expert databases; improve the relevant work system for the transfer of intellectual property rights; provide quarantine approval facilitation arrangements; encourage overseas talents to apply for professional titles, etc.[282]

The key word here is "absorb," as China sees foreign investment through only one lens: whether it can absorb into the broader Chinese innovation ecosystem the capabilities and knowledge foreign firms can provide.

2. Head Start

China has achieved a head start in certain industries, and because of this, it has been able to tip the balance decisively in favor of its companies that are far down industry learning curves and have achieved decisive scale economies, enabling them to produce products—if not as innovative as Western ones, then at a much lower price point. This is related to the traditional infant industries argument, where it can be difficult for countries to enter industries with declining marginal costs if the leader has a head start. In cases where China has been able to get out in front, its comparative advantage can be almost insurmountable. We see the potential for going forward in drones and nuclear power where China is at least 10 years ahead of the United States; and now with EVs, where because of government policy, demand for EVs in China was at least a decade ahead of other nations. We may see it in the future with industries such as humanoid robots and potentially quantum computing.

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3. Market Size

Related to getting a head start, which vaults the Chinese companies ahead of their competitors, in many industries, China either has caught up (telecom equipment, batteries, and EVs) or is rapidly catching up (robotics and chemicals) by achieving significant economies of scale and learning. Economies of scale mean that the marginal cost of every additional unit is lower than the prior unit. Learning or experience curves mean that companies learn how to produce better products and produce the same product better as they produce more. As the China Institutes of Contemporary International Relations wrote, "Once a population of 1.3 billion people has grown wealthy, the result will be a supersized marketplace."[283] China understands this, which is why it usually shuts its markets to foreign companies when it has its own capabilities, and why it has put so many resources into its Belt and Road Initiative.[284]

China's strategy seeks to achieve scale by ensuring a large market. China does this through a variety of means. As the second-largest economy in terms of GDP and the second largest in population, China's market size is enormous, and that size advantage will only continue to grow, since Chinese labor productivity, as a less-productive economy, will also certainly grow faster than U.S. productivity for the next 30 or 40 years. Not only is China's market size enormous, but in many key industries, foreign companies are effectively precluded from gaining any significant market access. For example, Chinese telecom services firms have to buy a small amount of equipment from Ericsson and Nokia in order to give the impression of an open market, but the reality is that their market share is essentially allocated by the government, with most of the market reserved for Chinese firms. China imposes this managed market access through a variety of means, including tax incentives, directions to SOEs, and informal pressures on other firms to buy domestic.

On top of that, China's Belt and Road Initiative, coupled with massive export-financing programs to much of the rest of the developing world, means that China is aggressively fighting for and gaining market share outside China, especially outside Western nations. Also, once Chinese firms enter new markets, consumers get comfortable with them and they are in the pipeline, including having distribution networks. These become self-reinforcing.

China also uses government policies to expand market demand for innovative products and services, knowing that robust domestic demand for these products gives their companies a leg up. One of the keys in Michael Porter's national competitiveness "diamond" framework is demanding customers who want innovative products.[285]

China has those companies. For example, the government provides massive subsidies for robotic adoption, which in turn helps its robotics producers gain scale. China has at least 25 nuclear reactors under construction, far more than any other country. It is driving "smart industry" transformation, in part to provide a market to companies providing these services. It enables the rapid deployment of drone deliveries. Its policies to pressure and incent Chinese drivers to buy EVs is why China leads the world in EV development and production. It makes it easy for AV makers to field cars. It has some of the most advanced infrastructure projects in the world that incorporate advanced technologies.

This societal risk-taking and seeding of new markets through government policy gives China an advantage over many other nations where stasis and market-dominated development have become the norm. Companies seeking to develop and sell innovative products can be more assured of sales when the government helps drive technology transformation and adoption. It is striking that China now far exceeds the United States in terms of policies to expand adoption of advanced technologies. If anything, U.S. policy is now decidedly neutral or even negative toward societal technology transformation.[286]

It is striking that China now far exceeds the United States in terms of policies to expand adoption of advanced technologies. If anything, U.S. policy is now decidedly neutral or even negative toward societal technology transformation.

4. Speed

The Chinese innovation system is centered not so much in laboratories but in production systems. As such, there is a requirement for speed. Constant feedback and learning from the market are incorporated as quickly into the product design and production system as possible. Like scale, this enables competitors to constantly bring market improvements, with the core imperative of gaining market share and getting scale before their competitors can, hoping for a virtuous cycle of growth. This is especially true for private Chinese companies, particularly newer ones. In contrast, many of the foreign companies they are competing against are large, bureaucratic multinationals whose complex processes get in the way of speed. Local, provincial, and national governments more often than not want to get out of the way of companies moving fast, unlike the United States, where slowing things down is now standard fare.

5. Local Suppliers

Henry Ford's River Rouge factory in Detroit was a model of vertical integration. In the last half century, production systems have become more spatially distributed with multiple tiers of suppliers. However, speed and innovation often require close linkages with suppliers. When most suppliers are in close geographic proximity of the large original equipment manufacturers(OEMs), the process of sending requirements to suppliers (and learning from suppliers) and getting back new products is much faster. Most companies in the West have chosen globally distributed supply chains, in large part to cut costs by locating some or most of their production in lower-cost places. But that has come at the cost of speed and innovation. As professors Joshua Murry and Michael Swartz argued in *Wrecked: How the American Automobile Industry Destroyed Its Capacity to Compete,* one reason for the relative decline of the U.S. auto industry is the Big Three producers geographically separated production and R&D systems by moving so much of the former to low-cost regions.[287] In contrast, since China is still largely a low-cost production system, most Chinese suppliers are still in China, often in the same region as the OEM. In addition, because China specializes so much in manufacturing, and particularly in certain kinds of industries, it is able to enjoy rich and deep local production agglomerations.

6. Subsidies and Other Protections

Firms often have to compete in "unfair" markets, if only because many factors affect the value of currency. Hence, firms can find themselves with an uncompetitive cost structure in global markets even though they are doing everything right. But leaving this aside, firm competition plays out through several key factors, with price and quality being the most important. If one firm is provided subsidies (including a devalued currency), it has—all else equal—a competitive advantage over its foreign competitors that receive limited subsidies. The firm can use that advantage to cut prices and gain market share. It can boost its scale and learning economies. Or it can invest those subsidies in R&D and other areas to boost quality and innovation, again taking market share from its competitors.

China's subsidies are on steroids because of the intense competition for industry between its cities and provinces, which shell out massive funds to support local champions. And it ignores the supposed WTO disciplines on subsidies.

While a number of nations have relied on many forms of subsidies (low corporate taxes, tax incentives, grants, subsidized costs of inputs such as energy, and a suppressed value of their currency), by and large, the scale of the subsidies is usually limited, often by domestic political pressures from voters demanding lower taxes or higher spending to directly benefit them. At the same time, many Western nations implement various subsidy-limitation measures because they want competition to be on a level playing field. But China is exempt from all of those limitations. China's subsidies are on steroids, in part because of the intense competition for industry between its cities and provinces, which shell out massive funds to support local champions. And China flouts the flaccid World Trade Organization (WTO) disciplines on subsidies.

The magnitude and extent of Chinese subsidies has been widely documented. Though dated, Haley and Haley's book *Chinese Industrial Subsidies* documents just how sizeable these were and the role they played in enabling China to gain global market share in the 2000s. More recently, Center for Strategic and International Studies (CSIS) found, “Even using a conservative methodology, China’s industrial policy spending is enormous, totaling at least 1.73 percent of GDP in 2019. This is equivalent to more than $248 billion at nominal exchange rates and $407 billion at purchasing power parity exchange rates.”[288]

A new study from a German institute estimates, “Overall, industrial subsidies in China are several times higher than those in large EU and OECD countries. The size of the estimated difference ranges from a ratio of at least three to four in conservative estimates to a ratio of as high as nine in more encompassing studies.”[289]

In 2022, 99 percent of listed firms in China received direct government subsidies. For example, the German study finds that Chinese EV maker BYD has received over $3.7 billion in subsidies. Overall, in 2019, Chinese industrial subsidies were 4.5 times greater than the United States as a share of GDP, and that is accounting for the U.S. subsidies related to national defense.[290]

Hand in hand with subsidies are market access restrictions. The first directly helps a domestic company gain market share; the second helps indirectly by reducing the market share of a foreign competitor and increasing that domestic firm’s share. For example, when the Chinese government tells its state-owned telecom providers to stop using American computer chips in their systems, this weakens companies such as Intel and AMD, while strengthening Chinese companies such as SMIC.

While other Asian Tigers used subsidies and sometimes closed markets to develop industrially, they were limited in what they could do. At the end of the day, the Japanese and South Korean markets were just not that big to really make a dent in Western company global sales if they were cut off from market access. Moreover, as allies were dependent on the United States, they faced political limitations to what they could. China is different. Losing access to the Chinese market while allowing Chinse firms to have access to all of it structurally weakens non-Chinese firms while structurally strengthening Chinese firms. And of course, the United States has no real leverage over the Chinese government.

Losing access to the Chinese market while allowing Chinse firms to have all of it structurally weakens non-Chinese firms while structurally strengthening Chinese firms.

The West’s model is different. The predominant conception of economic and business competition is akin to an ecosystem that should be kept in balance (or more accurately, should not be put out of balance by government interventions). In this model, markets achieve allocation efficiency (the preeminent goal in neo-classical economics) where there is a “goldilocks” allocation of production, not too much of x, and not too little of x. This same self-adjusting model works across borders too, through the magic of Ricardian comparative advantage. In this model, the country that has the inherent comparative advantage in making a good (textiles in England) trades with other countries for something they have an advantage in (wine in Portugal). All is in balance. In this naturalistic conception, everything moves toward harmony, as long as government has open markets (limited protectionism) and free markets (limited subsidies and regulations). Heaven on earth—allocation efficiency! The maximum long-run production curve.

That almost utopian model is fundamentally counter to China's conception of economic competition. And as such, it is no longer fit as a valid model for operating an economy, unless the other nations could find a way to completely isolate the Chinese economy. In this case, China would boost its own champions and keep Western firms out, but it would not destroy the latter. The rest of the world could have free markets with no subsidies and all would be mostly well.

But even with talk of decoupling, that "solution" will not happen because the fastest growing markets in the world—those in the developing world—will not choose this path. Many are already tightly linked to China, in large part because of the massive amounts of foreign investment and aid China receives in these countries, and because these nations are loathe to choose sides between China and the U.S.-led West. And even if Western nations could find the political will to completely decouple (they won't because some countries, especially in Europe, refuse, seeking their own short-term gains in China at the expense of the collective good of the West), the resulting share of the global economy would be modest in size and gradually shrinking, given the much-faster expected growth rates of the non-Western world over the next multiple decades.

Finally, some will argue that the United States has joined the subsidy race and that all is on par. But while the CHIPS Act was long overdue, it's important to note that its grant funding of $49 billion is dwarfed by Chinese semiconductor subsidies of over $81 billion.[291]

7. Firm Size With Competition

Firm size matters in international competition. This is even more crucial given the increasing share of knowledge-based industries, with high fixed costs and low marginal costs, including telecommunications equipment, aerospace, semiconductors, drugs, and software. More sales means continual lower marginal costs and increased revenues to reinvest. And the size of a firm also matters because, for some industries (e.g., jet airplanes, jet engines, high-speed rail, logic chips, etc.), the high fixed costs of production means the global market can only support a few players.

Antitrust is much more aggressive in the West than in China. As long as massive firms are acting in the interest of the state, China not only tolerates them, but also encourages them to get even bigger.

China understands this and has adopted a strategy of industrial consolidation. Often, in part because of competition between provincial governments but also because the central government does not know what firms will ultimately emerge as winners, Chinese governments support more firms than makes economic sense. However, at some point, the central government institutes policies to separate the wheat from the chaff and winnow down the number of competitors. In many cases, this can take the form of forced mergers, as we saw with the creation of the China Railway Construction Corporation, its national rail champion. In 2023, China began a massive consolidation of its steel industry that will result in just 10 producers holding 60 to 70 percent of industry capacity by 2025.[292] In other cases, such as Huawei, it supports companies to be full-solution providers to telecom providers around the world, allowing it to bring to bear turnkey solutions that are much harder for more narrowly focused Western telecom equipment firms to emulate.

Again, this is very different from the West, where antitrust officials are on constant vigil to prevent firms from getting too large, worrying that they will harm allocation efficiency, resulting in what economists call "deadweight economic losses." That is why antitrust is much more aggressive in the West than in China. However, as long as these massive Chinese firms are acting in the interest of the state, China not only tolerates them, but also encourages them to get even bigger. Like so many Chinese policy areas, antitrust is used as a competitiveness tool: encouraging scale in domestic firms and attacking foreign firms, either by limiting global mergers of firms that, because they need to do business in China, must get Chinese government approval, or prosecuting foreign firms in China on bogus charges such as "price fixing" as a way to reduce their revenue and provide low-cost inputs to Chinese firms.[293] China knows that international techno-economic competition is like Sumo wrestling: Bulking up makes a big difference. It is also important to note that Chinese policy is often to encourage hyper-competition for new industries, with vastly too many firms entering into markets. The central government lets these firms compete and eventually limits support so that many go out of business, leaving only the toughest and most efficient. In this case, hyper-market competition weeds out the weak. This is very different than certain regions such as Europe, where antitrust and other policy keep less-than-fully-competitive firms alive for long periods of time.

In contrast, the U.S. system, not only in antitrust but also in economic policy more broadly, has historically been oriented around maximizing consumer welfare. As discussed ahead, the anticapitalists on the left and the "worker capitalists" on the right reject even that and want to maximize worker and small business welfare (who they see as no different than oppressed workers). In contrast, the Chinese system is oriented around one goal: boosting national techno-economic power. Consumers be damned. Workers? Who cares? Optimally, economic systems should be about boosting productivity, not consumer or worker welfare directly. But given that the Chinese system is about national economic power and supporting competitively strong internationally traded firms, unless the United States also makes this a priority, it will continue to lose.

8. Specialization

China goes deep, and that makes innovation easier. For example, unlike the United States, where a research university may have just a few professors working on a particular area, China has established research institutes where a hundred researchers are working on the same topic. For example, China has close to 50 graduate programs that focus on either battery chemistry or the closely related subject of battery metallurgy. By contrast, only a handful of professors in the United States are working on batteries.[294]

This is similar to other Asian Tiger nations that have large specialized industrial research labs, such as ITRI in Taiwan focused largely on electronics and South Korea's Electrotechnology Research Institute.[295] In China, we see this with its State Key Laboratories (SKL) program, which, according to one report, is a "method of teaming researchers and developers as a strategy to tackle hard problems [and which] has long been hailed as a successful model, as was seen with Bell Labs in the United States."[296] The over 500 SKLs are usually located at universities, although in the last decade, the Chinese government has funded private companies to form SKLs, akin to Bell Labs.

We also see this focus on specialization in Chinese government efforts to form advanced technology regional clusters. A Center for Security and Emerging Technology (CSET) report on SKLs notes that "to streamline the innovation process from basic to applied research, Beijing has co-located enterprises, universities, research institutions, and SKLs to form industry clusters."[297] One participant told ITIF that there are universities in China that only focus on battery research. For example, China's SKL for Physical Chemistry of Solid Surfaces employs over 100 researchers at Xieman University.[298] In contrast, NSF funds 19 Engineering Research Centers (ERCs) and a total of 79 since the program's inception, and only about half of these are focused on technologies that could be used in globally traded industries. A typical one, such as the Center for Innovative and Strategic Transformation of Alkane Resources, has only about 30 researchers, and few of them work full-time at the center.

Another example is China's system of Manufacturing Institutes, copied from the Manufacturing USA system. But one big difference is that in China, activities are colocated with institutes, companies, and R&D labs. For example, the Dongguan robot city is a government-supported robotics research institute anchored by over 400 Chinese nearby robotics companies.[299] These Chinese institutes are funded usually at least more than 10 times the amount of the U.S. centers.

9. Space

By "space" we mean the space given for innovators to take risks and test technologies, or what Adam Thierer calls "permissionless innovation."[300] For the most part, China's innovators not only face few barriers compared with what Western innovators face, but they are also often encouraged and supported by the government to take these risks. We see this, for example, with Chinese policy toward AVs they support.[301] Likewise, China is supporting futuristic smart cities, drone deliveries, smart agriculture, and more.[302]

Given the importance of first-mover advantages and large markets, such an orientation is a key edge for Chinese firms. Because the Chinese government is so desirous of innovation leadership, it has largely refrained from imposing restrictions on technology firms, except in a few industries wherein it does not see their interests as aligned with state interests.

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It may sound strange to argue that innovators in a communist society experience more freedom to innovate than those in a democratic capitalist system, but that is in fact the case. Europe has long placed regulation ahead of innovation, even convincing itself that regulation and limiting technology and (U.S.) technology firms actually spurs innovation by boosting consumer trust. And in the last decade, the United States and Commonwealth nations have begun to embrace the same view, seeing a wide variety of innovations, including AI, big data, facial recognition, AVs, drones, and more as requiring strict regulation in order to ensure that they are "human centered."

Moreover, another factor giving Chinese companies space and permission appears to be what Columbia professor Amar Bhidé has also called "venturesome consumption": the eagerness of a nation's consumers to be early adopters of and experiment with new products and technologies. The United States used to be strong in that, but it appears that Chinese consumers are more risk tolerant now and are seeking out the newest and most innovative products.[303]

10. Strategy

Finally, what underpins the Chinese innovation model is strategy for achieving its goal of gaining advanced technology advantage over its adversaries. By "strategy," we do not necessarily mean a formal document or process laying out steps. Often, Chinese tech policy is more akin to "crossing the river by touching the stones," an incremental process, sometimes involving mistakes and reversals, but always in the service of crossing the river: innovation leadership. And unlike the United States, where multiple, often warring factions competing in the interagency process related to tech, trade, and industrial policy make all-of-government solutions all but impossible, those kinds of solutions are the norm in China.

Coupled with that is China's a deep and wide expertise in government and academia in science and technology policy, a discipline that is largely ignored in America. In China, they study global science and technology policy, are deeply familiar with the literature, especially of that in the West, and use that expertise to effectively shape policy. In addition, Chinese science and technology policy for competitiveness is very intergovernmental, where not only does Beijing drive science and technology policy, but so too do the 23 provinces and the multiple large cities.[304]

Finally, China is not a democracy, and that brings benefits and costs, although at this stage of its development, this may bring more benefits. The CCP's control means that it has more leeway to ignore vested interests and focus on its overall mission to lead innovation.

Coupled with that is China's deep and wide expertise in government and academia in science and technology policy, a discipline that is largely ignored in America.

There is one other important aspect of the Chinese innovation system, and that is it has largely been built from the bottom up. In other words, China was long a laggard and a copier and competed in sectors and parts of businesses that were more commodity-like and lower value added. The West, and especially the United States, was more than willing to shed many of these segments, content in the belief that it was shedding "dogs" and embracing stars. China used that and moved up the value chain, creating what Clay Christensen has termed "low-end disruption." Li and Zhang refer to this as "late development advantage," where these nations can copy and build on the leaders' technology, but only if they embrace a development state.[305]

To be sure, moving up to original and high-end disruption is hard, but that strategy does have advantages in that it builds on itself, as we have seen the same strategy used successfully by the other Asian Tigers. This bottom-up, supply-side approach is why Chinese innovation and dependencies—the processing of rare earths, every part of a battery, process know-how, etc.—now occur at every level of the value chain. As discussed ahead, the United States shed too much, and the lack of deep competencies along the supply chain now serves as a hinderance to success.

Implications of the Chinese Innovation Model

While the Chinese innovation model is similar to what Japan and the Asian Tigers relied on to become innovation leaders, it is different in fundamental ways—the most important being the size of the Chinese economy, the level of control by the government, and the level of commitment to dominate in innovation across most advanced industries.

What does this "Asian-Tiger on Steroids" model mean for Western economies? If the latter were a completely closed economy with no trade with China, and had no need for their largest companies to sell much outside the West, there would be no negative impacts on Western industry from this Chinese innovation system. Their companies and workers could thrive in such a bifurcated economy.

This is what both progressives and the "New Right" seek as a solution to the China challenge. The progressives, including the Biden administration, seek a more closed U.S. economy immune from global competition. Former President Trump appears to want the same. But the reality is that the United States must do battle for foreign economic "territory" and cannot cede these markets to Chinese firms. The U.S. market, as large as it is, is too small to support healthy rates of innovation and production in most advanced industries.

That leaves the question of what the United States and other Western nations should do. To date, most are in denial, arguing that China is a paper tiger, and even that its economy is stagnating, if not declining. This is wishful thinking at best.

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Others deny that we are even in competition with other countries. They subscribe to the Paul Krugman notion that competitiveness is a "dangerous illusion."[306] Still others have an ideological commitment to the view that the Western model of innovation, especially America's, is so superior to China's state-directed capitalism that we should just stay the course and that China will eventually crash and burn, as they wrongly believe that Japan's economy did.

Others argue that the challenge is principally militarily, with China seeking to invade and to take over Taiwan. In this case, China could gain control of key parts of the supply chain, particularly semiconductors. This was the principal rationale for the passage of the CHIPS Act. But the threat from China goes beyond its possible takeover of Taiwan. There are a host of advanced industries China is seeking to gain dominance in.

Related to this is the concept of derisking, something EU officials have focused on to ensure that they are not like the Americans who supposedly focus on decoupling. Derisking is designed to identify some key products, such as rare earths, that China could control, and ensure that there is adequate production in either home of allied markets. Derisking is important, but the very concept implies that only a modest share of materials is at risk of Chinese control, rather than the entire advanced industrial base.

To the extent elected officials, experts, and pundits worry about the ability of the United States to effectively compete with China, the dictate is to do what we have been doing, only more and better. In an article about what the new conservative movement should do to address the China challenge, David Goldman wrote that Congress should massively increase federal basic research funding "to revive the system of public-private partnerships that allowed the federal government to subsidize basic research while leaving the risk of commercialization to private entrepreneurs."[307]

The liberal Center for American Progress agrees, writing that we should be "capitalizing on our existing strengths, including our unique innovation ecosystem."[308]

The Rand Corporation tells the Department of Defense (DOD) that "features inherent to the U.S innovation system—robust IP protection, the prospect of high returns to innovation and strong government-university-industry linkages—stimulate creativity, encourage innovation, and foster entrepreneurship."[309]

The Atlantic Council proposes a number of steps to effectively compete with China, including boosting government R&D funding, improving STEM, and "[c]raft[ing] a more diverse tech sector," and allowing more high-skill immigration.[310]

Thomas Mahnken, president of the Center for Strategic and Budgetary Assessments, summed up the conventional view best when he said recently:

> The U.S. system is superior to the Chinese system overall, so we're not going to enjoy success by trying to out-authoritarian the authoritarians. We're going to enjoy success by bolstering our system—and I actually say in a number of cases—becoming more true to the nature of our system.[311]

This has become the new Washington Consensus. If the old Washington consensus was about "market capitalism: fiscal policy discipline, no subsidies, a neutral tax code, and trade liberalization," the new consensus is about "support capitalism"—more R&D, more skills, and deregulation—but all the while staying true to the "U.S. model."

These kinds of solutions might have worked 30 years ago when the global scientific research circulation system was more limited and many countries did not have the capabilities to absorb that research. But today, it is a recipe for giving the Chinese a massive amount of knowledge. This is even more true given China's development of "a vast artificial intelligence (AI)-powered platform dubbed 'Supermind' to track millions of scientists and researchers around the world."[312]

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If the West generally, and the United States specifically, is to not lose the global innovation production race to China, it will need to more than simply double down on what has worked in the past. Tweaking or even making significant improvements to our system is no longer enough. To be fair, that is at least better than ignoring the challenge (either through massive spending on redistribution or budget cuts and tax cuts on individuals) or attacking U.S. technology leaders (e.g., aggressive antitrust actions against tech leaders and even more restrictive technology regulation). But incremental reform it is not enough. If the United States is to avoid becoming a second-rate technology economy dependent on China, it's time to "break glass" and craft a completely new national innovation system.

America's Challenge: Ideological Divergence

There are five competing visions for U.S. capitalism in the age of China competition, and each supports a fundamentally different approach to competing with the Chinese. As we argue ahead, only one—"national power capitalism"—has any chance of succeeding against China.

Market Global Capitalism

The first vision is market capitalism, the traditional doctrine in the United States, at least since the 1980s and on the right and center right. In this view, proselytized by think tanks such as the Peterson Institute and the Cato Institute, free markets and unfettered globalization are the best way to drive growth, and any alterations impose costs. Moreover, price-mediated markets are ideally global in nature. For free-market capitalists, the ideal economy is a giant, globally integrated market, wherein capital, goods and services, and people should be able to move anywhere, any time, with no barriers or limitations. In this world, there are "no winners that take all, we are all winners."[313] In other words, there is simply no way that Chinese policies can hurt us, because it's free trade and free trade is welfare maximizing for all parties. This is why the worst thing we can do is respond with "protectionism." And because they privilege consumer welfare, if the Chinese want to sell Americans products below their production cost, that's great for us. Cheap goods! As a result, they see a government that doesn't imbibe the drink of market capitalism as a barrier to this nirvana.

If the United States is to avoid becoming a second-rate technology economy, dependent on China, it's time to "break glass" and craft a completely new national innovation system organized around "national power capitalism."

A key component of the market capitalism doctrine is that market failures are few, and government failures rampant. In only a very limited number of cases, government intervention is required, but it's a bit like drinking: only in moderation.

As such, for them, there are two key mortal sins: 1) anything that limits unfettered globalization (what they disparagingly call "protectionism"), and 2) industrial policy, which, for them, is pretty much any and all government actions to alter market-based outcomes for particular industries.

It's important to realize that the free-market capitalist believers base their argument on one key factor: It doesn't matter what a nation's industrial structure is. Car rental, car production—what's the difference? In fact, whatever industries a nation has are optimal, unless a government is stupid or craven enough to try to alter industrial composition through industrial policy. After all, the market knows best, and Chinese investment and trade are part of the market.

The reality is that even if market capitalism produced optimal results in a world without China, it fails in a world with China. The reason is simple: Because of Chinese state capitalism, Chinese companies overinvest in certain industries China desires leadership in. By definition, that lowers capital returns, not only in China but also in other countries competing in the same industries. Thus, firms in market capitalist nations rationally cut investment in these sectors because they cannot earn market-based returns. As such, Chinese policy reduces U.S. capital investment in the sectors China wants to dominate, not only distorting allocation efficiency, but also weakening U.S. key sectors. The doctrine of market capitalism never conceived of such a system, and as such is incapable of coping with this reality.

As hard as it may be for many people to believe that the market capitalists actually believe the doctrine, they indeed do. When one head of a leading international trade think tank was asked how much manufacturing the U.S. could lose and still be OK, he said "all of it."[314] Likewise, Adam Posen, president of the Peterson Institute, recently stated (wrongly) that trying to revive manufacturing is sexist and racist, because manufacturing largely employs white males.[315] If the market capitalists were to acknowledge that America's prosperity and power depended on technologically advanced traded sectors, the entire edifice of their ideological framework would come tumbling down. They would have to acknowledge that their belief in global free markets could be problematic. This is why they regularly and so vigorously try to claim that all is well with U.S. manufacturing, even though the evidence says otherwise.[316] And for most of them, data, evidence, and logic will not change their core religious views. The only thing to change this is their retirement and, hopefully, replacement by pragmatists.

If you don't have to worry about industrial structure, you're pretty much free to just do nothing, and your main task is to be on the constant vigil of identifying inappropriate market interventions such as trade restrictions, the CHIPS Act, and other nefarious things that distort free markets.

This is why they deny that China is a problem. Who cares whether China gets all the manufacturing and other high-tech sectors such as software, because financial services and tourism is just as good, and likely even better since these are likely where America's natural comparative advantage is. At heart, they are Panglossians: Whatever world America is in is the optimal one, unless it is a world where the voting know-nothings have pressed for market-distorting policies, especially protectionism.

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Over the last decade, some market capitalists have made two concessions to reality. First, many now feel compelled to talk about distribution and fairness. After all, even they are not blind to the costs of Chinese industrial predation. But their solutions are not to address U.S. competitiveness vis-à-vis China, but to help the "losers," many of whom should just get a degree in finance or computer science. And their solutions are market supporting (such as an earned income tax credit) rather than market "distorting," such as supporting manufacturing or a higher minimum wage. Second, some now give lip service to the need to restructure our economy around the "green transition," but again, only with market-based solutions such as a carbon tax, or second-best solutions, such as the tax credits for green production in the Inflation Reduction Act (IRA).

Many oppose other kinds of industrial policy, including the CHIPS Act, because they not only remain agnostic about the nation's industrial mix, but they also see any help for industry as simply boosting profits at the expense of the proletariat. One leading former Obama administration official noted at an off-the-record dinner that he opposed the CHIPS Act because it would by definition raise profits of semiconductor firms, ignoring the reality that the act was designed to reduce the delta between costs of production in the United States and other nations, especially Asian ones. For him and others, the key is to identify "limiting factors" that can keep industrial policy from spreading, like some kind of out-of-control virus. Green-transition policies are acceptable. Income redistribution is acceptable. But pretty much nothing else is. But there is really no limiting factor to defense spending, other than to maintain superiority over our adversaries. That should be the sole limiting factor for U.S. industrial policy.

Overall, free market globalists scoff at the notion that China could win and the United States lose in advanced industry competition. They see it as not only highly unlikely but also completely irrelevant because there is no winning and losing in international trade.

Finally, the global free market camp sees the optimal system as one of unfettered trade barriers, even if the trade of one country is based on massive subsidies and stolen IP. The greatest sin is to erect any barriers to free trade. As WTO Director-General Ngozi Okonjo-Iweala, said:

> We are certainly concerned. We don't want to see a further escalation of these kinds of measures between the two big powers in the world. We would not want the world to fragment into two trading blocs, one with the U.S. and one with China, because that will be a big loss to the world. When we do these studies of such a break, it shows everyone would lose. The U.S. would lose. China would lose. And developing countries would lose more if we broke into two geopolitical blocs along those lines. So, we are very concerned.[317]

In other words, the better system would be for the United States to erect no barriers to trade with China while allowing China to manipulate its currency, provide massive subsidies, tie market access to tech transfer, and limit market access for foreign firms.

Market globalists scoff at the notion that China could win and the United States lose in advanced industry concentration. They see it as not only highly unlikely but also completely irrelevant because there is no winning and losing in international trade.

Market capitalism still guides much of the elite narrative on what the United States should do. A recent article in *Foreign Affairs* states:

> By offering large incentives to companies that invest in critical sectors in the United States, Washington could replicate some of the same problems that are plaguing China's economy: a reliance on debt-fueled investment, unproductive resource allocation, and, potentially, a speculative bubble in tech-company stocks that could destabilize the market if it suddenly burst. If the goal is to outcompete Beijing, Washington should concentrate on what the American system is already better at: innovation, market disruption, and the intensive use of private capital, with investors choosing the most promising areas to support and taking the risks along with the rewards. By fixating on strategies to limit China's economic advantages, the United States risks neglecting its own strengths.[318]

In a game that has been fundamentally transformed, the stubborn adherence to free market globalization is a weakness, akin to the French belief in the Maginot Line before the emergence of mobile warfare in WWII.

Finally, one argument defenders of market capitalism make is that it helps keep individuals free from government, with many on the right worrying that any expansion of government leads to a kind of totalitarianism Hayek warned against.[319] But in 1944, when Hayek wrote *The Road to Serfdom*, the Soviets were allies, so America could afford to imagine that we could survive with small government. But soon after the Soviet Union gave the green light to North Korea to invade South Korea in 1950, it became clear that the much more significant threat to American's freedom was not Washington, but Moscow. So both parties built the national security state, and under President Reagan's leadership, America defeated the Soviets. Today, we need a national power capitalist state to keep American freedoms intact from Beijing.

Support Capitalism

As the limitations of market capitalism have become clearer, particularly as an adequate response to Chinese state capitalism, a new, slightly more interventionist form of market capitalism has gained adherents, what can be termed "support capitalism." In this framing, global free trade is still the model, but now the government plays a stronger role in supporting R&D, boosting education and skills, supporting entrepreneurship, and of course, helping workers who have been hurt by globalization to adjust.

A seminal article by Kurt Campbell and Jake Sullivan, warning of the decline of the United States vis-à-vis China, discusses the notion of "support capitalism":

> Washington must dramatically increase funds for basic science research and invest in clean energy, biotechnology, artificial intelligence, and computing power. At the same time, the federal government should scale up its investments in education at all levels and in infrastructure, and it should adopt immigration policies that continue to enhance the United States' demographic and skills advantage.[320]

While support capitalism is undoubtedly superior to market capitalism, it remains structurally deficient to enable America to compete with China. It is based on the notion of "ingredientism," the belief that a nation can succeed principally by having robust quantities of the right ingredients. These can include more trade agreements, good universities, the rule of law, educated workers, good broadband, more basic science, etc. If government can just provide adequate ingredients and framework conditions, firms will prosper and effectively compete with China.

While support capitalism is undoubtedly superior to market capitalism, it remains structurally deficient to enable America to compete with China. It is based on the notion of "ingredientism," the belief that a nation can succeed principally by having robust quantities of the right ingredients.

But when competing with China, it's not just the quantity of the ingredients, it is also having the right ingredients to make the right dishes. If China is seeking to dominate particular key industries, a policy that does not respond with recipes that focus on these industries will lose.

Moreover, ingredients are not enough to build regional technology hubs, start-ups, and high-productivity firms. Policy needs to be focused on getting firms to take the kinds of steps that will lead to long-term success against Chinese firms.

Anticorporate Capitalism

As the flaws of market capitalism have become more widely accepted, progressives have used them to advance a counter-doctrine of anticorporate capitalism. For them, corporate capitalism is the source of climate disaster, racial and gender oppression, inequality, the breakdown of democracy, worker victimization, and every other ill that can be imagined. They want small and mid-sized enterprises to dominate, or in industries where scale economies or technological complexity makes that impossible, heavy regulation or government ownership. They oppose investing in advanced industries because the money goes to corporations (something to be avoided at all costs), and instead call for massive government spending (or tax breaks) for childcare, housing, education, mass transit, distributed energy, universal basic income, and retirement security, all of which they portray as investment and even industrial policy. For them, the China challenge is irrelevant, and to the extent people call it out, they are racists. Anticorporate capitalism paves the road not only to the United States losing to China, but to U.S. de-technologicalization.

If market capitalists want the government to do nothing, anticorporate capitalists want it to do everything, including replacing large business. It is ironic and troubling that at the very moment America is in desperate need of an all-of-society, all-of-government approach to not losing to China in advanced industries, the Left has coalesced around an anti-big business doctrine and agenda.

Anticorporatists deny America is in competition with other nations, not only because of their desire for global wealth redistribution but also because they know global competition makes it harder to put in place a raft of needed policies they disdain, such as lower business taxes and limited regulations.

Like free market capitalists, they deny the importance of any particular industry over another, with the exception of green industries and social care industries, both of which are elevated to a privileged status: the “green, care economy.” For them, the most important aspect of the CHIPS Act was not building fabs, but rather requiring day care centers at fabs and compliance with Davis-Bacon construction labor requirements.

This gets to why both the libertarian Right and the anticapitalist Left deny the China challenge so vociferously. They know that if policymakers take China seriously, it destroys both the antimonopoly movement and the free-market movement. Libertarianism becomes thrown on the scrap heap of history because the state is needed to keep American industry strong. And for the anticorporatists, it means supporting large corporations. Lina Khan threw her weight into this revisionist effort with a recent speech at the Carnegie Endowment and an article in *Foreign Policy*, in which she declared, “To stay ahead globally, we don’t need to protect our monopolies from innovation—we need to protect innovation from our monopolies.”[321] In other words, it’s OK to break up big companies, it will even help us compete with China.

However, unlike the free market capitalists, the anticorporatists reject globalization. For them, globalization brings competition, something they abhor, in part because it limits the extent to which government can impose taxes and restrictions on business. Anticorporatism is economic isolationism and autarky, disengaging from competition with other nations (thereby allowing the government to impose any and all anticorporate policies with no impact on competitiveness) and not only ending trade expansion but reversing it. This is why we hear almost nothing from U.S. Trade Representative (USTR) Katherine Tai. Her job is not trade expansion; it is trade contraction.

The anticorporatists deny America is in competition with other nations, not only because of their desire for global wealth redistribution, even at costs to the U.S. economy, but because they know global competition makes it harder to put in place a raft of needed policies they disdain, such as lower business taxes and limited regulations. If the United States is relatively autarkic, such as before the 1970s, tax and regulate to your heart's content—we won't lose any jobs to nations that don't follow this path. Moreover, most anticorporatists see not only the U.S. proletariat as a victim of U.S. capitalist greed but also the great masses in developing nations, including China. They advocate for policies to support the global proletariat over U.S. companies, denying both the very idea of the U.S. national interest and the deep link between U.S. company interests and U.S. national and worker interests.

Finally, their goal is not competitiveness, as that is something they fear might help American capitalists instead of the global proletariat, especially people of color. As bizarre as it sounds, most anticapitalists side more with the Chinese (and third-world) proletariat than with U.S. companies. Economist Joe Stiglitz, who pushes for weak IP protection in the United States so that developing countries can pay less for U.S. IP, is a case in point.[322] This is why they want to do everything possible to avoid techno-economic competition with China, advocating instead for cooperation.[323]

Worker and Climate Capitalism

There is another contender to replace market capitalism as the dominant doctrine and that is what could be called "worker and climate capitalism." Indeed, there is one form of industrial and trade policy that is now at least somewhat acceptable across the political spectrum: using government policy, including trade and industrial policy, to support "noble" goals, which include using manufacturing policy as social policy to create more blue-collar jobs and industrial policy as green policy.

Many on the "new right" attack market fundamentalism for ignoring blue-collar workers and advocate for a robust focus on manufacturing.[324] New-right pundit Sohrab Ahmari writes that dismantling the neoliberal order requires "a labor market in which most sectors are unionized" and a higher minimum wage for all workers, giving labor the "security needed to mount countervailing power in the absence of labor organization."[325]

Bob Lighthizer's book *No Trade is Free Trade* is emblematic of this, as he wants to reorient trade policy to focus first and foremost on helping American workers, particularly blue-collar workers. In this doctrine, high tariffs on all manufactured goods are a positive because it will help manufacturing workers. Leaving aside that high tariffs on imported goods might actually hurt many U.S. manufacturers, the problem with worker capitalism is that it is not strategic vis-à-vis Chinese industrial competition. Making either jets and jars employs blue-collar workers, but only the former is strategic relative to China.

The Biden administration's worker-oriented trade policy is of the same making. USTR Tai recently stated:

> The Biden-Harris administration's approach to trade has been to democratize economic opportunity. We are breaking out of the technocrats' bubble to meet working people where they are, redesigning the incentive structure so that communities are not pitted against each other. For example, for a long time, workers in Ohio or Pennsylvania or Arizona have been set against workers in Mexico, where rights have been unfairly suppressed. This is what happens when we blindly believe that liberalizing trade rules leads to a gradual improvement in labor standards as countries grow wealthier through trade flows. We are flipping this narrative on its head, using a trade agreement.[326]

The problem with worker capitalism is that it is fundamentally indifferent to industrial competition. Making jets is the same as making jars.

This doctrine privileges workers, rather than the nation. For example, it often leads to opposition to automation on the grounds that it hurts workers. It also leads to an "all is good" approach to trade policy, where low-skill jobs are as good as high-skill ones. As such, it is largely a social policy doctrine—helping particular kinds of workers and the environment—that has the political benefit of appealing to voters in many presidential swing states.

Some on the left and center argue for the same goal, but will often add in "green jobs" and the green transition as the lodestar of a new kind of "climate capitalism," wherein all policies are oriented around decarbonizing the global energy system.[327] Their agenda is not just about supporting clean energy production; for some on the left, it is much more ambitious and calls for "reforming capitalism" itself, often involving "degrowth." Others, such as former Biden economic official Brian Deese, argue that the United States can regain competitiveness by leading the green economy.[328] However, the green economy simply cannot be the focus of an industrial policy designed to prevent China from winning, because energy sectors are too small.[329] More problematic, the green industrial agenda diverts needed attention from the China competition agenda.

Terms Used to Describe Chinese Trade and Economic Practices

Trade imbalances: Pudits use the term "trade imbalances" as if it's just something that happens, as it's a bit out of balance. In fact, systematic and large Chinese trade surpluses in advanced goos are not happenstance; they reflect a strategy in the service of techno-economic aggression.

China shock: Pundits refer to the massive offshoring and influx of products from China in the 2000s as a "shock," similar to the oil shock of the late 1970s. Likewise many suggest that the West may face a second China shock in a range of new industries, including EVs. Again, this implies that these are random, one-time forces of nature. It would be like saying that the invasion of a country is a shock. No, it is an invastion.

China as a trading partner: Canada and the United States are trading partners, as are Finland and the United Kingdom. "Trading partner" implies a country that is playing by the same rules and the result being mutually beneficial. That does not describe China's power trade to gain dominance in advanced industries.

Chinese excess capacity: This refers to industries such as steel, solar panels, and now EVs, and implies a temporary mistake. Oops, we overshot the market and are now producing too much. No, Chinese excess production is a form of predatory dumping to gain global market share.

Critical supply chain vulnerabilities: COVID was traumatic and, like other kinds of trauma, led people to the wrong conclusions. One is that the core challenge from China is supply chain vulnerabilities. At one level, this is correct, but some vulnerbilities don't really matter (e.g., industsries that are easily reproducable and have little national security implications), while some do (e.g., certain computer chips).

Derisking: This is a term the EU popularized as a way to show that it does not support the more hard-edged U.S. approach to China. It is based on the idea that the main techno-economic challenge from China is in a few narrow areas, such as critical materials, and that the West should take some narrow strategic steps to lessen dependency. The issue is not so much derisking, as destruction; in other words, Chinese actions that lead to reduced market share for advanced Western firms.

National Power Capitalism

The fifth model—one that is barely developed in the United States—can be called "national power capitalism." It is time to copy key elements of the China model and transform the American system to "national power capitalism," or as Michael Lind and I have written elsewhere, a system of national developmentalism.[330] National power capitalism is a subset of national developmentalism—the idea that the state plays a strong and conscious role to drive economic development. The former is more focused on policies that retain and gain techno-economic power over China.

National power capitalism is premised on the reality of states competing with each other, not in some kind of Ricardian win-win, but in a more existential competition for power. Market-based economics and even support capitalism deny this reality and still believe in the win-win, Ricardian utopian vision. These doctrines are not adequate for a situation that is akin to a win-lose techno-economic war. Just as winning a kinetic war requires national defense policy, winning a techno-economic war requires a national advanced technology policy, grounded in national power capitalism. If economists were in charge of defense policy, they would say, "Don't fund aircraft carriers or advanced jets because the cost-benefit is negative and there is no market failure." But we fund national defense because not doing so means giving up U.S. sovereignty. The same should be true for funding national advanced technology capabilities. This is not about market failures or narrow cost-benefit analysis; it's about not losing national power.

It is goal oriented, just as defense policy is goal oriented. U.S. weapons policy is not process oriented. It's not as if officials say, "Let's make sure procurement is streamlined and see what weapons get developed." Rather, the various defense forces identify their needs, and the system works to achieve those goals. That's what national power capitalism needs to do: We need a robust biotech industry, chip industry, aerospace industry, AI industry, etc., and then to design and implement policies to achieve that.

Immediately we can hear the cries of "We don't want to be like China." Some pro-market advocates invoke the incantation to object to what we are already doing, such as passing the CHIPS and Science Act. But for most who say this, it has become some general phrase that is required as part of the discourse about U.S. advanced industry policy, although seldom are any specific reasons given. It's as if we all know that we shouldn't be like China, yet we should embrace the Chinese model, but with American characteristics. As the Chinese say, they have capitalism with Chinese characteristics. We need a similar kind of system but with American characteristics.

One can hear the accusations now. You want the United States to limit democratic freedom? To not have the rule of law? To have heavy-handed government? Clearly there are many components of China the West should not copy: first and foremost, its Marxist-Leninist government with its authoritarianism, its rejection of human rights, high levels of corruption, lack of the rule of law, immiseration of the working class, government manipulation of technical standards, weak IP protection, and support of firms with massive subsidies that have no chance of survival without Chinese cash.

Just as winning a kinetic war requires national defense policy, winning a techno-economic war requires a national advanced technology policy, grounded in national power capitalism.[331]

However, we can walk and chew gum at the same time and emulate the many parts of the Chinese innovation system that would benefit us: China's high levels of investment, rather than spending. Its overarching focus on winning in selected advanced industries. Its building up strong levels of domestic agglomeration. Its becoming much faster and limiting the regulatory morass that in the United States has become reflexively "no." The widespread support for innovation and progress. The Chinese government's relatively deep understanding and embrace of science and technology policy for competitiveness.

As such, it's time for an open and honest debate about whether doubling down on the U.S. system is enough to address the unprecedented China techno-economic challenge or the U.S. government needs to adopt a new form of "national power capitalism": a system that relies on private companies, many of them very large, to fight our global techno-economic war, and also provides them with significantly more support (tax and direct spending) focused on significantly expanding techno-economic R&D and production in the United States in critical industries. A system that is more activist than "support capitalism," but less directive than China's state capitalism.

It's time for an open and honest debate about whether doubling down on the U.S. system is enough to address the unprecedented China techno-economic challenge or the U.S. government needs to adopt a new form of "national power capitalism."

A U.S. "10 S's" System

What would a U.S. national innovation system that were modeled after China's "10 S's" look like?

1. Science and Engineering Talent

The U.S. science system, like so many other U.S. systems, is no longer purpose fit for a world in which China is the pacing competitor. In the current model, researchers pick the areas of research. In a new model, the federal government and industry would prioritize key areas where China is a threat. In the current model, the federal government provides the lion's share of funding. In a new world, industry funding, incentivized by the federal government, would play a key role, including in the production of industry-oriented Ph.D.s. In the current model, publications are the key goal. In a new model, transferring knowledge to the domestic private sector would be the key goal. In the current model, science is seen as global, so cooperation with Chinese scientists and university students is an unalloyed good. In a new model, science cooperation with China would be seen as fraught with risks and largely stopped, and more focus placed on applied research.

To emulate China, the United States needs more and stronger scientific and engineering talent, but that talent should be 1) oriented to industry more than academia and 2) aligned with the key technologies and industries the United States must be competitive in. In contrast, the U.S. system is now focused on generating university researchers in whatever fields the researchers are interested in. Instead, the **college and graduate school system should be providing incentives for students to major in science (particularly fields related to competitiveness such as materials science, biology, engineering, and computer science).**

It is time to stop doubling down on science and hoping NSF will effectively support commercialization and innovation (it is not likely to) and instead **establish a National Advanced Industry and Technology Agency that supports technology development in the United States instead of science for the world.** This means the federal government, especially NSF and the Department of Energy, cease science cooperation with China. Just one of many examples: NSF is working with the National Natural Science Foundation of China and Beihang University, which is on the entities list, to fund quantum computing research.[332] In addition, **the federal government should not provide funding to any university that allows Chinese STEM post-doctorates, because they are unlikely to stay in the United States.**

Finally, U.S. research support has become risk averse. In contrast, the Chinese government appears more willing to fund things that have a higher chance of failure. Our research system needs to take bigger risks and more "swings for the fences."

2. Head Start

With the exception of a few certain technologies, such as AI and biotech, it has been decades since the United States had a head start, not just in invention and early-stage innovation but also in production. The United States needs to regain that in a number of industries, such as weapons systems, automation technology, autonomous systems, synthetic biology and other advanced biotechnologies, and quantum computing. **This will mean selecting key technologies and industries America can obtain a head start in, massively funding R&D, and then providing incentives to establish U.S. production facilities.**

3. Market Size

For many industries, adequate scale is not possible without global markets. This means the recent policy of retreating from global expansion must be reversed. This does not mean reverting to the prior era of globalization, which sought the creation of the one true global market and engaged in one-sided trade deals. The China challenge makes that an ill-advised, and impossible, strategy. But the opposite of trying to win as a largely national economy is just as ill advised.

Instead, **we need to create a new democratic, market-based trading bloc, ideally governed by a new organization separate from the WTO**, which is now compromised in pushing back effectively against Chinese unfair economic practices. It's time to create an alternative to the WTO that only accepts as members countries committed to fair trade and the rule of law.

Policymakers also need to ensure that the U.S. market is large enough and U.S. companies can adequately achieve scale globally. This requires three key things. First, a policy toward the dollar that lets it decline to a level where the trade deficit disappears. Regardless of macroeconomists claiming that the trade deficit is a result of a lack of savings, the reality is that the U.S. dollar's status as the reserve currency, and China's commitment to keeping the RMB low, is the principal cause of the U.S. trade deficit. **It's time for the Treasury to take determined steps to devalue the dollar.**

Second, we need to limit Chinese access to our and other allied markets when its firms are benefiting from unfair policies and practices. This should be simple. It is not protectionism. Protectionism would be limiting Chinese firm access even if the firm were completely market-based. As such, **the United States and its core allies, especially Europe, should identify Chinese firms that systematically benefit from more than de minimis unfair trade practices and block their market access**.

Third, **U.S. policy needs to make fighting for market access in unaligned nations a key priority.** This means steps such as Export-Import Bank expansion and aligning of U.S. aid policy with U.S. international economic imperatives. China sees market entry and expansion in the "unaligned" nations as critical to its plans to dominate industries. Through its massively funded export finance and development banks, China has been bribing the way for its industries to capture contracts and influence around the world. For them, it is a battlefield. For American policymakers, it is something that is nice to have, but not critical. U.S., and allied, policies need to make contesting unaligned markets a top priority.

Fourth, policymakers should not succumb to the many forces that want to decouple from China, especially those voices saying that U.S. companies should not sell or invest in China. Selling to China is a way to make our market larger and theirs smaller. Investing can do the same.

4. Speed

When Calvin Coolidge said that the business of America is business, America had speed. Innovators and builders could get things done, in rapid time. It took just 410 days to build the Empire State Building, the tallest building in the world then. Today, it takes decades to build big things, if they can ever get built at all. Congress and the next administration need to tear down many of the massive speed bumps, if not outright roadblocks, that keep enterprises from acting with speed. Maybe America could afford those in the pre-China competition days. It cannot today.

This should start with Congress repealing most or all of the National Environmental Protection Act (NEPA), with it only applying to projects on federally owned lands. States and local governments can manage their own local environments. This means regaining the mindset the federal government had when Operation Warp Speed was implemented in record time (although even then, there were unnecessary delays).[333] Mass producing a vaccine for COVID-19 could have gotten America motivated to break through the nonsense. Not losing to China should be equally as compelling a motivation.

This means not banning technologies. It means massive testbeds for new technologies, such as AVs (we have only one track in Michigan for testing). It means ending the paranoid narratives around AI and instead focusing national efforts and energy on speeding up AI development and deployment. It means that when Congress creates programs such as the Broadband Economic and Development (BEAD) program and the CHIPS Act that the administration agencies don't take years to finally get the programs rolled out. **Any program Congress creates should be fully funded in no more than 12 months.** As one working group participant said, "It's like America's hand and feet are bound, while China is sprinting away." Time to unleash our entrepreneurial energies.

5. Local Suppliers

Ever since Northern and Midwestern manufacturers started shifting production to the lower-cost South and Southeast in the 1950s and 1960s, local agglomeration of suppliers has weakened. That process only accelerated in the 1970s through 1990s to places such as Southeast Asia, and to Mexico and China since then. To be sure, some global division of labor is required when labor-cost differentials are so high. But too much production dispersion hollows out productive supplier agglomerations, limiting innovation. A much weaker dollar would help this, as would instituting a border-adjustable value added tax (with the revenue being used to pay down the debt and reduce the business tax rate). **An investment tax credit in new buildings and equipment would also help.**

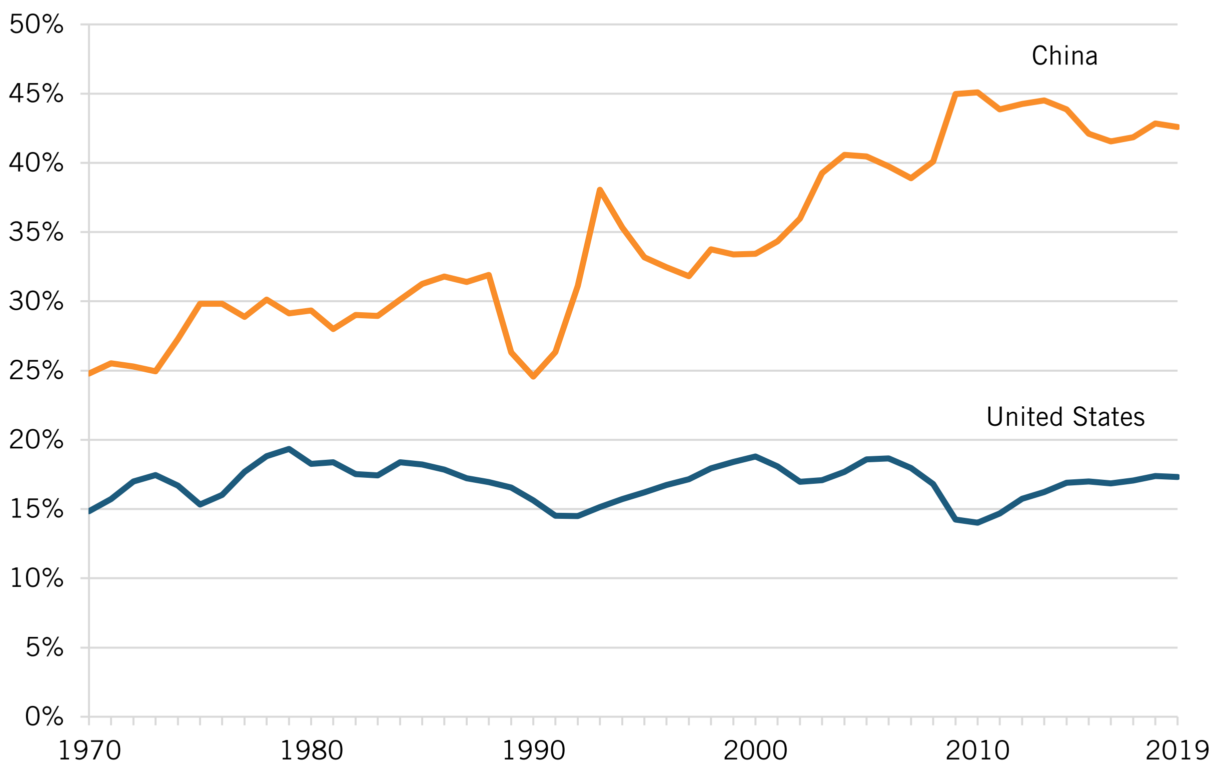
Not since Henry Ford's River Rouge factory have companies been as vertically integrated. Now production systems are distributed with multiple tiers of suppliers. Speed requires close linkages with suppliers. When most suppliers are in close geographic proximity to an OEM, the process of sending requirements to suppliers (and learning from suppliers) and getting back new product is much faster. Most companies in the West have chosen globally distributed supply chains, in large part to cut costs by locating some or most of their production in lower-cost places. Since China is still largely a low-cost place, most of its suppliers are in China. In addition, because China specializes so much in manufacturing, and particularly in certain kinds of industries, it is able to enjoy rich production agglomerations. As noted, American companies have gone too far down the top-down route, letting less-profitable segments go, usually to Chinese competitors. America needs to rebuild a much deeper and robust supply chain, including in intermediate segments.

6. Investment, Subsidies, and Other Protections

No legitimate economist would believe that, over time, a firm that is subsidized by the government could outcompete a firm that is not. And yet most economists turn a blind eye to Chinese subsidies, or even disparage China for being so dumb for misallocating capital. The stark reality is that the United States will not be able to be competitive in a range of advanced industries if the federal government does do not significantly boost industrial subsidies, via either direct spending or tax incentives.

The short answer is we need vastly more real investment in the U.S. economy. Figure 24 compares national investment in the United States and China (public and private). For decades, as a poor nation, China invested a lower share of its GDP in investment. But by 2003, the lines crossed, and now China invests about 75 percent more than the United States does.

Figure 24: Private investment as a share of GDP in China and the United States[334]



Congress took a step in that direction with the CHIPS Act and the IRA tax incentives for clean energy industries. It should be clear to any unbiased observer that absent the CHIPS Act, U.S. fab production would continue its long, steady decline. With the act, the United States has a real chance to significantly boost its global share of semiconductor production. But why only for semiconductors? While it is a critical industry, so are many others. While it is unlikely Congress can match the scale of Chinese industrial subsidies (including tax measures), **Congress and the administration should set a goal to triple U.S. industrial subsidies annually.** There has been some gradual recognition of this reality. Recently, Brad Seltzer argued that the federal government needs to provide "launch aid" subsidies for Boeing to bring to market at least two new airlines.[335]

To those who say that we cannot afford it, there are plenty of revenue streams to pay for this, including a border-adjustable value-add tax, a carbon tax, or taxing dividends as normal income. Most policymakers support a strong national defense budget, not because they believe it generates economic returns (although defense spending does create technology spillovers), but because it keeps our nation strong and secure. It's time for more policymakers to view techno-economic investments in the same light: key investments to keep our nation powerful.

The stark reality is that the United States will not be able to be competitive in a range of advanced industries if the federal government does not significantly boost industrial subsidies, via either direct spending or tax incentives.

Moreover, if Congress took the China challenge truly seriously, it would have done something quite different and far bolder than the CHIPS and Science Act, as important as that was. Congress would have created a National Advanced Industry and Technology Agency dedicated to working closely with industry.[336] It would have appropriated far more money and required that most of the money be spent in university-industry research partnerships to support industries and technologies threatened by China.

7. Firm Size

China knows that size matters. The CCP knows that only very large firms can marshal the capital needed for R&D investment, capital investment, and the overseas market expansion needed to better outlast foreign companies in battles of capital attrition—the kind of battle Chinese firms enjoy the most.

In contrast, the United States' approach to firm size and scale is undecided at best, and hostile at worst. From the emergence of the large corporation—something the United States pioneered and which was the single most important factor in vaulting the United States to global leadership—there have always been skeptics, arguing that either the benefit of bigness was not worth it or that there were few or no net benefits. Today, that view has devolved to outright anticapitalist antagonism toward large corporations, which the neo-Brandeisians see as their last big barrier to fundamental American transformation to a socialist economy.

It's time for policymakers to call out the neo-Brandeisian movement for what it is: a radical, anti-American movement that will undercut our abilities to compete with China. In its place, **we need an antitrust movement that moves beyond the consumer welfare principle to embrace the "national strength" principle wherein all antitrust actions directed at firms in globally traded sectors will be**

evaluated on the principle of "does this help or hurt America's ability to be a global leader in the particular industry involved?" America used to do more of this, especially when we were competing with the Soviet Union. For example, in the 1950s when antitrust authorities went after their "big tech of the day," AT&T, Eisenhower's DOD Secretary "Engine" Charlie Wilson, the former CEO of GM, wrote the attorney general a letter expressing serious concern saying a breakup would destroy the company's "usefulness for the future."[337] And the Department of Justice (DOJ) backed off. Once again in the 1980s when DOJ was at it again, DOD was opposed to breakup, with DOD Secretary Casper Weinberger coming out against it on national security grounds. In addition, Commerce Secretary Malcolm Baldridge argued that the suit was putting American leadership in telecommunications in jeopardy, as did a Reagan administration cabinet task force on telecommunications.[338] But this time, DOJ prevailed, and Bell Labs was all but decimated.

Moving forward, **Congress should strip FTC of antitrust authority and have DOJ be the sole arbiter. However, for all investigations involving companies in trade sector industries, DOJ should be required to get the public input of DOC and DOD.**

8. Specialization

As noted, China has built very specialized research institutes that concentrate talent and resources in one place. It's time for the United States to do the same. For example, **Congress should fund NSF to create 30 to 50 ERCs that are 10 to 20 times larger than current centers. Current ERCs provide a maximum of $6 million per year**. This is a pittance. We need a "SUPER-ERC" program that provides at least $60 million a year, with a requirement that industry match it with at least 15 percent of the funding. In addition, **Congress should provide funding for the National Institute of Standards and Technology (NIST) to create at least 5 to 10 national laboratories focused on key commercial technologies, modeled after what China,** South **Korea, and Taiwan have done.**

China is also supporting regional innovation hubs built around incredibly well funded advanced manufacturing institutes. Congress took one step in this direction with its passage of the Regional Innovation Hubs program (an ITIF proposal), but it remains massively underfunded and dispersed across government, with NSF, DOD, and DOC all having their own duplicative regional innovation hub programs.

9. Space

America needs to return to its roots of permissionless innovation, where for the most part innovators could innovate and didn't need government approval to do so—and in cases where government did intervene, the interventions were as light-touch as possible. With the rising antitechnology narratives that have taken over the United States, as spelled out in *Technology Fears and Scapegoats: 40 Myths About Privacy, Jobs, AI and Today's Innovation Economy*, that revival is likely to prove difficult.[339] But without it, it will be harder to effectively compete with China.

EVs and the 10 S's

With regard to the 10 S's ITIF has framed as part of its "Is China Innovative?" research series—**S**cience and engineering talent, a head **S**tart, **S**cale, **S**peed, local **S**uppliers, **S**ubsidies, **S**ize, **S**pecialization, **S**pace, and **S**trategy—China's EV/EV batteries policy and strategy hit upon most of these. As noted, China earned a head start on developing EV technologies when it identified them in the mid-2000s as a leapfrog technology that could remediate its lag in internal combustion engine vehicles. China has achieved scale across multiple dimensions: As noted, it currently counts over 200 EV manufacturers, manufactures the most EVs, and has created the world's largest domestic market size for EVs. China's EV manufacturers prioritize aggressive development timelines (much faster than legacy carmakers) and speed to market, with multiple product iterations. This speed to market is enabled by a deep bench of local suppliers that can alacritously respond to requests for component adjustments. Similarly, especially for EV batteries, Chinese producers benefit from fully vertically integrated supply chains that reach all the way down to the raw materials and their processing. And China far and away leads the world in subsidies for its EV sector. Thus, the 10 S's provide a nice synthesis for how China is seeking to compete in EVs and EV batteries.

10. Strategy

Emulating the best of Chinese policy means embracing an overarching goal—at minimum, not losing the techno-economy lead to China—and that means all areas of policy should be guided by this goal. If it sounds simple, that is because it is. The main reason the United States is losing ground vis-à-vis China on advanced industries and innovation is that this is not its overriding priority, the way countering the Soviet Union in the Cold War was. While the CCP puts technological advances front and center, this issue is virtually absent from our politics.[340] Where is the science and technology China agenda for either presidential candidate this year? It doesn't exist. Indeed, there is no real strategy in the United States other than perhaps to just get more innovation. To be sure, the United States now has a strategy to ensure chip production, but that is only for one industry. More often than not, the strategy appears to be to get less innovation through heavy-handed and aggressive regulation.

If this is the approach Congress and the administration takes, it means that all major areas of policy need to be guided by the doctrine of national power capitalism, including education (a focus on STEM), trade (a focus on advanced industries, not all industries), antitrust (a focus supporting large firms that can compete with Chinese state-backed companies), tax (a business tax system that supports R&D, capital investment, worker training, and exports), finance policy (a Treasury policy that no longer defends the dollar), a science policy focused not on principal investigator discovery but on supporting the U.S. advanced industry capabilities, and regulatory policy (regulations designed in ways to enable speed and scale for key traded firms).

This is perhaps the most important question: Double down on the current U.S. economic system or develop a new model of national power capitalism?

In addition, while the discipline of science and technology policy is prominent in China, perhaps even more important than the discipline of economics, that is not the case in the United States. Science and technology policy is at best an insignificant sideline, with few in Washington focused on it—and those that are consigned to the sidelines (e.g., the White House Office of Science and Technology Policy) not the center (e.g., the National Security Council, the Treasury Department). Moreover, it is almost completely ignored by the dominant economics and foreign policy disciplines, which know almost nothing about the discipline and practice of science and technology policy for competitiveness.[341] Perhaps one reason is that the United States became a global innovation leader without much of an explicit science and technology policy (unless one wants to classify defense spending on tech as one). But now that the United States is declining in science and technology relative to China, science and technology policy for competitiveness needs to be elevated to a much higher position. **Vastly more needs to be done to educate local, state, and federal staff involved in economic policy in what science and technology policy for competitiveness is and how a government or set of governments should craft and implement effective science and technology strategy.**

Of course, many will argue that it is apostasy for the United States to emulate the Chinese model. As one study argues:

> The United States holds a lead in all the dynamically evolving fields examined in this study. The best way to sustain this leadership is to adopt a strategy that builds on America's asymmetric advantages, including our superior ability to operate and attract talent in an open global knowledge economy. Permitting the global technology system to bifurcate into hostile camps led by the United States and China would be self-defeating and impracticable. Engaging in a race to the bottom with China by emulating its statist and protectionist policies is a recipe for a weaker and less secure America.[342]

Rather than admitting that there is anything to learn from China, the comfortable narrative is to double down on the distinctive U.S. model of commercial innovation.[343] Stay the course, but perhaps swim a bit faster. This is perhaps the most important question: Double down on the current U.S. system (which means support capitalism) or develop a new model of national power capitalism?

HOW CHINA MIGHT STALL

The 10-S aspects of the Chinese innovation system form a powerful engine for dominating globally advanced industries. But China's ultimate victory is not assured. There are a number of ways it could come up short.

First, China's fiscal challenges may limit the government's ability to continue to subsidize its exporting industries to the extent it already has. This is especially true given the demographic challenges China faces. But it's important to note that China has significantly more fiscal policy headroom than many nations do because it is running huge trade surpluses and has greater ability to raise taxes and cut spending than do democratic nations.

Second, China's Achilles' heel is Schumpeterian innovation. This is what hurt Japan, at least in ICT industries, as it was not able to quickly adapt to what was first "Wintelism" (Windows and Intel), and then the Internet and TCP-PI standards. However, unlike leaders in Japan, Chinese leaders are much more aware of the need for Schumpeterian innovation, which is why China is investing so much in next-generation leading-edge technologies.

Third, efforts by the Western nations could significantly slow Chinese efforts, especially if they limit Chinese firm market access, fight more vigorously in third-country markets for market share, and cooperate on advanced technology development. But to date, while there are embryonic steps being taken, there is not much evidence that either America or its trading partners (especially the EU) are truly serious. Europe in particular continues to want to undercut allied nation interests by expanding business and investment in China while advancing the truly astounding claim that the United States and China are both equal competitors to the EU.[344] The reality is that without the EU waking up and seeing China as its principal threat and America as its ally, China will likely ultimately prevail.

Moreover, it appears that the hope of export controls being the magic ingredient for restraining China is vastly overstated. A report by Georgetown's CSET highlights the relationship between export controls and innovation with a historical case study exploring past U.S. efforts to decouple its satellite technology supply chain from China.[345] Although export controls were able to delay China's advancement, today, the report notes, "China has caught up and even exceeded U.S. capabilities in some respects in spite of these restrictions on technology transfer." Similar concerns have been expressed about the recent expansion of export controls placed on advanced semiconductors and semiconductor manufacturing equipment by the Biden administration.[346] Moreover, by definition, export controls reduce U.S. sales, thereby weakening U.S. firms in their ability to continue to innovate.

Fourth, a military invasion of Taiwan, should such a catastrophic event occur, could potentially change things dramatically for China, leading more countries to start to restrict trade and other exchange with China. However, given that many nations continue to trade with Russia after its invasion of Ukraine, it's not clear if the global response would be much different. Europe, in particular, would likely issue some strongly worded declaration and even restrict trade and investment for a while, but they could very well return to business as usual at the conclusion of armed conflict, especially if China promised more European FDI.

Fifth, once the Asian Tigers reached a certain level of technological capabilities, their original top-down industrial strategies gave way to more collaborative, industry-led strategies, more suited to their countries' new innovation system. It's not clear that the CCP will be able to show similar levels of flexibility, because in all the Asian Tigers' cases, democratic reforms accompanied and enabled industry policy reform.

Sixth, a coalition of leading nations/regions in the West, including the United States, Japan, and the European Union, could collaborate to jointly develop technology advancement programs while putting in place policies to limit China's advantage, especially when it comes from unfair practices.

While all these and other challenges are certainly possible, it would be folly for U.S. policymakers to put their head in the sand and hope for the best. Even if these Chinese challenges do emerge, the amount of damage that China and its firms could do to the U.S. economy in the interim is still massive. Moreover, if China follows the Japanese model of becoming a technology leader and then somewhat stalling out at a per capita income level of about 80 percent of U.S. levels, it would mean that Chinese GDP is three times greater than that of the United States, with more R&D spending, more global technology leaders, and probably five times more manufacturing. Not a pretty world for American or Western interests.

HOW THE UNITED STATES MIGHT NOT LOSE MORE

Clearly, the relative position of the United Stats vis-à-vis China on innovation production will depend in part on what China does. But it mostly depends on what the United States does. There are at least three possible scenarios for that.

First, our politics don't respond. The United States may continue to stumble along, never really making not losing to China a top priority. In this scenario, other issues—climate change, income inequality, social justice, breaking up large businesses—dominate American politics. On top of that, divided government precludes any real reform from happening. Should this happen, we should not delude ourselves. The results would be bleak in terms of America's ability to not lose further techno-economic ground to China. Indeed, many on the left view any efforts to compete with China as stimulating a new Cold War (bad) and spurring Asian racism.[347] The liberal Center for American Progress's main goal for competing with China is redistribution: "Our policy should advance the interests of ordinary Americans by improving their opportunities, wages and working conditions."[348] And it goes on to argue that fighting climate change and racism are more important. In other words, the Left doesn't care.

Related to continuing to stumble along, a traditional Republican Right would try to resurrect its old free-market tool kit, believing that lower taxes, reduced regulation, less public investment, and more free trade would do the trick. It would not do the trick of keeping America from losing.

A Trumpian agenda would certainly put China economic competition more front and center. The problem is that it would likely not prioritize computer chips over potato chips. Tariffs on everything is not a strategy; it is a social policy. And there is little evidence that a Trump administration would pursue a China tech-focused tax or investment policy (e.g., a much higher R&D tax credit or much higher spending on R&D and advanced production).

At the same time, we are likely to see core allies, such as Europe, continue to deepen their protectionism and anti-U.S. policies, making it more difficult to form a true alliance against Chinese techno-economic dominance.

Second, if we are lucky, U.S. politics will embrace supporting capitalism and the policies that would entail. But doing so would mean significantly higher investments (e.g., tax and spending) in U.S. advanced technology capabilities, and given the massive U.S. national debt, this would have to be accompanied by tax increases (not on companies) and spending cuts. Let's be honest, neither are likely until U.S. finances are so dire that default is imminent.

Third, another scenario is that, because of inherent U.S. strengths, the United States takes the lead and keeps it for at least a couple decades in an array of transformative technologies: new kinds of semiconductors, AI, quantum computing, and biotech. To be sure, such a scenario is possible, especially given the strength of the U.S. science and entrepreneurial ecosystem. But it would be harder than it might have been in the past because of Chinese capabilities.

Finally, that leaves national power capitalism. Absent an invasion of Taiwan by China, the best hope for that is the U.S. national security establishment awakening from its stupor and raising the alarm of the structural weakness of the United States in advanced industries. While there have been some voices attempting to do that, by and large, the U.S. national security establishment has been quiescent.

As troubling as it is to say, that suggests that only the invasion of Taiwan by China would be enough to shake America out of its stupor. After WWII, even though there were prescient voices warning U.S. leaders that the Soviet Union represented a generational threat to American interests and the free world, America largely let its military shrink. "Time to come home" was the view. It was only after the Soviet-backed invasion of South Korea that U.S. politics coalesced around significantly increased military and R&D spending. Indeed, inflation-adjusted federal R&D spending increased from $8.6 billion in 1950 to $55 billion in 1962.[349] But that was then, and this is now. Back then, the U.S. economy was growing much faster. Entitlement spending was limited. Tax rates were higher. The national ethos was to "ask not what your country can do for you." That is all different now. It's not clear if Americans have the stomach for another fight, and if our leaders have the courage and integrity to call for what it takes to win that fight.

WHAT TO DO?

It is beyond the scope of this report to lay out a full agenda to ensure that the United States, and for that matter its Western allies, does not lose its techno-economic lead to China. ITIF has laid out such a detailed agenda, including trade measures to protect U.S. and allied markets from unfair Chinese competition, in various reports.[350] However, this report does lay out five key proposals:

1. **Triple the Research and Experimentation Tax Credit.** The Chinese R&D credit is already likely at least three times more generous than America's, its R&D labor costs are less than half, and its R&D personnel costs are likely at least half of costs in the United States.[351] One of the simplest and easy-to-administer steps Congress could take would be to triple the R&D tax credit for the Alternative Simplified Credit from 14 percent to 42 percent and allow expenditures on global standards setting to qualify.
2. **Establish five national industrial research institutes** focused on key, dual-use industries and technologies, modeled after Tawain's Industrial Technology Research Institute, an industry-government advanced technology lab focused largely on IT technologies, with a long track record of working on technologies in what is referred to as the "middle Technology Readiness Levels" beyond what universities work on and earlier than most companies work on.
3. **Establish a "Competitiveness Advanced Research Projects Agency (ARPA–C)"** to co-invest with industry on research and application of key technologies needed for dual-use national security leadership in the commercial sector. Funded by year five with at least $20 billion per year, such an entity could be administered by NIST.
4. **Establish a national industrial development bank** to provide low-interest patient capital for new domestic manufacturing investment.[352]
5. **Institute a seven-year, 25 percent investment tax credit** for all new machinery and capital equipment. America is "capital equipment lite"; China is not.

CONCLUSION

Unless U.S. techno-economic policy changes to embrace "national power capitalism," it is less likely that the United States will be able to maintain competitive position in a broad array of advanced industries against not only China but also other nations that play more by the rules but are still competing for global market share.

There are four main challenges to making this intellectual transition. First, the world has never been confronted with a model such as China's: a massive country dead set on practicing power trade to win in advanced industries. Too many American policymakers, experts, and pundits simply refuse to believe what is right before their eyes.

Second, the lion's share of policy experts focused on China come from a national security or foreign policy background, not a techno-economic one. As such, the narrative and agenda are colored by these concerns. Case in point, the dominant argument for limiting Chinese imports is almost always about security, not preserving U.S. techno-economic capabilities.

Third, the strong commitment still by many to free-market capitalism, coupled with the emerging commitment to worker and climate capitalism, is likely to drown out voices and forces advocating for national power capitalism. Vastly more pundits, experts, and policymakers see climate change and reducing inequality—not China—as the existential challenges of the day. Moreover, even those who recognize a China threat, default to "doubling down" on support capitalism and the American system. We need to understand that this system has failed to address the China challenge. It is time to accept the reality that we need to construct a new national innovation system.

The lion's share of policy experts focused on China come from a national security or foreign policy background, not a techno-economic one. Their concerns color the narrative and agenda.

Finally, America has never been able to be on a "war" footing unless war came to America first (e.g., the American Revolutionary War, the War of 1812, the Civil War, WWI and WWII, and the Cold War with the Soviet Union fought in a series of proxy hot wars [e.g., South Korea, and Vietnam]). But each time war came, America responded with overwhelming productive force. But this time is different. At least in the last century, America never faced an adversary that could outproduce it. Now it does. Unfortunately, the odds are that America will not be able to get on techno-economic war footing absent a Chinese invasion of Taiwan.

This is problematic because the results of this study suggest that China has for the most part not caught up to the world's innovation leaders, but that it is making extremely rapid strides and, absent some kind of external or internal shocks, is likely to be at or very close to the global innovation frontier in most advanced industries in the next 10 to 20 years. There are several implications for this, and the outcome depends in large part on Western nations' responses.

Scenario One: China as Innovation Leader

One outcome, what we term "China as the Center," sees a decline in global market share of technology value added in the leading Western nations, with China becoming dominant. The United States would still have some innovative companies, just as the United Kingdom, for example, has companies such as Rolls Royce and Glaxo Smith Kline. But many U.S. companies would have been forced into bankruptcy; others purchased by Chinese firms; and still others downsized and moved to less intensely competitive parts of the market (e.g., services). The odds of this scenario increase if the current U.S. political economy of anticorporate and antitech animus, fiscal crisis, and political polarization continue.

Such a geographic shift in the center of global innovation production is not unprecedented. In fact, that has been the nature of industrial transformations since the first industrial revolution the United Kingdom led starting in the 1790s. As the second transformation starting in the 1840s involving exiles, rail, and hand-crafted metal works emerged, the center of gravity became less diffuse, with parts of Western Europe and America becoming active players. With the third transformation starting in the 1890s and powered by steel, precision machine tools, electricity, and the internal combustion engine, the United Kingdom was displaced, with Germany and the United States becoming the leaders. With the fourth wave of innovation starting in the late 1940s, and powered by electronics, chemicals, and mass production of consumer goods, the United States cemented its lead, with Germany weakened by the war and the Soviet Union constrained by communist central planning. It was only by the end of this period in the late 1970s and early 1980s that followers began to catch up, including Germany and Japan. With the fifth transformation starting in the late 1980s and powered by information technology, including computing and software, the United States still led, although the center of gravity for U.S. innovation shifted from the East Coast and Midwest to the West Coast.

As we enter into the sixth wave of innovation, powered it appears by AI, autonomous systems, and materials innovation, it seems likely that China will gain the mantle of the world's innovation center.

Within a few decades, we could be in a world where it is China that is imposing export controls on the United States.

It is impossible to overstate the implications of this potential development, as it would entail a massive switch in the center of global economic power and innovation from a geopoint somewhere in the Atlantic Ocean to somewhere in China. To be sure, just as the United Kingdom still has some tech capabilities and firms after its half century of industrial decline, the West will not become, as Alexander Hamilton warned, a complete hewer of wood and drawer of water, dependent on the innovation leader of the time, the United Kingdom. But if China can move to the frontier of global innovation—a destination all forces in China are pulling toward—the world economy and relative national power will be fundamentally transformed.

If China gains significant capabilities, the limits of U.S., or even allied, export controls will significantly decline. Export controls work when one side has something the other side does not. When both are at parity, they are ineffective. Who knows? Within a few decades, we could be in a world where it is China that is imposing export controls on the United States.

Scenario Two: Strategic Parity

Here China succeeds in a number of industries, such as robotics, chemicals, EVs, nuclear power, and consumer electronics—putting major competitive pressures on Western firms in these industries—but it cannot achieve innovation parity in more engineering or scientifically complex sectors such as biotech, aerospace, software, or semiconductors. This scenario is more likely if the Western nations, and the United States in particular, are able to overcome their significant political economy challenges and put in place world-class national innovation systems, including with significantly more funding for industrial technology development. This would require the United States to move from a science-based innovation system—with the view that scientific research is the foundation of national innovation success—to an industrial-production-capabilities view that sees utilizing knowledge in products and service at scale as the key.

Scenario Three: Japanification

In this scenario, like the Japan challenge of the 1980s and early 1990s, China loses steam and its companies fail to make the needed transitions to new technology systems. This is certainly possible, but its probability is greater if the United States can accelerate the speed of innovation in a variety of technologies, including semiconductors, biotechnology, AI, and others, while slowing China down, including by joint action to increase the value of the yuan and limiting Chinese exports.

Regardless of which scenario plays out, the best strategy from the U.S. and other Western nation perspective is to embrace national power capitalism designed to maintain the lead over China on most advanced technology industries.

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The Information Technology and Innovation Foundation (ITIF) is an independent 501(c)(3) nonprofit, nonpartisan research and educational institute that has been recognized repeatedly as the world's leading think tank for science and technology policy. Its mission is to formulate, evaluate, and promote policy solutions that accelerate innovation and boost productivity to spur growth, opportunity, and progress. For more information, visit itif.org/about.

ENDNOTES

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