Strategies for China to Overcome the "Middle Technology Trap" Postprint

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Abstract

From the perspectives of supply chain, industrial chain, or value chain, China's current technology is generally at a medium technical level. The specific circumstances are as follows: (1) There is a lack of original technologies, i.e., a deficiency in "from 0 to 1" technological creation; (2) Development is primarily focused on applied technology, positioned at "4–7" on a scale of "1–10" while lacking the "8–10" technical level, meaning that in many fields it has not yet reached world-leading levels, and external dependency on many core technologies and key components remains high; (3) While world-leading levels have been achieved in certain applied technology fields, these areas remain in a fragmented state and have not formed a systematic whole, or in other words, the overall technological level is far from achieving comprehensive systematic strength. The article explores how China can seek to transcend the "medium technology trap" under these aforementioned circumstances.

Full Text

Preamble

In recent years, the United States has progressively advanced its technological blockade and technological "decoupling" against China, with its high-tech export controls reaching unprecedented levels in scope, intensity, and impact. Objectively speaking, although China has achieved technological breakthroughs in many fields, its dependence on foreign sources for many core technologies and key components remains very high. The U.S. technological containment has negatively affected China's capacity for scientific and technological innovation and development, gradually increasing the external risks for China to cross the "middle-technology trap." Professor Zheng Yongnian, Dean of the Institute for International Affairs, Qianhai, at The Chinese University of Hong Kong, Shenzhen, has proposed the concept of crossing the "middle-technology trap" based on his summary of historical experiences in global technological and economic development. This concept points to the fact that, whether from the successful experiences of developed economies or the lessons of economies that have long remained at middle-income levels, the key to achieving high-quality sustainable development for an economy lies in industrial upgrading based on technological progress. Centering on this concept, Professor Zheng Yongnian initiated and coordinated collaborative research among the Institute for International Affairs, Qianhai, The Chinese University of Hong Kong, Shenzhen, the Guangzhou Greater Bay Area Institute for Research, and the Institute of Public Policy at South China University of Technology, producing a series of research outcomes. Under Professor Zheng's guidance and promotion, the *Bulletin of the Chinese Academy of Sciences* has organized this special issue titled "Crossing the Middle-Technology Trap and Achieving Chinese Path to Modernization," incorporating the aforementioned research findings to stimulate attention and discussion and to support relevant decision-making.

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Strategies for China to Cross the "Middle-Technology Trap"

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Abstract

From the perspectives of supply chain, industrial chain, or value chain, China's current technology is generally at a middle-technology level. Specifically, this manifests in three ways: First, there is a lack of original technology, meaning a shortage of technological creation "from 0 to 1." Second, development focuses primarily on applied technology. If we measure applied technology development on a scale of "1 to 10," China currently stands at "4 to 7" but lacks the "8 to 10" level of technological sophistication. In other words, China has not yet reached world-leading levels in many fields, and dependence on foreign sources for many core technologies and key components remains high. Third, while China has achieved world-leading positions in certain applied technology fields, these fields remain fragmented and have not formed a systematic whole. The overall technological level is far from achieving comprehensive, systematic strength.

The Twentieth National Congress of the Communist Party of China proposed that the country's goal in the next stage is to achieve high-quality development of the Chinese economy. Although the realization of high-quality economic

development is driven by many factors, the experience of world economic history shows that whether for Western countries that first achieved industrialization or for latecomers that became developed economies, technological upgrading and the resulting industrial upgrading are the key and core for a country to achieve high-income status. Especially for a large economy like China, achieving high-quality economic development will be difficult without technological upgrades. Thus, China not only needs to achieve "8 to 10" technological progress at the applied technology level but also needs to transform from applied technology to original technology "from 0 to 1."

In recent years, the author and his research team have studied how China can achieve high-quality development and upgrade to a developed economy. Through comparative analysis of developed economies including Europe, the United States, Japan, and Asia's Four Little Dragons, as well as other economies in Latin America and Asia, we have refined a new concept: the "middle-technology trap." This concept demonstrates that if an economy wants to upgrade from middle-income to developed economy status, it must avoid the middle-technology trap. An economy can rely on technology diffusion and learning from technology transferred from developed economies in its early development stages. However, to achieve the goal of becoming a high-income economy, China not only needs to cultivate original technological innovation "from 0 to 1" but also needs to achieve sustainable technological upgrades in existing technology fields—that is, to continuously move from a technical level of "4 to 7" or lower to a level "above 8" on the technological scale.

Keywords: middle-technology trap, original technology, basic research, application technology, financial system, venture capital, enterprise reform

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1. What Is the "Middle-Technology Trap"?

The report of the 20th National Congress of the Communist Party of China proposes that the country's goal in the next stage is to "comprehensively build a modern socialist strong country, achieve the second centenary goal, and comprehensively advance the great rejuvenation of the Chinese nation through Chinese path to modernization," with one of the essential requirements of Chinese path to modernization being "achieving high-quality development." From the experience of world economic history, whether for Western countries that first achieved industrialization, latecomers that successfully achieved high-quality development to become developed economies, or economies that have long faced development challenges, technological upgrading and the resulting industrial upgrading are the key and core for a country to achieve high-quality development. Especially for a large economy like China, achieving high-quality economic development will be difficult without technological upgrading. This demonstrates that China not only needs to achieve "8 to 10" technological progress at the applied technology level but also needs to transform from applied technology to original technology "from 0 to 1."

In recent years, the author and his research team have been contemplating how China can achieve high-quality development and upgrade to a developed economy. Through comparative analysis of developed economies including European and American countries, Japan, and Asia's Four Little Dragons, as well as economies in Latin America and Asia that have long faced development challenges, we have refined a new concept: the "middle-technology trap." The experiences of both developed economies and those facing development challenges tell us that if an economy wants to achieve high-quality development, it must cross the "middle-technology trap." Simply put, an economy can move from low-level development to middle-income status by leveraging technology diffused from developed economies, but it is difficult to cross from middle-income to developed economy status through technology diffusion alone. In other words, an economy's early development can rely on technology diffusion and learning to replicate technologies transferred from developed economies, but to achieve the goal of becoming a high-income economy, it needs, on the one hand, to cultivate original technological innovation capabilities "from 0 to 1," and on the other hand, to have the capacity to achieve sustainable technological upgrades in existing technology fields—that is, to continuously move from a technical level of "4 to 7" or lower to "above 8" on the technological scale.

The term "middle-technology" discussed here is a dynamic concept. Internally, within any country, technology is always changing and progressing, whether through iteration and improvement of the same technology or the emergence of new technologies. Externally, "middle-technology" refers to the comparison of technological levels between one country and another or a group of countries. For example, in manufacturing, the United States is in the first echelon, Europe and Japan in the second, and China in the third. In the arena of international politics, the external meaning is more significant, as a country's technological level essentially determines its competitiveness in the world economy. This article refers to the external situation.

Generally speaking, a country falls into the "middle-technology trap" in the following five scenarios:

First, developing countries undertake capacity transfers of mature industries from developed countries based on low-cost advantages. However, in the long run, because multinational corporations always retain core technologies in their home countries and only transfer mature technologies to developing countries, this means that once the dividends of mature technology transfer have been "harvested," and if domestic enterprises in developing countries cannot elevate their technological levels in existing fields through their own efforts while also failing to successfully transform from applied technology to original technology, their economic growth will enter a state of long-term relative stagnation.

Second, both science and technology are essentially open; they can only develop through open processes. Empirically, scientific and technological ideas must spread relatively freely, and applied technologies can only be improved through open and competitive states. If developing countries cannot create free spaces for thought for their domestic researchers or maintain openness to the outside world, these factors will prevent their technological levels from achieving sustainable improvement.

Third, the brain drain of scientific and technological talent from developing countries is another important reason they cannot overcome the "middle-technology trap." Many developing countries have limited self-trained scientific and technological talent to begin with, and these talents are often attracted by professional immigration policies of developed economies due to job opportunities, economic compensation, and quality of life, leading to severe talent shortages that greatly constrain their development pace.

Fourth, because developed countries are at the forefront of science and technology while developing countries are in a catch-up position, once developed countries perceive that developing countries pose competitive pressure on their technology, they will suppress those about to catch up, hindering the technological progress of developing countries.

Fifth, influenced by geopolitical factors, when countries engage in geopolitical competition, developed countries often impose technological blockades or even "decoupling" on catching-up countries, thereby effectively obstructing their scientific and technological advancement.

2. Crossing the "Middle-Technology Trap": A Systematic Process

Although the core of the "middle-technology trap" is technology itself, crossing it is a systematic project involving all links: technological invention, basic scientific research, applied technology, enterprises, markets, and government. These links must coordinate and develop together; otherwise, crossing the trap will be difficult. This explains why some economies succeed while others fail.

2.1 Successful Development Experiences of Developed Economies

The development experiences of developed European and American economies demonstrate that crossing the "middle-technology trap" is a systematic project. Since modern times, Britain was the first country to achieve industrialization, which then spread throughout Europe and North America before spreading worldwide. Compared with Britain, Germany was a late-developing country, so its government had to play a more important role in achieving industrialization than Britain did. Therefore, Germany developed the concept of a "national economic system," which Britain lacked. Similarly, compared with Britain, the United States was also a late-developing country. Consequently, during the early period of American nationhood, politicians including Hamilton practiced mercantilist economic policies, protecting national industries until they matured before implementing comprehensive opening-up policies.

The experience of several developed East Asian economies also illustrates that crossing the "middle-technology trap" is a systematic project. In East Asia, Japan was the first economy to achieve industrialization. In terms of technology, Japan primarily learned from Germany and the United States, which were among the developed countries. After Japan came the "Asian Four Little Dragons." Japanese economists once proposed the concept of a "flying geese pattern," with Japan as the "lead goose" and the Asian Four Little Dragons following. In other words, the early development of the Asian Four Little Dragons relied on technology diffused from Japan. Although the flying geese pattern exaggerates Japan's role, its description of technology diffusion's role in an economy's early development is correct. In fact, South Korea and Singapore among the Asian Four Little Dragons targeted Japan for catching up. However, after China's rise, the flying geese pattern became less applicable because, obviously, China's rise did not result from applying Japanese technology or that of the Asian Four Little Dragons. In the technology field, Japan has always been concerned about the rise of neighboring China and has maintained a very conservative attitude toward technology exports to China. China, in contrast, has opened up to the world, extensively applying technologies from around the globe and improving and innovating upon them. This explains why China today has the most complete industrial chain. Although China remains at a middle-technology level, its technological level has improved comprehensively compared to the past.

2.2 China's Development Benefits from Technology Transfer

It must be acknowledged that during its development over the past several decades, China has extensively applied technologies originating from developed economies. The United States has consistently slandered China, claiming that China's development has "stolen" American technology. However, the views of some American political figures are ideologically driven rather than based on the logic of technological development itself. While China has indeed extensively applied American and Western technologies, this has effectively facilitated technological upgrading in the United States and Western countries themselves. Both basic scientific research and technology application and transformation require substantial capital investment. Technologies must be converted into products and sold in markets to generate returns; otherwise, sustainable development is difficult to achieve. Therefore, a country needs to transfer older-generation technologies to other countries to obtain sufficient returns to realize sustainable technological upgrading. In recent years, the United States and Western countries have transferred large amounts of older-generation technology to China, obtaining generous returns and achieving continuous domestic technological upgrading. In this process, while China has become the largest market for Western technology application, it has also developed through this technology transfer process.

2.3 China's Position in Global Industrial Chains

However, it must be recognized that "Made in China" has a completely different meaning from "Made in USA," "Made in Germany," or "Made in Japan" before the 1980s. Before the 1980s, developed countries mostly manufactured complete products, whereas "Made in China" is essentially "assembled in China." The "hyper-globalization" since the 1980s has led to the global flow of production factors including capital, technology, and talent, forming the industrial and supply chains we see today. Today, no single country can monopolize the entire industrial and supply chain for all technologies. A country can only occupy one part of an industrial and supply chain and strive to climb upward to compete in the value chain. Generally speaking, China has occupied the middle and lower ends of industrial and supply chains in this wave of globalization.

This process demonstrates at least two points: technology diffusion is win-win, benefiting both exporting and importing countries; and original technology cannot be waited for—it must be created independently. The United States and Western countries have never and will never export their most advanced technologies to China. The most developed countries, whether in terms of capital or government, fear other countries mastering the most advanced technologies. Therefore, once competitors emerge, they often implement suppression policies, including both internal suppression and external suppression or blockades. U.S. suppression of Japan, Germany, and France are typical examples of internal suppression. Although these countries belong to the Western camp and are U.S. allies, the United States has nonetheless ruthlessly suppressed them. The U.S. policy toward the Soviet Union during the Cold War was a typical example of external suppression and blockade.

2.4 Major Challenges Facing China's Technology Upgrade

From the perspective of technology upgrading, China today faces major challenges in achieving high-quality development. In the past, there was globalization; now there is "de-globalization." Although the United States also suppressed Japan, Japan was not only part of the Western economy but also part of the U.S. security system, so U.S. suppression of Japan was limited. Because the Asian Four Little Dragons were small in scale, they could not pose any challenge to the United States, let alone a threat, and therefore were not suppressed. For the United States, competition from today's China is not of the same nature. U.S. previous technological suppression of Japan, Germany, and France could be called "in-system suppression," while its suppression of the Soviet Union during the Cold War and of China today could be called "out-of-system suppression." It is not difficult to understand that today's U.S. suppression of China is comprehensive, similar to its suppression of the Soviet Union; but because China differs from the Soviet Union, U.S. suppression of China is unprecedented.

China's rapid rise has led the United States and some Western countries to believe that China not only poses a challenge to their economic competitiveness but also to their national security. Therefore, in recent years, the United States has systematically implemented "decoupling" and "chokepoint" tactics against China's high-tech sectors, with the recently established so-called "Chip Alliance" being one such instrument. Due to the resilience of China's economy, the United States has not been able to deal with China as quickly and effectively as it did with the Soviet Union, leaving the U.S. political establishment in a state of collective panic regarding China. The United States' intention to comprehensively hinder China's technological progress is clear, and its means are extremely diverse.

In any case, judging from current international realities, crossing the "middle-technology trap" is not only a challenge and difficulty that China must face and overcome but also the key to achieving high-quality development and upgrading itself to a developed economy. The technology field is one that can be precisely described and tested, leaving no room for falsehood; problems must be viewed and solved realistically.

3. Crossing the Trap Through Open, Whole-Nation Innovation

How can China cross the "middle-technology trap"? At the macro level, an open policy is key. We must scientifically understand the "new whole-nation system" emphasized in recent years, continue to implement open policies, and become increasingly open.

3.1 Western Countries' Historical Emphasis on Whole-Nation Systems

The whole-nation system is important. To a large extent, since modern times, all powerful countries have implemented whole-nation systems. In the West, although economic development since modern times has been capital-driven, war mobilization during World War I and World War II also facilitated the evolution of Western countries into whole-nation systems. This is especially true for the United States. After World War II, with the release of the "Bush Report" (i.e., *Science: The Endless Frontier*), the U.S. government found areas and methods to intervene in technological progress using the concept of "national security," namely making substantial capital investments in technology and health and organizing research, development, and transformation. Both technology and health were related to battlefield victory—technology was used against enemies, and health was used to protect soldiers' lives. Today's U.S. containment of China is also a whole-nation system. During the Trump administration, the U.S. government openly declared it would use a "whole-of-government" and "whole-of-society" approach to deal with China. Since the Biden administration, although the United States no longer uses such concepts, its methods of suppressing China have not changed and have even become more severe.

3.2 Implementing China's New Whole-Nation System in a More Open Context

Faced with today's U.S. "chokepoint" tactics and systematic "decoupling," China undoubtedly must respond with a whole-nation system approach. However, what China emphasizes is a *new* whole-nation system, which absolutely does not mean closing the door for self-reliance innovation but rather keeping the door wide open and conducting whole-nation system innovation under more open conditions.

Empirically, such thinking is not only a fantasy that does not conform to historical experience but also very dangerous. The world of science and technology can only have "one mountain." If a country leaves this "mountain," it will be very difficult to build "another mountain." The "mountain" of world science and technology is jointly created by all civilizations and all countries. China's ancient "Four Great Inventions," the science and technology of the Arab world, and the science and technology of the West since ancient Greece have all contributed to this "mountain." However, because modernization first occurred in the West, Western countries have dominated this "mountain" in modern times. Before World War II, European countries dominated the "mountain," and after World War II, the United States took over this role. After China's reform and opening up, China voluntarily ended its previous relative isolation, and the international environment at that time facilitated the acceptance of China by the United States and Western countries as part of the world economy, leading to China's accession to the World Trade Organization (WTO). In other words, China entered the "mountain" of world science and technology and, through decades of humble learning and diligent development, has continuously climbed this "mountain," posing competitive capabilities to the United States and some Western countries at the "mountain top." This is the reason behind the "China threat theory" propagated by some Western countries.

Today, the U.S. "chokepoint" tactics indicate that the United States no longer allows China to continue climbing this "mountain," while systematic "decoupling" is even more severe, showing that the United States intends to drive China down from this "mountain." China must not fall into America's trap and act impulsively by closing itself off and leaving this "mountain." Instead, China should tell the United States that although the U.S. currently dominates this "mountain," the "mountain" includes contributions from both American and Chinese science and technology—it belongs to both America and China. China's future choice is not to leave this "mountain" but to remain within it and contribute more to it. There will come a day when not only will China be unable to leave this "mountain," but the "mountain" itself will be unable to do without China.

In advocating for a new whole-nation system today, China needs to conduct scientific and technological innovation in an open state and continue to contribute Chinese strength to the "mountain" of world science and technology. Recognizing this point is crucial because the historical experiences of China's "closed-door" policy and the Soviet Union's "innovation behind closed doors" both demonstrate that regardless of how advanced a country's science and technology were previously, choosing isolation will inevitably lead to backwardness.

3.3 Pursuing an "Innovation Economy" Through More Open Policies

Therefore, China must learn profound historical lessons and must not fantasize about leaving today's world science and technology system to build "another mountain." Facing the "de-globalization" policies of the United States and some Western countries, China needs even greater openness, even unilateral openness. Even if the United States and some Western countries implement technological closure policies against China, China still needs to remain open to them.

The United States and some Western countries fear China's scientific and technological rise and have implemented comprehensive suppression policies against China. However, in the long run, they will not succeed because they practice political logic rather than capital logic, technological logic, or market logic. Regarding the West's own development experience, what has driven Western development is not political logic but capital, technology, and markets. The several waves of globalization that have occurred in the West since modern times have been the result of production factors such as capital and technology breaking through politically established boundaries to form international markets. For China, facing political suppression from the United States and Western countries, it must respond with capital logic, technological logic, and market logic.

According to research by British science and technology historian Joseph Needham and others, China's Song Dynasty technology was at the world's leading level at that time. The modern British thinker Francis Bacon pointed out in *The New Organon*: "These three inventions (printing, gunpowder, and the compass) have changed the whole face and state of things throughout the world: the first in literature, the second in warfare, and the third in navigation; and innumerable changes have been thence derived, so that no empire, sect, or star appears to have exerted greater power and influence on human affairs than these mechanical discoveries" [1]. Later, Marx inherited Bacon's view, stating: "Gunpowder, the compass, and printing—these are the three great inventions that heralded the arrival of bourgeois society. Gunpowder blew the knightly class to pieces, the compass opened up the world market and established colonies, and printing became the tool of Protestantism and, in general, the means of scientific revival, the most powerful lever for creating the necessary prerequisites for spiritual development" [2]. However, due to the closed-door policy, China first lost a nautical era and subsequently lost an industrialization era that followed.

How, then, can a country cross the "middle-technology trap"? Since the industrial revolution, world economic development has been a continuous process of innovation, known as the "innovation economy." Although innovation encompasses many aspects including institutions and technology, its core is technological innovation. The birth of a new technology not only gives rise to new industries but also facilitates institutional innovation in other areas. New technologies are often destructive to existing societies—the new economic interests generated by new technologies undermine old economic vested interests, change existing social structures, and force current institutional systems to reform. Therefore, economist Joseph Schumpeter called this process "creative destruction."

4. Three Essential Conditions for Crossing the Trap

From the perspective of these three conditions, China needs to undertake a series of reforms at the institutional and policy levels. This does not mean that China should replicate Western successful experiences. Western experiences can be learned from but are difficult to replicate. China needs to consider how to meet these conditions based on its own actual circumstances. If it cannot obtain exactly the same conditions that developed economies had initially, it must find alternative solutions and use its own methods to meet these alternative conditions.

The three necessary conditions are:

First, **basic research**. From the experience of developed economies, basic research is generally conducted by universities and research institutions. The research activities of Nobel Prize laureates largely fall under basic research. Basic research is not capital-driven nor capital-intensive; it begins with a sense of mission or curiosity about major scientific questions. Therefore, governments provide university professors and research institution scholars with decent salaries and living conditions to ensure they have full academic freedom, especially freedom for international exchange. In the West, such professors and scholars often call themselves or are called "anarchists." However, these "anarchists" are not anti-government; rather, they do not need excessive government intervention because scientists believe that science and technology have their own logic. Nevertheless, since World War II, governments have played increasingly important roles in scientific research, such as establishing basic research funds and building laboratories needed for basic research. The United States has been particularly prominent in this regard.

Second, **applied technology**. Applied technology differs from basic research. Historically, many technologies did not come from the transformation of basic research; many early technologies came from artisans' discoveries. After World War II, increasingly more applied technologies have come from the transformation of basic research. The transformation of applied technology is often driven by capital or commerce and is capital-intensive. Precisely because it requires large amounts of capital and involves significant risks, applied technology is often undertaken by enterprises or state-supported enterprises, such as state-owned enterprises in the Soviet Union and China or corporate conglomerates in Japan and South Korea. The direct goal of many industrial laboratories in developed countries is the transformation of applied technology.

Third, **financial support**. Financial support is equally important and increasingly so. Both basic research and applied technology require substantial financial support; without it, neither can be sustained. Basic research in the United States and Western countries is generally supported by both government and private sources. While many European universities are government-supported, U.S. universities receive support from both private and government sources, with private sources often being more important in many cases. Numerous private schools and research institutions in the United States are supported by private capital. Because of the profit-seeking nature of private capital, the integration of industry, academia, and research in the United States is far better than in Europe. Applied technology is capital-intensive, requires massive investment, and involves huge risks, making it difficult for traditional financial systems to meet its needs. In the United States, this need is primarily met by the venture capital system. In fact, the venture capital system is the protagonist of the U.S. applied technology market; without it, American scientific and technological progress would be hard to imagine. Although Europe's venture capital system is not as developed as that of the United States, because it belongs to the Western market, it can obtain support from U.S. venture capital. Economies such as Japan, South Korea, Singapore, and Taiwan also have similar characteristics and can obtain venture capital from the West because they belong to the Western market.

5. Institutional Reforms Needed

5.1 Basic Research

5.1.1 Distinguishing Basic Research from Applied Technology Because much applied technology comes from basic research, the two are closely related and difficult to distinguish. However, if basic research and applied technology are not clearly distinguished, most of a society's human, material, and financial resources will be invested in applied technology. The reason is simple: applied technology is "concrete" and can be transformed into tangible benefits, whereas basic research appears "abstract" and far removed from immediate practical interests. The current reality is that basic research and applied technology have not been clearly defined, and some "basic research" defined in national research guidelines still belongs to applied technology, with national investment concentrated on applied technology rather than basic research. The scientific community needs to make more scientific distinctions between the two.

5.1.2 Establishing the Main Body for Basic Research After defining basic research, it is necessary to establish universities and research institutions as strategic scientific and technological forces and as the main bodies for basic research. Basic research is not capital-intensive, but it must ensure that researchers have decent living conditions and sufficient freedom to pursue their scientific interests. Administrative intervention must be minimized, and administrative logic must not replace scientific logic. Additionally, the state needs to help establish laboratories required for basic research and provide necessary experimental equipment. These laboratories and equipment must be open to avoid redundant construction among various universities and research institutions and to improve usage efficiency. Drawing on the experience of the European Union, horizontal cooperation should be established between universities and laboratories in different regions to form basic scientific research networks.

5.1.3 Building Talent and Idea Markets For basic research, nothing is more important than having a talent market and a free market for ideas. Basic research cannot be separated from talent—basic science is almost entirely the result of scientists pursuing their scientific interests. Similarly, basic research cannot be separated from full exchange among researchers from different civilizations, cultures, and countries. In both aspects, the greatest uncertainty for China's basic research comes from the "decoupling" imposed on China by the United States and Western countries.

In basic research, the United States holds an absolute advantage. Although the United States did not have so-called basic research before World War II, with most global basic research dominated by European countries, after World War II—or more precisely, after the release of the "Bush Report"—the United States quickly changed this situation and has maintained a dominant position. The main reason lies in America's open talent policies and the free exchange of ideas created by talents from different civilizations and cultural backgrounds. The importance of talent to basic research stems from the empirical fact that, to a large extent, basic research is essentially scientists (talents) exploring and expressing scientific knowledge and truth driven by their intrinsic interests and pursuit of scientific frontiers. This intrinsic interest cannot be bought with money and is the key factor in determining whether a scientist is truly a "genius."

Given China's own conditions, it must fully utilize the comparative advantages of Hong Kong. Among Hong Kong's ten statutory public universities, five rank in the top 100 of the QS World University Rankings, and three rank in the top 50. Moreover, Hong Kong possesses a well-developed education and research system due to its university strengths. In the Guangdong-Hong Kong-Macao Greater Bay Area, if integration and development based on labor division can be achieved between Guangdong's nine cities and Hong Kong and Macao on the foundation of the Basic Law of the Hong Kong Special Administrative Region of the People's Republic of China, it can to some extent compensate for weaknesses in basic research capabilities in mainland areas. Hong Kong (or Hong Kong and Macao together) still holds great attraction for international talent. Hong Kong has long been an open city and for a long time has been one of the gathering places for European and American talent. Hong Kong's infrastructure for international talent remains intact, including salary levels, low taxation, freedom of movement, international school education systems for the children of international talent, healthcare systems, and the rule of law. As mentioned above, in the field of basic research, the state must ensure that scientists have decent living standards.

In ensuring a market for scientific ideas, when intergovernmental relations become difficult, exchanges with foreign universities should be strengthened. The United States and Western countries mostly fear applied technology, while much basic research is far from applied technology and not particularly sensitive. Since basic research mostly originates in universities and research institutions, obtaining the latest scientific ideas through university exchanges is undoubtedly the most effective approach. Furthermore, beyond traditional academic journals, big data tools should be fully utilized to understand global basic research trends. Although direct exchanges between China and the United States (or between China and Western countries) may become somewhat difficult, "third locations" (such as Southeast Asian countries) can be used for indirect exchanges to ensure that China does not become "decoupled" from developed countries at the level of scientific and technological ideas.

5.1.4 Reforming the Scientific Research Evaluation System In addition to the three aspects mentioned above, the current scientific research evaluation system needs to be reformed. Basic research requires long periods and sustained investment. Currently, some overly bureaucratic research evaluation systems are very detrimental to scientists' persistent pursuit of their interests. Under the current evaluation system, the phenomenon of basic research becoming "applied technology-ized" is very serious, with many scientists shifting to "useful" research—that is, to applied technology. As mentioned earlier, some "genius" scientists explore scientific knowledge and truth only when driven by their intrinsic interests, which cannot be bought with money nor created through administrative ranks or academic promotion channels. China's current research evaluation system is extremely unfriendly to the intrinsic interests that drive "genius" scientists. Only when scientists can freely pursue their scientific interests without worrying about evaluations can basic research hope to develop well.

5.2 Applied Technology

5.2.1 Establishing the Main Body for Technology Transformation Compared with basic research, the transformation from basic research to applied technology requires substantial capital and is capital-intensive. From the perspective of developed countries, enterprises are the main body for applied technology transformation. Once successful, applied technology transformation can yield significant economic benefits, but it involves considerable risks. Therefore, it is difficult for governments to justify the legitimacy and rationality of their investment, and governments should not be profit-seeking. Enterprises pursue profits and have the motivation to bear risks. In China, the main body for applied technology transformation can be either state-owned enterprises or private enterprises, but regardless of the type, they must be market-oriented or commercially oriented. Of course, this refers to the civilian economy, not the military and strategic domains. In military and strategic domains, technology transformation can be undertaken by state-owned enterprises or private enterprises designated by the state.

5.2.2 Building an Open Industrial Laboratory System Since World War II, the industrial laboratory system has been the most important tool for transforming basic research into applied technology. Because enterprises are the main body of applied technology, industrial laboratories should also be built and operated by enterprises. In this regard, China has established numerous national-level engineering laboratories, with an increasing trend at both central and local government levels. Additionally, a few large private enterprises (such as Huawei) have established their own industrial laboratories. However, industrial laboratories established by central and local governments still have many shortcomings, including excessive bureaucracy or administrative control, insufficient marketization, and closed, non-open operations. These shortcomings are centrally reflected in the lack of competitiveness and efficiency—government investment becomes a bottomless pit while laboratories are not held accountable for outputs.

Therefore, market-oriented reform of industrial laboratories is indispensable; we cannot only talk about inputs without considering outputs. In particular, openness is needed to improve the effective utilization rate of industrial laboratories. Industrial laboratories at all government levels should be open to each other and, more importantly, open to private enterprises. As in other countries, a large amount of technology transformation in China is carried out by small and medium-sized private enterprises that lack the capacity to build industrial laboratories themselves. Opening national laboratories to private enterprises can effectively promote the building of technological innovation capabilities in private enterprises. Furthermore, to achieve the goal of integrating industry, academia, and research, the state's industrial laboratories should also be open to universities and researchers interested in applied technology.

5.2.3 Regional Labor Division Whether for basic research or applied technology, regional labor division is necessary. Regarding basic research, the distribution of universities and research institutions is uneven. Although universities and research institutions have been established everywhere, their establishment based on comparative advantages and principles of labor division is more efficient. Similarly, in the transformation and utilization of applied technology, regions are also uneven because this involves various other factors, including sufficient engineers, industrial clusters, and supply and industrial chain layouts. The uneven regional distribution of basic research and technology application further demonstrates the urgency of building a unified national market in these two fields. Governments at all levels should not adopt a "self-sufficiency" mentality and erect various obstacles but should promote the formation of a unified national market for basic research and technology application through market-oriented reforms.

Labor division is particularly applicable between Hong Kong and mainland China. From a manufacturing perspective, the lack of enterprises that can transform basic research into applied technology is Hong Kong's shortcoming because Hong Kong's entire manufacturing system has been transferred to the Pearl River Delta and other mainland cities since the reform and opening up, leaving Hong Kong with industrial hollowness. Moreover, Hong Kong's re-industrialization is neither highly possible nor necessary. In contrast, enterprises in the Pearl River Delta possess world-renowned technological transformation capabilities, and it is precisely because of this enterprise system with strong technological transformation capacity that the Pearl River Delta has gradually become the "world's factory" since the 1990s. In other words, the advantages of the Pearl River Delta in the enterprise domain can compensate for Hong Kong's shortcomings. Equally important, the Pearl River Delta has a large number of national and provincial industrial laboratories with transformation capabilities, while it is neither possible nor necessary for Hong Kong to establish similar industrial laboratories.

5.2.4 Establishing an Open Enterprise System In terms of corporate operations, the lack of openness among enterprises is China's biggest shortcoming. In the West, since the 1980s, corporate supply chains have become longer and more open. This is the main institutional factor that has made Western enterprises increasingly internationalized and competitive. Taking American enterprises as an example, they focus on controlling key, high value-added parts while leaving other parts to the market (i.e., other enterprises) for production, or keeping design in-house while outsourcing production to other enterprises. This approach creates a "competitive" relationship among various components within a product—when one component's technology improves, other components must keep pace. More importantly, American enterprises extend their supply chains worldwide, fully utilizing production factors from around the globe.

China's situation is exactly the opposite. Enterprises are essentially in a mutually closed relationship, similar to potatoes growing on the same plant. Whether state-owned or private enterprises, all components of a product are produced in-house. Even when supply chains exist, their length is negligible. Consequently, Chinese enterprises prioritize market share most, using it to guarantee profits. Once the market becomes saturated, profits become problematic. More importantly, closed enterprises lack competitive drive. Although internal labor division exists within enterprises, it cannot compare with the external labor division of American enterprises. In terms of internationalization, an enterprise that produces everything itself is difficult to internationalize.

Overall, because American enterprises are open to each other, they can become both large and strong, whereas Chinese enterprises, though large in aggregate quantity, are large but not strong. The mutual openness among American enterprises enables them to occupy an absolutely dominant position in technical standards, rules, and regulations. Chinese enterprises are too fragmented and lack sufficient capacity to play a leading role in technical standards, rules, and regulations, remaining in a follower position.

The openness among American enterprises is not because they are naturally inclined to be open. Like Chinese enterprises, American enterprises would pursue monopolies if possible. In this regard, the U.S. government has played a crucial role. Through antitrust laws and other means, the U.S. government forces enterprises to open up. The Microsoft antitrust case is a typical example. The government originally intended to break up Microsoft, but breakup measures were less applicable to internet enterprises, so ultimately Microsoft's openness was used as an alternative to breakup. In contrast, Chinese governments at all levels often practice local protectionism, and their various administrative measures toward enterprises further strengthen the closed nature of enterprises.

Therefore, enterprise systems must be reformed. Openness should be mutual between state-owned enterprises and large private enterprises, among state-owned enterprises affiliated with different regions and ministries, between state-owned and private enterprises, and large private enterprises should be open to small and medium-sized private enterprises. This mutual openness can facilitate the lengthening of supply and industrial chains, thereby enhancing competitive awareness and capability. In recent years, to encourage the development of small and medium-sized private enterprises, the government has often formulated specific preferential policies for them. However, small and medium-sized private enterprises lack talent and technological strength, often leading to vicious competition at the low-end technology level and producing products with inferior quality and performance. In view of this, the government can legislate to force large private enterprises to open up to small and medium-sized private enterprises. For large private enterprises, they only need to extend their supply chains to small and medium-sized private enterprises.

At the international level, enterprise openness and supply chain lengthening will better help Chinese enterprises "go global" and achieve internationalization. Chinese enterprises can learn from the United States by extending their industrial and supply chains to other countries, allowing those countries to share technology, employment, and income. This approach allows other countries to share benefits while also establishing the credibility of Chinese products and achieving true interdependence.

5.3 Finance

5.3.1 Finance as Coordinator Finance is the most effective "coordinator" between basic research and applied technology. Because capital aims for profit and is highly sensitive to it, capital has enormous profit motives for transforming basic research into applied technology and knows which basic research can be converted into applied technology. In this regard, the United States has excellent experience. For many years, American universities have implemented an integrated system of industry, academia, and research, cultivating a large number of talents who understand both technology and finance. These talents are active in the venture capital world and have greatly promoted both basic research and applied technology in the United States. As mentioned earlier, government, market, and venture capital are the three main actors in scientific and technological progress in developed European and American countries.

Regarding the financial system, the absence of a venture capital system is the biggest shortcoming in China's scientific and technological progress. China's financial system serves the real economy and socioeconomic stability and cannot play the role of the Wall Street financial system, making it difficult to generate a venture capital system like that of the United States. It cannot be denied that state-owned capital or private institutions in some central cities like Shenzhen and Guangzhou are also trying to conduct some venture capital activities. However, empirical evidence shows that whether state-owned or private venture capital, they tend to be relatively short-term, especially private capital venture capital, which is also very small in scale, far from meeting the financial support needed for China's scientific and technological development. But if Hong Kong's financial center advantages can be leveraged, the financial support needed for basic research and technology application transformation can be realized. The author's research group has recently advocated that China should establish a dual financial center system, centered in Shanghai and the Guangdong-Hong Kong-Macao Greater Bay Area respectively. The Shanghai-centered financial center would serve the financial stability of the real economy, while the Greater Bay Area-centered financial center would, based on the "labor division" among the bay area's central cities, build through integrated development a financial center that can compete with Wall Street.

5.3.2 Encouraging State-Owned Capital to Play an Important Role in Venture Capital If China's banking system finds it difficult to play the role of venture capital, we can consider allowing state-owned capital to perform venture capital functions. Today, state-owned capital exists from the central to local levels in China and has already begun various investment activities. Recently, some localities have utilized state-owned capital stock to establish industrial investment and sci-tech innovation funds to meet local government economic development needs. Rather than controlling local state-owned capital, it would be better to encourage state-owned capital to perform some venture capital functions. Moreover, compared with private capital, state-owned capital can play a broader and more important role, especially in providing public goods that can be shared by both state-owned and private enterprises.

According to research by the author and his team, at the current stage, state-owned capital or funds composed of state-owned capital can at least attempt to operate around the following five aspects:

First, map the world industrial technology landscape. China must accurately understand the global distribution of industries, especially advanced industries, know China's position in the world industrial map, understand where existing industries come from, grasp their current status, and make predictions about their future, thereby helping national decision-making departments better understand how to achieve industrial upgrading.

Second, use big data and other tools to predict future industries. There are two types of industrial upgrading: one is technological upgrading within the same industry, and the other is switching between different industries. Today, emerging technologies are constantly being discovered, and the emergence of a new technology can completely replace old technologies. Because industrial funds should not only invest in industries currently considered advanced but also need to know about new industries that may emerge in the future. Only in this way can a city's or a country's industries remain in a leading position. New technologies emerge in two forms: first, technological invention, and second, transformation from basic research. Using big data and other means, it is not difficult to discover future industries.

Third, cooperate with universities to invest in basic research. Since World War II, new technologies have increasingly depended on basic research. Basic research is mainly conducted by universities and some research institutions. As discussed earlier, basic research is not capital-intensive; what it needs is space for people to pursue knowledge. Therefore, basic research generally takes university professors and researchers as the main body. This group needs decent salaries to maintain a decent living standard, and on this basis, pursue research interests, make scientific contributions from time to time, and form frontiers in basic science. Industrial funds can select some universities and cooperate with the education system to cultivate such a group of researchers dedicated to pursuing scientific interests, thereby better building an integrated industry-academia-research system.

Fourth, explore a venture capital system with Chinese characteristics to invest in applied technology transformation. The transformation from basic research to applied technology is capital-intensive and requires massive capital investment. This investment can be conducted by either government capital or private capital, but regardless of which type, it must conform to market rules. China's current financial system is not equipped to make large-scale investments in applied technology transformation, so alternative institutions must be found. Funds are undoubtedly a feasible alternative system.

Fifth, invest in emerging industries. Existing industries need investment, but because many participants will invest in existing industries, industrial funds should invest more in emerging industries. Investing in emerging industries is risky, and other institutions (including banks) generally avoid such venture capital.

At this point, industrial funds must play this role. Therefore, even government industrial funds must be open to private capital, absorbing, accommodating, and leading private capital's industrial investment to achieve complementary advantages, risk-sharing, and return-sharing between state-owned and social capital.

It should be emphasized that if state-owned capital is to play the role of venture capital, administrative system reform of state-owned capital management departments is needed to overcome shortcomings caused by the existing administrative system, transcend short-term interests, and make long-term investments in the future. Current state-owned capital venture capital has a nature of pursuing short-term interests and is not venture capital in the general sense. Venture capital returns generally require a long time, typically 8-15 years or even longer. Such long-term investments are not permitted under the current system because the tenure of state-owned capital managers is generally 3-5 years. Obviously, current managers cannot invest for their successors and must also be accountable for their own investments. To overcome this systemic shortcoming, reform is necessary. For example, learning from Singapore's state-owned asset management, state-owned capital management could be granted non-governmental status, such as statutory bodies, with tenure not constrained by general administrative structures, while also establishing effective evaluation and supervision mechanisms. In any case, within China's institutional system, state-owned capital is an objective existence that can be utilized to play a greater role in scientific and technological progress.

5.3.3 Government's Coordinating Role In addition to the roles of finance and state-owned capital, the government must also play a role in scientific and technological innovation through financial reform. The current dilemma of China's financial structure is that sci-tech innovation enterprises that truly need capital cannot obtain it, while enterprises that do not need capital are "given" funds. China's financial industry is dominated by state-owned banks that mainly serve state-owned enterprises, especially large ones, while private enterprises, particularly small and medium-sized ones, find it difficult to obtain the financial services needed for survival and development. Although major state-owned banks have established institutions to serve small and medium-sized enterprises, they lack motivation or even have no motivation to do so. Large private enterprises that have developed well are also served by state-owned banks, but a common situation occurs: once state-owned banks provide these enterprises with excessively "cheap" funding, these private enterprises unconsciously drift toward policy rent-seeking, leading to weakened competitiveness and even eventual bankruptcy. Moreover, a number of approved small and medium-sized banks specifically designed to serve small and medium-sized enterprises still have "officially-run" licensing and management selection processes. Apart from policy rent-seeking, unsound management systems also lead to frequent irregularities.

After the 2008 global financial crisis, what drove U.S. economic recovery was not

Wall Street or large banks but community-based small and medium-sized banks. Large banks only played a stabilizing role; the real drivers of economic recovery were small and medium-sized banks truly related to the people's livelihood economy and innovation and entrepreneurship.

To address related issues, three adjustment paths can be considered: First, promote the development of private finance specifically serving small and medium-sized private sci-tech innovation enterprises, with the government regulating the scale, service targets, and regions of private finance according to regulations. Second, establish a large number of small and medium-sized state-owned banks specifically serving small and medium-sized enterprises, with assessment standards different from those for large state-owned banks. Third, guide funds released after quantitative easing into these small and medium-sized banks related to the people's livelihood economy and innovation and entrepreneurship.

Currently, the related issues are prominent. The central government requires banks to direct funds to small and medium-sized enterprises, but most banks still do everything possible to direct funds to state-owned enterprises or large private enterprises. This is caused by structural misalignment. If the financial structure is not adjusted, China's loan problems for small and medium-sized sci-tech innovation enterprises cannot be solved. However, it is clear that this problem can be solved through reform.

5.3.4 Role of Private Venture Capital Although private venture capital has been permitted and encouraged by the government in recent years, its scale remains very small and is still negligible to date. Moreover, because private venture capital is still a relatively new phenomenon, it suffers from insufficient experience and a lack of rules, regulations, and management systems. Once it reaches scale, problems can easily arise. However, the problems occurring in private venture capital do not mean it is unimportant; on the contrary, the general trend is that private venture capital must play an increasingly important role. Compared with state-owned capital, private capital has its own comparative advantages. Private venture capital can effectively absorb private capital into the sci-tech innovation field. Private capital has stronger sensitivity and greater flexibility regarding technology transformation. Because private capital more easily combines with foreign capital, it can play a greater role in attracting foreign capital when the United States and some Western countries impose "chokepoint" tactics and "systematic decoupling" on China. At the international level, private capital is more easily internationalized than state-owned capital. In fact, after foreign capital enters China, it often cooperates with private capital; similarly, when private capital "goes global," it easily cooperates with local capital. In this regard, private capital already has considerable experience.

Regarding the venture capital role played by private capital, what China needs to do is: first, allow and vigorously encourage private capital to conduct venture capital activities and provide adequate space; second, regulate and govern private venture capital to reduce and avoid its potential negative impacts on society and the economy.

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How can China avoid the middle-technology trap?

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Abstract: From the perspectives of supply chain, industrial chain, or value chain, China's current technology is generally at a middle-technology level. Specifically, this manifests in three ways: First, there is a lack of original technology, meaning a shortage of technological creation "from 0 to 1." Second, development focuses primarily on applied technology. If we measure applied technology development on a scale of "1 to 10," China currently stands at "4 to 7" but lacks the "8 to 10" level of technological sophistication. In other words, China has not yet reached world-leading levels in many fields, and dependence on foreign sources for many core technologies and key components remains high. Third, while China has achieved world-leading positions in certain applied technology fields, these fields remain fragmented and have not formed a systematic whole. The overall technological level is far from achieving comprehensive, systematic strength.

The Twentieth National Congress of the Communist Party of China proposed that the country's goal in the next stage is to achieve high-quality development of the Chinese economy. Although the realization of high-quality economic development is driven by many factors, the experience of world economic history shows that whether for Western countries that first achieved industrialization or for latecomers that became developed economies, technological upgrading and the resulting industrial upgrading are the key and core for a country to achieve high-income status. Especially for a large economy like China, achieving high-quality economic development will be difficult without technological upgrades. Thus, China not only needs to achieve "8 to 10" technological progress at the applied technology level but also needs to transform from applied technology to original technology "from 0 to 1."

In recent years, the author and his research team have studied how China can achieve high-quality development and upgrade to a developed economy. Through comparative analysis of developed economies including Europe, the United States, Japan, and Asia's Four Little Dragons, as well as other economies in Latin America and Asia, we have refined a new concept: the "middle-technology trap." This concept demonstrates that if an economy wants

to upgrade from middle-income to developed economy status, it must avoid the middle-technology trap. An economy can rely on technology diffusion and learning from technology transferred from developed economies in its early development stages. However, to achieve the goal of becoming a high-income economy, China not only needs to cultivate original technological innovation "from 0 to 1" but also needs to achieve sustainable technological upgrades in existing technology fields—that is, to continuously move from a technical level of "4 to 7" or lower to a level "above 8" on the technological scale.

Keywords: middle-technology trap, original technology, basic research, application technology, financial system, venture capital, enterprise reform

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Note: Figure translations are in progress. See original paper for figures.