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Disruptive technology and industrial policy paradigm shifts: a discussion based on China

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Abstract

How to understand the relative success and institutional basis of the industrial policies implemented by the Chinese government since the reform and opening up? And, In the context of a new round of scientific and technological revolution, disruptive technologies are constantly emerging, what kind of challenges will this new situation bring to China's existing industrial policy paradigm? In this paper, I employ the method of literature and theoretical analysis, combined with a series of related studies, especially of my own, to answer the above questions. In my view, China's relatively successful industrial policy paradigm will become a trap of China under the rise of disruptive technologies. To prevent China from falling into the trap, the Chinese government need to transform from a selective industrial policy to a functional industrial policy. It should conduct a comprehensive reflection on the existing national innovation system and reshape the science policy, technology policy, talent policy and competition policy. Therefore, it is also necessary to establish an institutional foundation compatible with the new industrial policy paradigm in terms of incentives through institutional reform.

Keywords: Disruptive technology, Industrial policy paradigm, Selective industrial policy, Functional industrial policy, Logistical state

On May 14, 2021, the State Leading Group for Science and Technology Structural Reform and Innovation System Construction held its 18th meeting in Beijing. One of the items on the agenda was to discuss the potential disruptive technology of integrated circuits (ICs) for the post-Moore era. This moment marks the first time the Chinese government has publicly expressed its focus on opportunities for disruptive technology. The new round of scientific and technological revolutions represented by big data, artificial intelligence (AI) and the mobile internet is deeply affecting the industrial and economic development of various countries and thus may drive global economic growth into a new long-term cycle. Clearly, whether this opportunity can be seized could be directly related to the major issue of whether China can achieve an innovation-driven development strategy.

When a latecomer country strives to approach the world's technological frontier through technological learning or the new scientific and technological revolution makes it possible for a latecomer country to keep pace with first-mover countries in

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the direction of new technologies, how can a latecomer country shift from technological catch-up to strengthening original innovation through industrial policy paradigm shifts? This question raises an important academic and policy issue. Based on the relevant literature, this paper uses theoretical analysis methods with China as the subject to discuss the issue of industrial policy paradigm shifts in latecomer countries in relation to the new round of scientific and technological revolutions.

This paper is structured as follows: China's catch-up industrial policy paradigm and its institutional basis section summarizes the characteristics of China's industrial policy paradigm for technological catch-up and analyzes its institutional basis; Evaluation of the effectiveness of the selective industry policy in the catch-up stage section evaluates the effectiveness of China's industrial policy in the technological catch-up stage; Towards a new industrial policy paradigm under the new round of scientific and technological revolution section discusses why China requires industrial policy paradigm shifts against the background of the new round of scientific and technological revolutions; Institutional discomfort and comprehensive reform for the industrial policy paradigm shift section analyzes the incompatibility between China's current system and the new industrial policy paradigm and the institutional reforms that must be carried out; and Conclusion section presents the conclusion.

China's catch-up industrial policy paradigm and its institutional basis

For many years, most industries and enterprises in China have been far away from the global technological frontier. As a latecomer country, China is in the technological catch-up stage, and an important goal of its industrial policy is to introduce, absorb, and localize advanced foreign technologies——localization means adaptive innovation based on a country's resource endowment characteristics——and use imported technology to achieve economies of scale and lower production costs through mass production methods, thus enhancing the global competitiveness of China's economy to achieve economic catch-up. Both the 156 major industrial projects aided by the Soviet Union in the early stage of the planned economy and the continuous introduction of a large amount of production equipment and assembly lines from Western developed countries since the reform and opening up belong to this catch-up strategy.

In the 1980s, in the process of promoting the transformation of the economic system, China learned from the East Asian "developmental state" model, especially Japan's experience, established and implemented a catch-up industrial policy system, and attempted to use industrial policy tools to achieve the goal of "state regulating the market, market guiding enterprises". Therefore, industrial policy has become an important "handle" for the Chinese government to realize the state catch-up strategy based on the market mechanism. China's catch-up industry policy[1] includes the following contents:

[1] The literature on China's industrial policy is extensive, and representative works include the followings: He Liu, Huanchang Yang and Junping Liang, The general idea of industrial policy implementation in China, Economic Theory and Business Management, Vol. 2, 1989, pp. 14–19; Xiaojuan Jiang, Industrial Policy during Economic Transition: An Empirical Analysis and Prospects for China, Shanghai: Shanghai People's Publishing House, 1996; He Liu and Weimin Yang, China's Industrial Policy - Concept and Practice, Beijing: Economic Press China, 1999; and Feitao Jiang and Xiaoping Li, Direct market intervention and restriction of competition: the orientation and fundamental flaws of China's industrial policy, China Industrial Economics, Vol. 9, 2010, pp. 26–36. For review papers, please refer to Feitao Jiang and Xiaoping Li, Evolution and development of China's industrial policy in the forty years of reform and opening up - and the transformation of China's industrial policy system, Management World, Vol. 10, 2018, pp. 73–85.

(1) In terms of industrial structure policies, a list of industries that are clearly encouraged, restricted, and eliminated is developed, and key industries for development are identified. In addition, supporting policies, such as finance and taxation, land, credit, and import and export, directly intervene in resource allocation in different types of industries, with particular emphasis on prioritizing key industries in resource allocation.
(2) In terms of industrial organization policies, economies of scale is emphasized. In key industries, a series of standards are used to determine the key support enterprises, to encourage their large-scale development, to achieve internal professional collaboration through a series of horizontal and vertical mergers and acquisitions (M&As), and to prioritize them in resource allocation.

The main feature of the industrial policy implemented by China in the catch-up stage is "selectivity" (Jiang 2021).[2] "Selectivity" includes the selection of not only specific industries but also specific enterprises to achieve the goal of catch-up policy, that is, the selection of both industries and enterprises, the selection of both winners and losers. To ensure faster development of selected leading industries and key enterprises, various administrative intervention measures must be used to influence resource allocation. Although the planned economy has gradually withdrawn from China's historical stage since the mid-1980s, a large number of production factors, including capital and land, are still controlled by governments at all levels and state-owned financial sectors. With the help of administrative power, governments at all levels require sectors that control production factors to allocate resources in accordance with industrial policies. On this basis, China's industrial policy has developed a series of specific characteristics:

(1) In terms of target subjects, industrial policies prefer to support large enterprises, especially large state-owned enterprises (SOEs), or enterprises with political connections, including private enterprises, to help them scale up as soon as possible, thus forming an oligopoly market structure.
(2) In terms of instrument selection, industrial policy prefers policy instruments for factor price intervention, such as suppressing interest rates and industrial land prices, so that supported enterprises can reduce their scale costs. In the early days of the reform and opening up, China's economic policies were always financially repressive and were implemented to complement industrial policies. In addition, governments at all levels prefer the industrial organization policy of vertical or horizontal M&As to form leading enterprises to scale up as soon as possible.
(3) In terms of policy orientation, industrial policies tend to encourage exports or industries and enterprises with export competitiveness. Due to large-scale production, it is difficult to rely solely on the domestic market to process the output of the supported industries. Therefore, governments at all levels often use financial and

[2] Industrial policies are usually divided into two main categories of selective industrial policies and functional industrial policies. In contrast to selective industrial policies, the theoretical starting point of functional industrial policies is "market failure", so this type of industrial policy and the corresponding policy instruments aim to restore market functions and create conditions that encourage national entrepreneurs to invest in and develop relevant industries based on comparative or competitive advantages. Although in terms of results, functional industrial policies also promote the development of specific industries, the entrepreneur rather than the government chooses which industry or type of industry to develop.

tax instruments, such as export tax rebates, to attract the purchasing power of the international market to achieve sustained growth in supported industries or enterprises.

The above practices inevitably lead to long-term tensions between industrial policies and market mechanisms. On the one hand, industrial policies try to influence the results of the operation of the market mechanism; on the other hand, the market mechanism is constantly seeking gaps in industrial policy to make breakthroughs according to its own logic. In general, industrial policies usually take precedence over market mechanisms and maintain a dominant position in resource allocation. This situation was not relieved until China joined the World Trade Organization (WTO) in 2001. In addition, after entering the twenty-first century, some changes have taken place in industrial policy, such as the increase in inclusive and functional content. In particular, innovation policy has received a certain amount of attention in industrial policy.

Catch-up industrial policy characterized by selectivity can be implemented by government officials at all levels because of its institutional basis, i.e., China's special central-local relationship and the performance appraisal system for the appointment and removal of local officials, which provide an incentive mechanism for implementing selective industry policies. The central-local relationship has undergone multiple rounds of administrative decentralization since the founding of the People's Republic of China (Wu 2015), and at the core is the power-sharing (rather than decentralization) of organizational structure between the central government and local governments. This organizational structure is similar to the corporate organization of the "holding company" (i.e., H-form organization) (Wu and Huang 2008) and is characterized by the isomorphic responsibility between central and local governments. The central government delegates the administrative resource allocation power to local governments, and local officials are authorized to use their power to achieve the central government's policy goals. However, the central government maintains flexibility and control over the degree of authority it delegates to local governments and officials, so the authority can be adjusted according to the actual situation, with necessary supervision and incentive measures. Local officials make strategic choices based on their own characteristics (ability and age) to determine the allocation structure of financial resources (Huang et al. 2019).

Specifically, this central-local relationship and institutional framework have the following three main characteristics: (1) a performance-oriented promotion mechanism with a focus on economic growth, i.e., political incentives; (2) reservation of space for local officials to obtain private monetary benefits from economic growth, i.e., financial incentives; and (3) vertical supervision and parallel supervision of local government officials by the central and local committees of the Communist Party of China (CPC) to prevent excessive resource misallocation and excessive corruption of officials.

Evaluation of the effectiveness of the selective industry policy in the catch-up stage

In the more than 40 years since the reform and opening up, especially the first 30 years, China's overall economic performance has been quite outstanding. Clearly, industrial policy seems to have achieved remarkable results. After all, China has become the most

important country in the world and has the highest proportion of manufacturing in the global industrial chain. Why does the selective industry policy appear to be relatively effective? There are two main reasons, which reduce the potential inefficiency of selective industrial policies.

First, in the economic catch-up stage of latecomer countries, the catch-up industry policy has relatively low information requirements for officials when "selecting the right industry" and "the right technology". Pioneering countries with mature and cutting-edge technologies have relatively clear technical standards and technical routes, which reduce the possibility of choosing inappropriate technology routes for the latecomer countries when introducing technologies. In addition, the relative maturity of the introduced technology means that there are limited opportunities to generate new technologies in the direction of established technology development, thereby reducing the option value of small and medium-sized enterprises (SMEs), especially startups, and the opportunity cost brought by ignoring or even sacrificing SMEs, which is ignored or even sacrificed, is in a relatively affordable range.

Second, the manufacturing process or the service process has the characteristics of economies of scale. For sectors or industries demonstrating economies of scale, the selective industry policy of "picking winners" and scaling up as soon as possible is likely to succeed. For technologies and learning methods that are based on the introduction of equipment and production lines, production usually exhibits economies of scale; therefore, supporting key enterprises can achieve economies of scale.

For example, high-speed rail (HSR), which has been considered a success in recent years, clearly exhibits the above two characteristics of economies of scale and clear technical routes. The fixed cost of HSR is substantial, therefore, the effect of economies of scale is prominent. Moreover, the HSR technology developed in China has fully referred the existing technologies in Germany and Japan. On this basis, Chinese enterprises have carried out derivative innovations in many aspects.

The relative "effectiveness" of selective industry policies is undoubtedly related to the aforementioned organizational structure between the central and local governments. Under the power-sharing system between the central and local governments, to balance political promotion and personal monetary interests, local officials often support the most productive enterprises, which is the optimal behavioral strategy to maximize personal welfare. In the form of a "power auction", local officials select the enterprise with the "highest bid" for support, which is an incentive-compatible behavioral strategy in line with their political and economic interests (Huang et al. 2022). The enterprise with the highest bid must be the enterprise that can create the largest entrepreneurial rent under the given production resources; the maximum entrepreneurial rent is conducive to local officials' political promotion or the acquisition of economic benefits (although the selected companies might thereafter show X-inefficiency). Only by supporting enterprises that are most efficient and most likely to achieve the entrepreneurial rent can officials achieve their power rent to the greatest extent possible. In this sense, officials' motivation to choose poorly efficient enterprises to support them is relatively weak, which is an important reason why the effect of selective industrial policies seems not bad.

In addition, selective industry policies often have a strong export orientation, which requires developing industries with comparative advantages. Many industries selected by the selective industry policy are indeed industries with comparative advantages in China, and the development of industries lacking comparative advantages does not motivate local officials because it is even more difficult to achieve the industrial policy goals they are pursuing. As Berger and Martin (2011) found, since China's accession to the WTO, China's export growth has been concentrated on a few products in a few industries, and a careful analysis can easily reveal that the exported products of these industries are usually industries and products that are supported and encouraged mainly by various local governments (Berger and Martin 2011). An export orientation has undoubtedly promoted the participation of Chinese enterprises in the global economic division of labor, which is conducive to improving the production efficiency and competitiveness of enterprises and the allocative efficiency of production resources.

Nevertheless, the above analysis does not mean that the selective industrial policy has achieved the maximum potential efficiency in resource allocation for the following reasons. First, local officials often choose enterprises with the highest efficiency among enterprises with political ties rather than among all enterprises, which thus weakens competition. Local officials do not want enterprises that are more competitive without political ties to outperform the enterprises they have selected. Hence, once the selected enterprises are protected from fierce competition, they often gradually lose their existing efficiency, and eventually, the X-inefficiency can emerge in the internal management of enterprises, which could produce increasingly serious consequences over time.

Second, selective industry policies prefer policy instruments for factor price intervention, therefore, both comparative advantage and absolute advantage factors play roles in China's exports. Artificially reducing the price of production factors could improve enterprises' competitiveness by reducing their financial costs of enterprises, but these advantages are only artificially created false advantages. Consequently, compared to the optimal export volume determined by the comparative advantages, the actual export volume of Chinese export industries or export enterprises often exceeds the theoretical optimal export volume, that is, the export volume is too large. Excessive exports not only reduce efficiency but also easily induce trade frictions with other countries, which is inherently related to the policy instruments used by selective industry policies. Moreover, because local governments are usually the main bodies of implementation of various types of selective industrial policies, they often try to use industrial policy instruments to maximize the region's export volume based on their own interests, thereby causing interregional export competition and leading to continued deterioration in China's terms of trade.[3]

Third, policy instruments for factor price intervention are prone to breeding rent-seeking and corruption. Enterprises with political ties to local governments are more likely to obtain production resources with lower prices, which induces them to seek rent. The largest waste of rent-seeking behavior is the consumption of production factors and resources by the rent-seeking process itself, which is a deadweight loss. And, the

[3] Here I wish to thank the anonymous reviewers for their clear suggestions.

rent-seeking can cause a more serious problem, namely, once corruptive political ties are established with certain enterprises, in subsequent stages, local officials could abandon some objectives of the selective industrial policy, such as the pursuit of a higher level of technology and the pursuit of the economics of scale, but tend to maintain the enterprises selected in the previous stage, thus selecting enterprises that lack a higher technological level or economies of scale.[4] Moreover, long-term support for a small number of enterprises can easily lead to an excessive scale of enterprises and diseconomies of scale.

In short, the Chinese government replaces the planned economy with selective industrial policy, which brings about continuous improvement in economic efficiency, improves the efficiency of resource allocation in the Chinese economy, and promotes the rapid development of the Chinese economy in the process of reform and opening up. However, compared with the theoretical Pareto optimality, the operating efficiency of this "semimarket and semicontrol economic system" that relies on selective industrial policies is lower, and even when compared to some benchmark countries, such as the United States (US), the lack of efficiency is evident. Hsieh and Klenow (2009) studied the productivity gap between China, India, and the US and found that the productivity gap between China and the US is 30–50%. Clearly, this gap is considerable, which reveals the limitations of relying on selective industrial policies and indicates considerable room for the Chinese economy to further improve efficiency through reforms that strengthen competition.

Towards a new industrial policy paradigm under the new round of scientific and technological revolution

With the advancement of technology in China, some enterprises and industries are gradually moving to the forefront of global technology. More importantly, the new round of scientific and technological revolution could lead to creative destruction of existing technology and bring about disruptive technology, making the technological gap between China and the frontier countries in traditional fields less important and enabling some Chinese enterprises and industries to start from the same position as former technologically advanced countries. However, there is a problem that cannot be ignored, i.e., the selective industrial policies that have produced certain effects in the past could face the risk of complete failure, and even successful experiences from the past are very likely to become policy traps in the future.

In recent years, disruptive technologies have emerged, such as three-dimensional (3D) printing, 5G, genetic engineering, smart grids, quantum computing, and digital currency. In particular, the semiconductor industry has received attention. As Moore's law approaches the physical limit, the lithography process, as a technology node, has reached 5 nm and is moving toward 3 nm. After reaching 2 nm, the quantum effect could cause the function of silicon-based semiconductor integrated circuit (IC) devices to fail. Therefore, the technical route reducing costs by improving the number of transistors in a dense IC, i.e., Moore's law, cannot be valid. At present, the direction of the new

[4] One of my theoretical studies (with colleagues) suggests that in countries with a weak rule of law, even when the central government initiates competition-enhancing market reforms, local officials are usually reluctant to abandon support for enterprises with political ties in favor of more efficient potential market entrants, unless, of course, the latter's productivity exceeds a threshold that is significantly higher than that of the selected enterprises, as shown in (Huang et al. 2019).

disruptive technology route in the semiconductor industry is unknown, including developing new materials, developing new processes, complexifying the chip architecture, and introducing new design concepts (e.g., from single system integration to multisystem multifunction integration). These aspects are currently being tried, and only market competitiveness can ultimately determine the direction of disruptive technological breakthroughs.

The inherent uncertainty of disruptive technology could introduce two major changes to economic activities. First, economies of scale are no longer as important, and even premature pursuit of economies of scale is dangerous. Thus, if the selective industry policy continue to be implemented, once an inappropriate technology route is selected, all enterprises under the industrial policy could fail, and the opportunity for technological development could be lost. An overarching lesson of Japan's failure by choosing analog technology on high-definition television (HDTV) in the 1980s still has clear warning value today. For example, early determination of the technology path for China's 5G development may need to be considered more cautiously, as there is still great uncertainty about which information and communication technologies will represent the world's dominant technical route in the future. The US entrepreneur Elon Musk plans to launch tens of thousands of satellites to form the so-called "Starlink" or "Skynet", which poses great challenges to China's current 5G communication network. Moreover, 5G is characterized by microwaves and shortwaves, with large propagation power and short distances, and has high requirements for latency. In the future, 5G will be used more in various industrial automation scenarios. Recently, some US companies have developed ultra-shortwave technology. Compared with the current 5G technology in China, this technology has obvious advantages in terms of latency. Some may think that the "Starlink" technology or ultra-shortwave technology is too advanced. During debates concerning the HDTV technology route, some experts in Japan suggested that the amount of data transmitted by digital technology was too large to commercialize in a short period. However, a US company developed compression and decompression technology through algorithms to rapidly reduce the amount of data transmission and transmission costs and ultimately completely outperformed analog technology, which caused Japan's substantial investment to be in vain. At technology frontiers, no one knows what technology truly has promising prospects, which could ultimately be screened out by the market through competition. Therefore, in the early developmental stage of disruptive technologies, economies of scale are not as important and even dangerous.

Second, the option value of SMEs is highly prominent. Since the potential optimal technological route of disruptive technology is in the hands of a certain SME, a country must develop enough SMEs to gain a competitive advantage in frontier technology. According to history as presented by scholars, at the beginning of any disruptive technology, there may be many SMEs competing for "dominant design" in production technology. Only after the dominant design is accepted and determined by the market do the surviving SMEs start to develop the process technology to reduce production costs (Abernathy and Utterback 1978). Since it is impossible to determine in advance which dominant design could win, when a new round of scientific and technological revolution is approaching, a country can gain an advantage in global competition only if it develops enough SMEs to offer sufficient diversified technological routes.

These two changes have directly led to a loss in value of China's past relatively successful selective industrial policy amid a new round of scientific and technological revolution, and the selective industrial policy may even lead to failure and become a trap in the future. Our recent empirical work (Huang et al. 2021) indicates that as a result of China's implementation of the selective industrial policy of "selecting winners", the selected enterprises often eventually become winners. In the high-tech industry, government subsidies promote subsidized enterprises to carry out more technological innovations and successfully expand their market share, thereby improving production efficiency. At the same time, enterprises that are not selected show a decline in productivity because the market share shrinks and eventually become zombie companies. In an era when the disruptive technological revolution is ongoing, the SMEs not selected by the government have a significant option value, and their technological innovation efforts determine the technological direction that is most likely to succeed in the future. If the opportunity cost of sacrificing SMEs in the catch-up stage with a clear technological route is not large and the benefits of economies of scale are not low, then it could be very dangerous for China to continue employing the industrial policy of choosing winners today. Only by promoting innovation and entrepreneurship, relaxing market access, improving the business environment, and allowing as many SMEs as possible to grow rapidly can these SMEs play an important role in economic development driven by innovation. Therefore, how to achieve a shift from the selective industrial policy paradigm to the functional industrial policy paradigm has become critical and urgent.

How can China shift to a functional industrial policy that promotes disruptive technology? To answer this question, the complete process of innovation activities must be accurately understood. In the era of science-based technological innovation, innovation can be understood as a "4x100 meter relay", i.e., innovation can be divided into four stages of scientific research, basic technology development, product and process development, and market introduction (Fig. 1). Each stage can be compared to a 100-m dash. Participants in each stage must not only "run well" on their own course but also coordinate with participants in previous and subsequent stages to eventually become global winners in the innovation arena. There are obvious differences in participants' behavioral patterns, incentive mechanisms and evaluation systems at different stages. To form effective incentives at each innovation stage, the government must build effective systems and policy guarantees according to the characteristics of each stage.

Therefore, to ensure that China forms an efficient "4x100 meter relay" innovation system and continues to promote its own disruptive technology amid a new round of scientific and technological revolution, the functional industrial policy paradigm should have the following characteristics.

First, in the era of science-based technological innovation, disruptive technology must be established on the basis of scientific prosperity. In his seminal work on science policy, *Science: The Endless Frontier*, Vannevar Bush emphasizes that the practical knowledge that enterprises obtain from technological development results from scientific capital and scientific prosperity (Bush 2021). Future functional industry policies must include science policies. Scientific prosperity requires the establishment of a series of institutional arrangements, such as a financing mechanism based on national financial funds,

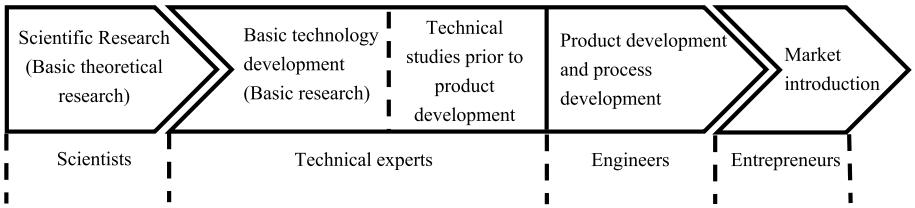

Fig. 1 Four innovation stages. Source: Brem and Voigt (2009), modified by the author

autonomous decision-making power of scientists on research topics, priority of scientific discoveries, and a peer review system among scientists (Dasgupta and David 1994; Stephan 1996). However, China's current science policy and institutional system are fragmented,[5] and some practices even violate the laws of science. For example, less than 6% of China's entire research and development (R&D) funding is used for basic research, which is far from the proportion of 30–40% in most developed countries. Consequently, China's current basic research capacity is still at a significant disadvantage compared to that of developed countries.[6]

Second, scientific prosperity and technological development rely on talent. At this stage, the cultivation of high-quality scientific and technical personnel is becoming increasingly important, which requires that functional industry policies include higher education and personnel training policies. Aghion and Durlauf (2007) emphasize that, when a country's development stage shifts from technological catch-up to self-innovation, its education policy must shift its focus from primary and secondary education to higher education, increase investment in higher education, and cultivate enough high-level scientific and technological talent to meet the needs of domestic innovation. Aghion and Durlauf (2007) particularly criticize the lower investment in higher education by the countries of the European Union (EU) compared to the US, which hinders improvements in innovation capacity. China began expanding college enrollment at the end of the twentieth century, and the number of talents in the disciplines of science, technology, engineering, and mathematics (STEM) in China has leapt to the forefront of the world. However, there are problems that must be addressed in China's higher education system, such as overly planned curricula for university majors, harsh access to universities run by social forces, and excessive distribution of financial resources to a few universities.

Third, the government should establish a universal policy to promote enterprise R&D. The government must intervene in enterprise R&D appropriately, and Arrow (1962) has already provided a theoretical explanation for this issue. Moreover, according to Aghion et al., as a country approaches the technological frontier, R&D activities

[5] The central government departments involved in setting China's science policy include the Ministry of Education, the Ministry of Science and Technology, the Ministry of Industry and Information Technology, the Ministry of Finance, the Ministry of Ecology and Environment, the National Health Commission, and the central institutions directly under the Chinese Academy of Sciences, the Chinese Academy of Engineering, the China Meteorological Administration and some bureaus managed by national ministries. This arrangement has led to a multiplicity of departments being involved in science policy, a fragmentation of resources such as research staff and funding, and a clear tendency towards administrative allocation mechanisms, which is particularly detrimental to coordinating major scientific research.

[6] In his speech at the Symposium of Scientists in September 2020, Xi Jinping stressed that basic research "must follow the laws of scientific discovery, driven by curiosity to explore the mysteries of the world, and encourage free exploration and full exchanges and debates" and that "the advance of scientific research institute reform should be accelerated, higher education institutions and scientific research bodies should be entrusted with ever greater autonomy, and leading innovation talent should be given greater decision-making powers over technological pathways and funding use."

become increasingly important, and the government's policies and systems to promote R&D also become more important. This view is also applicable to China. Our empirical analysis of Chinese industrial enterprises (Huang et al. 2021) shows that, in general, the higher the intensity of government subsidies for a high-tech industry is, the higher the technological innovation of enterprises in this industry is, and the better their productivity is. The average subsidy rate per unit of sales is used as a measure of the intensity of the functional industry policy. The results show that the functional industry policyis quite effective in improving the production efficiency of the industry and the enterprise, even in the previous catch-up stage. In other words, the government must universally promote innovation activities and help enterprises overcome the death trap of innovation (Hsieh and Klenow 2009). How the government should subsidize activities in the future requires meticulous mechanism design. The former practice of screening subsidized enterprises based on certain characteristics, such as the investment amount, the number of R&D personnel or the number of patents, may be inappropriate. Instead, behavior-based financial support policies should be implemented, such as R&D tax credits, which are granted only when R&D investment takes place. In short, more functional industrial policy instruments based on inclusive rules should be used.

Fourth, as the option value of SMEs becomes more prominent, future functional industrial policies should more include competition policies. In recent years, the Chinese government has vigorously promoted the reform of "simplification of administrative procedures, decentralization of powers, combination of decentralization with appropriate control, and optimization of services", and since last year emphasized the antitrust regulation, one of the core elements of competition policy. These measures have been effective in creating a business environment conducive to entrepreneurship and innovation. However, based on past evaluations by the World Bank, there is still much room for improving China's overall business environment. The purpose of strengthening competition is not just to strengthen the competition between incumbents; more importantly, it is necessary to emphasize the market entry and continuous growth of startups. Antitrust supervision should pay attention to the fact that many SMEs with new technologies are merged into large enterprises and large platform companies, leading to new technologies being hidden or even directly strangled. This practice is not conducive to strengthening market competition and giving play to the option value of SMEs. In addition, various inclusive financial systems that improve financing access to SMEs should be improved, and the key role of the Shanghai Stock Exchange Science and Technology Innovation Board in promoting the growth of high-tech enterprises should be fully realized.

In short, different tasks must be completed at different stages of the innovation process, and different implementation entities need different incentives. Constructing an innovative country requires the public and private sectors to carry out a division of labor and collaboration based on their respective advantages.[7] To shift to the

[7] The US is undoubtedly a prime example of an innovative nation. Gruber and Johnson provide a fascinating account of how the public and private sectors have worked together to build the US national innovation system and innovation capacity since World War II and the problems this system has faced in recent years that have threatened its global innovation competitiveness (Gruber and Johnson 2019).

functional industrial policy paradigm required for disruptive technology, Chinese government departments must adopt different policy instruments for different types of "market failure" at each innovation stage, thereby helping private enterprises compete in technological innovation in a well-functioning competitive market. In other words, to strengthen the country's original innovation capacity, the Chinese government's role is not to weaken but to optimize. In particular, the financial responsibilities of the fields of science and higher education have long been seriously insufficient, which must be addressed urgently.

Institutional discomfort and comprehensive reform for the industrial policy paradigm shift

Compared with the content and requirements of functional industrial policies, there are many issues with the current policy and institutional environment in China, resulting in considerable distortion of incentives.

For example, science, as basic research, has the attributes of a pure public goods and must use financial funds as the main financing mechanism. However, the current investment in basic research by the Chinese government is seriously insufficient; thus, scientists must seek financial support from society and enterprises. The needs of society and enterprises have placed pressure on scientists when selecting research topics and conducting research activities, leading to the departure of scientific activities from the basic goal of exploring the objective world and general laws and causing the level of science in China to lag that of developed countries for many years. In addition, regarding the assessment and evaluation mechanisms of scientists, according to Vannevar Bush, scientists should not be evaluated because the effort to generate new ideas is difficult to measure. Based on internationally accepted rules, peer review evaluates scientists' work, while administrative agencies are not suitable for the task. In China, however, various levels and types of administrative agencies dominate the evaluation of scientists. Therefore, counting the number of papers has become the simplest and most effective evaluation method, leading to distorted incentives for scientists and preferences for research topics that easily produce results, while fundamental theoretical research with a high risk of success and publication has been sidelined.

Another problem is that enterprises should follow the market mechanism to obtain financing from the market during application technology development. However, from the central government to the local governments, governments at all levels have set up many industrial or technological innovation funds to encourage enterprises to develop and apply technologies. Therefore, the goal of enterprise R&D is not to please the market and develop products that meet the needs of the market, but to satisfy the government to obtain government funding.[8] Thus, technical personnel in both enterprises and universities have developed many technological

[8] As pointed out in the previous analysis, such supportive measures may not only lead to the wrong choice of technological route, but also easily breed corruption. Just as this article is about to be printed, many senior executives of China national integrated circuit industry investment fund Co., Ltd. are suspected of serious violations of discipline and law and are placed on file for investigation by the judicial department.

achievements that must be commercialized. If technology development is market demand-oriented from the beginning, why is the process of commercialization needed? In fact, technologies that must be commercialized are often shelved because no one cares about them.

These systems are not compatible with the new industrial policy paradigm, which requires the central government to review and reflect on the current science and technology policy system and the national innovation system and make corresponding adjustments. However, reaching a consensus on the industrial policy paradigm shifts at the central government level is not enough to fundamentally solve the problems. The current China-specific "power-sharing" central-local relationship and the evaluation and promotion mechanism of local officials form an institutional framework, which is compatible with the selective industrial policy paradigm but has a fundamental conflict with the requirements of the functional industrial policy paradigm. It is difficult for leading enterprises to adapt to disruptive technology (Bower and Christensen 1995). Similarly, as a "superior student" of the catching-up industrial policy, the Chinese government could encounter institutional and organizational challenges in the industrial policy paradigm shifts. From the perspective of incentive mechanisms, it is difficult for the new industrial policy paradigm to obtain the support of local governments and officials at different levels.

More specifically, the problems are as follows:

(1) Policy intervention by local governments to transfer production resources to various types of innovation activities could harm the interests of incumbents who use existing technologies in traditional industries. Considering the pivotal position of large incumbents in local economic development (in terms of both gross domestic product (GDP) creation and tax contribution), they are the objects that local officials must rely on. Allocating resources to promote disruptive technology with the effect of "creative destruction" directly reduces the resources available to incumbents, and more importantly, incumbents are often the victims of new disruptive technologies. Under the existing intergovernmental organizational structure of the central and local governments, this adjustment in resource allocation not only generates political promotion risks for local officials but also may lead to the breakdown of their relationship with incumbents, resulting in the loss of personal monetary interests.

(2) Under the existing assessment and promotion framework, it is difficult for local officials to devote more local financial resources to basic scientific research or to encourage the development of disruptive technologies. On the one hand, scientific research is a kind of pure public goods with strong spatial spillover, and as "useless knowledge", it is difficult for scientific research to directly create economic value for local governments. On the other hand, SMEs can create the option value of technological innovation; however, unlike physical capital investment, which usually introduces local GDP and tax contributions in the current period, the value of technology development by SMEs often requires two or more periods of market competition to manifest. In other words, there is the problem of intertemporal exercise of SMEs' option value, which contradicts the top-down appraisal mechanism for

local officials and the limited tenure system (in recent years, there has been a tendency to further shorten the tenure of chief local administrative officers at different levels).

(3) The incentive problem cannot be solved by adjusting the evaluation mechanism for local officials. As pointed out by Xu (2011), China has multiple conditions for the effective operation of the assessment system for local officials under the existing central-local relationship, such as a competitive goal (GDP) that can be clearly measured for local officials and ignoring other goals (such as environmental protection, public health, and even technology) without serious consequences (Xu 2011). Once the multitask assessment mode is adopted, the information problems between the central and local governments can be exposed, making it difficult for the central government to accurately evaluate the performance of local officials. In particular, scientific research activities are characterized by a high degree of uncertainty in output, and it is difficult for the central government to judge the efforts of local officials in encouraging scientific and technological research and development from the results. Eventually, local officials still work diligently to promote short-term GDP growth that is easier to measure.

Therefore, seizing the historical opportunity of a new round of scientific and technological revolution, creating an institutional environment and policy conditions conducive to disruptive technology development, increasing China's scientific and technological strength, and truly achieving innovation-driven economic development requires the Chinese government to adjust its functions in this new development stage, reposition the relationship between government and market, restructure the relationship between the central government and local governments, and change the assessment model for local officials by incentivizing them to support the shift to functional industrial policies.

Scholars have emphasized that China's economic development has benefitted from being a "developmental state". Correspondingly, I advocate that the Chinese government should consider being a "logistical state (government)" in the future.[9]

The construction of a logistical state (government) requires the Chinese government to immediately initiate reforms in various aspects. First, the logistical state (government) is a service-oriented government. In addition to providing traditional public services such as infrastructure and the rule of law, two important public services must be promoted in the future. The first is to create adequate scientific and educational resources for society, and the second is to improve people's ability to take risks. There have been many discussions on the first point earlier, so they are not repeated here. Regarding the second point, since a variety of disruptive technologies in the new round of technological revolution could result in a continuous "creative destruction" effect, if technological innovation is not prevented, the risk of competing in the market could be significantly magnified. In the "risk society" of the future, the government's important function will be to provide various social security mechanisms, including unemployment protection

[9] A similar concept of 'insurer state' is proposed by Aghion et al. (2021) in "The power of Creative Destruction: Economic Upheaval and the Wealth of Nations", The Belknap Press of Harvard University Press, 2021. The concept of "logistical state (government)" proposed in this paper is broader than that of 'insurer state.'

and lifelong employment training, and even the provision of a universal basic income (UBI) plan should be considered when financial capacity permits. Based on this functional positioning, the Chinese government should use financial resources mainly in the public supportive affairs and insurance and not for productive expenditure. Therefore, by accelerating reform, the Chinese government should limit its direct involvement in the production of various private goods and services, especially limit its administrative power to directly intervene in the operation of the market mechanism.

Second, the central government and local governments should shift from the current power-sharing system with isomorphic responsibility to a truly decentralized system. Reforms in this aspect include two dimensions. In terms of fiscal revenue, a standardized tax system under a decentralized structure should be established; in terms of power, the responsibilities of the central and local governments can be divided according to the scope of public goods and services to truly establish an intergovernmental structure similar to that of a multidivisional enterprise (i.e., M-form organization). In this process, public services, such as science, basic education, and social security, should be defined as the responsibilities of the central government.

Finally, the central government should adjust the supervision and evaluation mechanism for chief local administrative officials. On the one hand, the assessment target of the GDP growth rate should be abandoned as soon as possible, and various indicators that are conducive to innovation activities and social stability, such as related to scientific research, unemployment protection, and education and training, should be used. On the other hand, it is necessary to gradually establish a mechanism for the local people's congress to supervise and account for chief local administrative officials and form an incentive-compatible system that maximizes the utility of local officials and the long-term welfare of local residents. Therefore, any intrinsic motivations of local officials that do not support or even hinder the shift to the new industrial policy paradigm under the original institutional framework can be dispelled.

Conclusion

This paper uses China as the research subject to explore how governments in developing countries can shift from a "developmental state" to a "logistical state (government)" through the industrial policy paradigm shift in the context of disruptive technology. First, this paper reviews the characteristics of the catch-up selective industrial policy adopted by the Chinese government since the 1980s and the institutional basis for implementation and evaluates the effectiveness of this type of industrial policy. Due to the relatively low information requirements of industrial policies and the relatively strong economies of scale in the catch-up stage, the selective industrial policy adopted by the Chinese government has helped the Chinese economy catch up, although it exhibits serious shortcomings in terms of efficiency. The disruptive technology-induced new round of scientific and technological revolution has high uncertainty. Hence, economies of scale are no longer important, and the option value of SMEs is highlighted; therefore, the industrial policies originally implemented by the Chinese government are highly likely to constitute a policy trap for the development of disruptive technologies. To seize the opportunity presented by the new round of scientific and technological revolution,

this paper constructs the theoretical framework of "4x100 meter relay" to understand the innovation system and accordingly proposes relevant policy elements for constructing a new functional industrial policy paradigm. Finally, to overcome the incompatibility between the new industrial policy paradigm and the existing system, this paper offers a series of suggestions for institutional reform.

Considering China's considerable development achievements in the past four decades as the largest developing country, as well as the enormous challenges it faces to achieve sustainable economic development, the analysis in this paper not only contributes to a better theoretical understanding of China's successes and challenges but also has theoretical and policy implications for other developing countries that face similar challenges.

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