Building Scientific and Technological Innovation System of Adaptive to Economic and Social Development Trend

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Abstract
The S&T development has shown an accelerated and superimposed development trend in the 21st century. As the coming of new round of technological changes and the industrial revolution, the world has entered a new era of development with the dominated features of innovation. The global innovation patterns of S&T fields and countries change sharply under the strong driving force of the new demand of global economy. Based on the brief summary of global economic and social development trends, this study discusses the economic and social development trends of China including China's total economic scale, population and aging, digital China and smart society, green ecological and safe agriculture, natural resources and energy, ecological environment, S&T and industry revolution and external competition challenges. The demand for S&T innovations are analyzed and discussed and nine main S&T innovation systems have been put forwarded that adapt to the general trend of economic and social development and support the construction of science and technology power, which including the science and technology innovation systems of basic scientific research, key core technologies, advanced information networks for the Digital China and the smart society, clean and renewable advanced energy, green and intelligent manufacturing, modern green ecological and sustainable and efficient agriculture, medical and health care of the Healthy China, ecology and environment of human-land harmonious coexistence of the Beautiful China, deep space and deep sea exploration, etc.

Keywords
economy; society; development trend; science and technology; innovation system; world; China

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Building Scientific and Technological Innovation System Adaptive to Economic and Social Development Trend

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Abstract: The S&T has shown an accelerated and superimposed development trend in the 21st century. As the coming of new round of technological changes and the industrial revolution, the world has entered a new era of development with the dominant features of innovation. The global innovation patterns of S&T fields and countries change sharply under the strong driving force of the new demand of global economy. Based on the brief summary of global economic and social development trends, this study discusses the economic and social development trends of China including China’s total economic scale, population and aging, digital China and smart society, green and safe agriculture, natural resources and energy, ecological environment, S&T and industry revolution and external competition challenges. The demand for S&T innovations is analyzed and discussed and nine main S&T innovation systems that adapt to the general trend of economic and social development and support the construction of a S&T power are put forward. The nine S&T innovation systems involve basic research, key core technologies, advanced information networks for the Digital China and the smart society, clean and renewable advanced energy, green and intelligent manufacturing, modern green, sustainable and efficient agriculture, medical and health care of the Healthy China, ecology and environment of human–land harmonious coexistence of the Beautiful China, and deep space and deep sea exploration. DOI: 10.16418/j.issn.1000-3045.20200427001-en

Keywords: economy; society; development trend; science and technology; innovation system; world; China

Since the 21st century, the world’s S&T has shown a systematic, groundbreaking and superimposed development trend, and a new round of technological changes and industrial revolution is coming [1–3]. Economic restructuring of all the countries in the world is increasingly dependent on the S&T innovation, and the competition among technologically advanced countries will undoubtedly contribute to their comprehensive national strength and reshape the map of global development and the competition pattern between countries and regions, thus determining the geopolitical competition in the world. Since the modern scientific and industrial revolution, China has for the first time been present in the scientific and industrial revolution and become a major participant and promoter. China must actively rise to the challenges and become a major force promoting the S&T development.

During the past two decades, major S&T powers have competed to introduce and update their innovation strategies and policies to ensure the operation and improve the efficiency of their S&T innovation systems. In an era when S&T activities are increasingly nationalized and corporatized [3], the S&T development must be highly integrated with the economic and social development to play its role in solving a series of problems during the process. To become a S&T power and modern power and meet the S&T demand of economic and social development, China should follow the general trend of international and China’s medium- and long-term economic and social development. Specifically, the government should strengthen the strategic support of S&T innovation for and establish a systematic and efficient national S&T innovation system adaptive to the economic and social development trend. The national S&T innovation system consists of S&T decision-making and management bodies, S&T research and development bodies, S&T platforms, S&T talent teams, S&T policies and S&T achievement transformation and application systems. In China, a large country with a population of 1.4 billion, such system should be complete and systematic, and must cover all the fields of national economic and social development demands and the whole value chain of S&T innovation. We summarize the general trend of economic and social development and its S&T demands, and propose suggestions for building an S&T innovation system that adapts to the general trend of economic and social development.
1 General trends of medium- and long-term economic and social development in China

The general trend of economic and social development in China is closely related to and interacts with that in the globe. The international economic and social development presents the following general trends: eastward shifting of the world economic center, rising of developing economies, declining of the global birth rate, population aging, accelerated development of the digital world and smart society, rebuilding of international rules, restructuring of geopolitical pattern, increasing risks and challenges to human security and global social governance, persistent competition for global natural resources and energy, continuous global warming and eco-environmental deterioration, emergence of problems in biosafety and S&T ethics during the development of new technologies.

China, large in population and economy, has unique features in the economic and social development. In summary, the general trends of China’s economic and social development in the medium to long term are mainly presented in the following eight aspects.

1.1 With the rapid globalization, China will emerge as the world’s largest economy

With the rapid globalization since joining the World Trade Organization (WTO) in 2001, China surpassed Japan in economic aggregate to become the world’s second largest economy in 2012. China has become an important engine of the world economic development. Persisting in the general principle of pursuing progress while ensuring stability, China may surpass the United States in the economic aggregate to become the largest economy by around 2030[^1]. As China develops toward the largest economy, the international community is bound to require more international obligations from China, and China must be prepared for this in ideology and work.

After China became one of the upper-middle income countries in 2010, the economic growth began to slow down. As the economy scale continues to expand and economic structuring leads to the development towards high quality, the economic growth will inevitably slow down. However, this slowdown is dependent on the release of economic potential brought by improvement of the total factor productivity through such measures as encouraging S&T innovation and deepening reform and opening up. In the next decade, China’s gross domestic product (GDP) growth may remain at a rate of around 5% on average, which requires strong support from S&T innovation.

To become a top innovative country and a modern power in the next 15 years, China needs the support in resources, energy, manufacturing, materials and other aspects, and keeps green and sustainable development, all of which rely on the progress and breakthroughs in S&T. Therefore, attention should be attached to the frontiers in basic research and original achievements. Moreover, the application-oriented basic research should be strengthened to promote S&T innovation which will propel the breakthroughs in key generic technologies, frontier and leading technologies and modern engineering technologies, thus supporting the steady transition of economic development toward high quality.

1.2 Birth rate will decline and population aging will aggravate

The construction of the Healthy China is challenged by the decline in the birth rate and the population aging. Despite the implementation of two-child policy in 2015 and the full liberalization of family planning policy in the long run, the annual births in China have descended since 2016. Meanwhile, the proportion of people over the age of 60 and 65 in the total population of China has increased significantly. From 2022 to 2036, aging people in China will increase from 268 million to 423 million and the aging level from 18.5% to 29.1%[^2].

Aging will impose far-reaching impact on economic and social development. Specifically, it will lead to the sharp decline of labor force population, disappearance of demographic dividend, surging costs of old-age care, increased demands for health security and pressure on the medical and health system. In particular, the incidence of chronic diseases such as cardiovascular and cerebrovascular diseases, cancers, respiratory system diseases and diabetes show sharply increased incidence, making them major public health problems threatening the health and life quality of people[^3]. In addition, the health of 1.4 billion people is seriously threatened by major diseases such as emerging infectious diseases. The medical and healthcare system of the Healthy China is facing great challenges.

1.3 The Digital China will lead the world and the smart society will be comprehensively formed

With the acceleration of digital transformation, China has stood in the forefront of global digital technology, possessing great potential of digital development[^4]. In digital economy, China and the United States have become the leading countries. In 2017, the proportion of digital economy scale in the total GDP is 6% (narrow sense)–30% (broad sense) in China, 6.9% (narrow sense)–21.6% (broad sense) in the United States, and 4.5% (narrow sense)–15.5% (broad sense) in the world. About 50% and 25% of blockchain technology related patents are from China and the United States, respectively. China accounts for 24% and the United States for 26% in the global Internet of Things (IoT) expenditure. For the market value of the world’s top 70 digital platforms, 22% and 68% are in China and the United States, respectively. China and the United States together shared more than 75% of the global cloud computing market[^5]. It is predicted that China’s digital economy scale will reach 16 trillion US dollars in
2035, showing a prosperous Digital China[9]. Unavoidably, however, China’s core digital technologies are mainly introduced. For example, the so-called China’s “New Four Inventions” (high-speed railway, mobile payment, bicycle sharing and online shopping) are successes in business models mainly based on the huge population size and market capacity, whereas the key S&T innovations are still weak since the underlying core technologies are not invented by China.

1.4 The demand for green, safe and sustainable agriculture will be strong over the long term

“China should be fully self-sufficient in food at all times and supplied mainly with Chinese grain.” Safely feeding 1.4 billion people has been one of the major challenges for the populous China. In the white paper of Food Security in China released again after 23 years by the State Council Information Office on October 14, 2019, China’s grain output and demand still need to maintain a tight balance in the medium-long run.

In recent years, the green and intelligent development drives the transition of food industry development from quantity increase to green and healthy development, and S and T have contributed more than 60% to food industry. With the continuous urbanization and improving living standards, China’s demand for agricultural products is growing, and requirements for quality are getting higher. It is urgent to develop green and safe agriculture. The principal issue in China’s agricultural development has shifted from the shortage of total supply to the structural problems.

However, some major problems still impact China’s agricultural development on the foundation, primarily including the continuous reduction of high-quality arable land resources, pressure on ecological environment (such as serious non-point source pollution), decline of growth driver, low productivity, loss of labor force and price inversion of agricultural products. At present, the structure and regional layout of agriculture remain to be optimized, and agricultural production resources are inefficiently utilized. The small-scale agricultural management does not match with the demand of food security and modern development, and the threats to food quality safety still exist. The biggest threat is the significant decrease and poor protection of agricultural germplasm resources of crops, domesticated animals, aquatic products and agricultural microorganisms[10]. Preliminary statistical data show that local varieties of grain crops have dropped from 11 590 in 1956 to 3 271 in 2014, with a loss rate of 71.8%[11]. Balancing the food security and resources, environment and sustainable agriculture is a strategic issue in the green and sustainable agricultural development.

1.5 Shortage of natural resources and energy will be long-standing

The shortage of energy and resources in China will become increasingly serious, determined by the basic national conditions of a huge population and a weak foundation of natural resources and energy. There is a serious shortage of verified oil and gas resources and bulk mineral resources in China. It is predicted that the proportion of China’s energy consumption in the global total, China’s dependence on foreign petroleum, and the proportion of imported natural gas in China will reach 22%, 76%, and 43%, respectively, by 2040[12]. It is estimated that the total annual water demand in China will reach 818 billion cubic meters and the water supply gap will reach 25% by 2030[13].

1.6 Eco-environment pressure and local deterioration will be long-term constraints

Eco-environment pressure and local deterioration will threaten the construction of the Beautiful China in the context of global warming. The deterioration and degeneration of ecosystem will persist in China as the population and economic and social activities continue to expand. Large amounts of high-quality arable land resources in the eastern coastal areas are occupied by the burgeoning cities. The air pollution in some big cities and the soil pollution especially in the Yangtze River Delta, the Pearl River Delta and the Circum-Bohai-Sea region remain severe. Eco-environment pressure and even local deterioration will restrict the sustainable development of economy and society in China over a long period of time.

1.7 China will become the main participant and promoter of a new round of technological changes and industrial revolution

Though missing the opportunity of previous three industrial revolutions, China will become a major participant and promoter of a new round of technological changes and industrial revolution. Led by the idea of ecological civilization and the concept of green development, China’s industrial system will upgrade for high-quality development with the support from intelligent manufacturing technology.

However, some problems persist in China, such as big but weak manufacturing industry, weak capacity of independent innovation, high external dependence of core components and high-end equipment in key fields, tightening rigid constraint of resources and environment, rising costs of labor force and other factors of production, slowdown in investment and export growth and overconsumption of manufacturing resources. The situation that the core technologies for key fields are dependent on foreign countries and innovation capacity hits a bottleneck will hinder the upgrading of China’s manufacturing industry in a long run.

1.8 Competition and challenges for development will increase significantly

For four decades of rapid development, China has ushered in a rare historical opportunity for the globalization and the great rejuvenation of the Chinese nation. However, the rise of China will undoubtedly change the world pattern and the balance of global power, which is bond to produce fierce
competition of S&T powers. In the future, the development of China will inevitably encounter more complex international environment and various obstacles.

With the rapid rise and development, China has been highly focused and antagonized by traditional superpowers such as the United States, and is faced with more and severer risks of Thucydides’s Trap, Kindleberger Trap and other international conflicts and challenges. With the rising global status of China, the world expects more from China and requires China to undertake the due role or greater responsibility in international affairs.

China may encounter multiple challenges such as middle-income trap, low birth rate trap and high welfare trap. Challenges may also appear in China’s rights and interests in the development of marine energy and resources and sea supremacy, ecological environmental protection, open access to information and guidance of public opinion. National and public security issues expand and extend to food, public health, energy, space and even virtual cyber world regardless of the traditional boundaries of territorial land, waters and sky.

To solve various external traps and internal risks in the future, China must continue to take the initiative in S&T innovation and strengthen the development of core S&T in key fields as soon as possible.

2 National S&T innovation systems adaptive to the trend of economic and social development

To adapt to the general trend of the future economic and social development in China and its S&T demands, efforts should be made to build the following S&T innovation systems.

2.1 National strategic long-term basic research

Basic research, the source of S&T innovation system, is the strategic cornerstone of building an S&T power. In recent years, the basic research in China develops rapidly, which markedly improves the overall research ability, basic conditions and original innovation capacity. However, it makes few outstanding contributions to the modern scientific knowledge system, and leading core technologies remain rare. The top priority of building a S&T power is to strengthen basic research. Therefore, it is urgent to build a national strategic long-term system to elevate the basic research to the world-class level.

A policy system and funding mechanism for stably supporting basic research should be established to make the investment and proportion of fund for basic research reach the average levels of developed countries. A new basic research institution management system suitable for the basic scientific exploration and innovation should be built to support the construction of new excellent innovation institutions that adapt to big data paradigm, and promote the research and development cooperation of basic research institutions with application-oriented research institutions and world-class scientific innovation institutions. An international cooperation plan and talent exchange system should be formed to take the initiative in S&T. A system of talent cultivation and career development for basic science research centering on the world-class research universities should be established. It is essential to make breakthroughs in major issues and key fields and achieve major application-oriented discoveries that meet the national strategic demands in the frontier basic science, which can break the bottleneck in the core technologies and form a theoretical basis.

2.2 Key core technologies

A new S&T industry is a mark of a S&T power, which requires key core technologies. China should improve the high-tech innovation capacity and the industrial system level to meet the industry development demands and reach the level of developed countries by 2035. The core scientific problems and the bottleneck technologies that need to be tackled in information network communication, medicine, high-end manufacturing, advanced materials and military industry should be made clear. On this basis, breakthroughs in major pioneering and exploratory technologies can be achieved to promote the demonstration of relevant technologies and the development of new technology industries for the innovation of key core technologies.

The future transformative frontier research topics include quantum communication and quantum computing, a new generation of mobile network and telecommunication, big data storage and computing, rapid transit and transport, high-end equipment and machine tools, new energy development, storage and application, smart city and sustainable community and intelligent health care for aging population.

By around 2035, breakthroughs should be made in emerging industries such as energy conservation and environmental protection, information communication, biomedicine, high-end equipment, new energy, new materials and new energy vehicle. A research and development system of key core technologies based on the industry-university-research innovation center network and a system for cultivating the emerging industries and innovation enterprises centering on the high-tech industrial park and “incubator” need to be built.

2.3 Advanced information networks for the Digital China and the smart society

Guided by the principle of constructing the Digital China, China will build an information and intelligent society. The Digital China is characterized by the society informationization level similar as that of major developed countries, a digital economy and intelligent society system with the same level and scale as that of major developed countries, and the formation of information networks for smart society.
Priority should be put on the development of artificial intelligence and information communication technology and the construction of an autonomous and controllable intelligent information network on top of the advanced manufacturing process and equipment of integrated circuit and the new ecosystem of the autonomous desktop operating system. The comprehensive application of automation and network information technologies and the upgrading of information infrastructure should be realized. Transformative breakthroughs need to be achieved in automation, artificial intelligence, machine learning, Internet of Things (IoT), information communication components, equipment and software.

By around 2035, a sustainable intelligent social network application service system should be established, and breakthroughs in key technologies such as quantum computing, design of intelligent robot, design of low-power chip and system, practical knowledge ontology and knowledge grid should be achieved. With the aid of transformative integrated innovation, an intelligent network of Internet of Everything (IoE) in the era of fusion of human, machine and thing can be built to improve the ubiquitous application of advanced information network system in the smart society. Particularly, effort should be made to build a completely autonomous and controllable Internet information infrastructure of the Digital China and the smart society.

### 2.4 Clean and renewable energy

Energy revolution plays a leading and driving role in the industrial revolutions. The safe supply and efficient utilization of energy is a premise of building a modern power. Therefore, a S&T innovation system of clean and renewable advanced energy should be built to ensure energy safety.

The development of energy S&T involves the clean and efficient utilization of fossil energy, the multi-energy complementation and scale utilization of clean energy and the integration of low-carbon and other energy strategies. The breakthroughs of transformative key technologies in energy field can be leveraged for the integrated development of fossil energy, nuclear energy and renewable energy. The basic frontier science of energy should be emphasized to promote the development of the core technologies in key fields, as well as the integration, demonstration and commercial application of relevant technologies.

By around 2035, the clean and efficient utilization of fossil energy will still play a prominent role in China’s energy consumption. Therefore, the large-scale commercial application of biomass liquid fuel should be promoted based on the research and development of advanced technologies. Breakthroughs should be made in high-capacity and low-loss electric power transmission technology, grid connection for scattered and unstable renewable energy generation and distributed power system technology, which will greatly increase the proportion of technologies for electronic equipment safety and new technologies for grid safety and preliminarily form a distributed and independent micro-grid power supply and transmission system dominated by solar power technology, wind power technology and so on.

### 2.5 Green and intelligent manufacturing

A S&T power must be powerful in advanced manufacturing. Therefore, the advanced high-end intelligent manufacturing needs to be developed to make China reach the level of developed countries in the high-end manufacturing S&T field in the next 15 years. Such development aims to realize independence in key fields and thus guarantee the safe and sustainable supply of key materials, devices and core equipment in the modernization process of China. Meanwhile, the upgrading of intelligent and green manufacturing should be promoted to develop a clean production and circular economy development model for a resource-saving and environmental friendly society. Therefore, it is urgent to build a green and intelligent advanced manufacturing system.

The development of the green and intelligent advanced manufacturing relies on efficient, clean and cyclic utilization of resources, design of green products, design and manufacturing of major equipment, and intelligent control, which will promote the commercial application of new technologies. Since materials are the basis of manufacturing, emphasis should be put on the development of advanced materials such as special steel, high temperature alloy, special fiber and its composite, rare earth, special elastomer and the third generation of semiconductor materials. On the basis of such materials, a method for the green design and evaluation of products should be established to help achieve breakthroughs in the secondary cyclic utilization and pollution control of bulk wastes, as well as biomass high-valued utilization. A human-machine harmonious manufacturing system with human as the decision-making core should be developed with the improved design of new products and breakthroughs in key technologies on the coadaptation and coordination between machine and human.

### 2.6 Modern green, sustainable and efficient agriculture

The growing needs for the total quantity, quality, safety and functions of agricultural products, as well as the grain and food safety in China requires the high-quality, nutritious, functional and safe agricultural products and the informationized, digital and precise agriculture in the next 15 years. Continuous S&T support should be guaranteed in such aspects as the safety of agricultural products, agricultural sustainability, as well as intelligence and ecological high value of agricultural production. It is necessary to build a modern green, sustainable and efficient agricultural S&T system characterized by continuous cycle of ecosystem, beautiful landscape, efficient utilization of resources, function diversity and urban-rural integration.

The key S&T problems in the conservation and utilization of animal, plant and microbial genetic resources, molecular
breeding, green agriculture production process, pest and disease control, intelligent and digital agriculture should be solved for the demonstration and application. The distribution of animal and plant resources and population dynamics should be predicted and breakthroughs in the animal and plant molecular breeding and animal cloning should be made. A dynamical model for the warning of animal and plant diseases and pests, an intelligent expert system, and the theoretical system of systemic acquired immune mechanism of animals and plants should be established. Breakthroughs in environmental friendly and multi-functional key technologies of animal and plant product production should be achieved. The networking of agricultural information service and the digital management of production should be promoted for the comprehensive, intelligent and precise management of agricultural production.

2.7 Medical and health care and biosafety guarantee of the Healthy China

The goal of building the Healthy China brings forward a high requirement for China’s medical and health care. Two epidemics (SARS and COVID-19) in less than two decades have seriously impacted China’s medical and health system. Therefore, efforts should be made to build the public medical and health system with public welfare, and improve the prevention and control system and emergency management system for major public health emergencies such as infectious diseases. Besides, a national biosafety risk prevention and control system should be planned and established from the national level as soon as possible, on the basis of which a S&T system for the Healthy China can be built to guarantee the medical and health care, food safety and biosafety.

The construction of the Healthy China necessitates the establishment of life health S&T system, the development of modern medicine and the inheritance and innovation of traditional Chinese medicine, based on which a power in medical and health care and in modern bioengineering and pharmaceutical industry with Chinese characteristics can be built to provide medical S&T security in line with Chinese people’s needs. The long-term plan for the development of life health S&T fields should be made to stably support the basic research and help achieve breakthroughs in the research on major infectious diseases, malignant diseases, chronic diseases and geriatric diseases. The research and development of advanced medical diagnosis, detection reagents and vaccines should be fostered. The innovative research and development of advanced high-end medical equipment and advanced medical protective equipment need to be carried out. The innovative research and development of original drugs in China, traditional Chinese medicine and the conventional drugs for new use should be promoted. In addition, the research level of biosafety should be improved and a world-class high-level biosafety laboratory facility system and research system be formed[14].

2.8 Ecology and environment with human-land harmonious coexistence of Beautiful China

The building of the Beautiful China makes it essential to improve the research on the ecological environment and the earth, and strengthen the protection and restoration of ecosystem and the remediation of contaminated environment. The ecological and environmental evolution rules and the major influencing factors should be clarified based on S&T. Further, the key technologies and technical system integration problems need to be solved for the building of an S&T system for ecology and environment with human-land harmonious coexistence of the Beautiful China.

Attention should be paid to the core scientific and technical problems to integrate the technical systems for application in the uncovering of environment quality evolution rule, the development of ecosystem restoration and pollution control technology, and the establishment of the network for monitoring the evolution of ecosystem and environment quality. The research of major frontiers and key issues of resources and ecological environment, such as the interactions between the earth’s interior physical structure and various spheres and the livable environment and life origin of the earth should be enhanced. The cooperative process and mechanism of global ecology, environment, resource and society should be revealed using the multi-scale, quantitative and integrated research means. The technical systems for ecosystem restoration and function improvement, for the prevention and control of environmental pollution, for systematic management of mountains, rivers, forests, farmlands, lakes and grasslands and for water security in cross-border basins need to be formed to complete a solution for the ecological and environmental sustainability of the Beautiful China. A stereoscopic all-weather seamless earth observation system and digital earth composed of land base, air base, star base and moon base should be built to realize the seamless monitoring, high-precision simulation and dynamic analysis of global resources and environmental elements. Besides, it is essential to construct a big database for global resources and ecological environment to serve the big data research of ecological environment.

2.9 Deep space and deep sea exploration

Deep space and deep sea are two fields the world powers are scrambling for. Building a S&T system for the exploration and development of deep space and deep sea help to strengthen China’s ability in ocean exploration, development and utilization, aerospace research and exploration, aerospace technology and integrated information application, make China become the world’s leading power in space and ocean, and guarantee S&T competitiveness and international discourse power in space exploration and ocean development.

The space science and space exploration focus on black hole, dark matter, dark energy, gravitational wave, solar ac-
tivity and extraterrestrial life exploration. Focusing on these issues, the plan of space science satellites and exploration should be carried out for space science research and application based on manned space station platform. Space technology has both military and civilian uses and should be autonomous and controllable. A perfect key technology and equipment system for space exploration, an air-based cloud technical architecture integrating multiple networks, the core technologies of effective load of quantitative remote sensing and the ultra-static, ultra-stable, ultra-precise and intelligent satellite platform technologies should be developed for achieving breakthroughs in manned lunar-landing, Mars exploration and deep space exploration. In this way, China will become a world power in space science. In the field of deep sea, the research and development of core technologies and key generic technologies centering on the offshore sustainable development, deep sea exploration, earth system evolution, key marine technology and equipment, and deep seabed resource exploitation should be taken into account.

3 Policy suggestions

S&T innovation should be prioritized to meet the S&T demand for economic and social development and build a S&T power, Digital China, Healthy China, Beautiful China, Healthy China, Peaceful China and so on, we must implement the S&T innovation as a major national strategy and plan and promote the S&T innovation from a global perspective [13]. We must develop a complete innovation system from such aspects as strategy planning, S&T layout, field selection, talent cultivation, innovative environment and system construction so as to meet the demands of economic and social development–our S&T must be in our own hands. Herein, four suggestions are proposed on relevant policies of China’s S&T innovation systems.

3.1 Guidelines for the S&T development in the new era

The National Guideline on Medium- and Long-Term Program for Science and Technology Development (2006–2020) established the S&T work guidelines of strengthening independent innovation, making strides in key fields, supporting the development and leading the future. China driven by relevant guidelines has made remarkable achievements and rapid development in S&T in the past 15 years, exhibiting significant improvement in the innovation capacity.

In a new round of technological changes and industrial revolution, global economic and technological center is shifting eastward and the competition between S&T powers is unprecedentedly fierce. To become a power in S&T, China must make great strides in the capacity and efficiency of S&T innovation. Therefore, we must follow the new laws and characteristics of S&T innovation and deepen reform to build a dynamic innovation system which can provide long-term and stable support for basic research and make China a power in S&T. It is essential to support the supply of primitive science discovery knowledge by independent innovation, and motivate the creation of new S&T industries for building a power in the creation of S&T industries and supporting the high-quality development and the construction of a modern power. Therefore, China established the National Guideline on Medium- and Long-Term Program for Science and Technology Development to guide the S&T innovation in the next 15 years and even 30 years.

3.2 Formulating and implementing a forward-looking and binding S&T innovation planning system

The competition between nations is basically a system competition. The key of S&T competition between nations is the competition of strategies and policies. S&T planning system is the top priority for building a systematic S&T innovation system that supports the development of a country.

A sound S&T planning system should be considered during the formulation of the national medium- and long-term development plan. We should, focusing on the general trend of the economic and social development in China and its S&T demands, develop an overall medium- and long-term S&T development plan and a special plan for S&T innovation system that serves China’s economic and social development. Besides, a plan for S&T innovation system in innovation centers, especially in the integrated development regions such as Beijing-Tianjin-Hebei region, the Yangtze River Delta, Guangdong-Hong Kong-Macao Greater Bay Area and Chengdu-Chongqing Urban Agglomeration should be formulated. Particularly, we should place great emphasis on some national strategic security-related plans in key S&T fields, such as those for biosafety, food security and information network security, as well as some ecological conservation plans in key zones (such as the Yangtze River ecological zone and the Yellow River ecological zone).

3.3 Promoting the modernization of S&T management system and capacity

With the updating of S&T innovation paradigm and the increasing breakthroughs in its application, the traditional S&T management unsuitable for the new patterns of S&T innovation is bound to hinder the S&T development. Therefore, the S&T management system and capacity must be updated. The specific problems than need to be solved include the weak foundation of scientific culture in the whole society, administrative management in research institutions, eagerness for quick success in S&T management, out-of-date mechanism for training and using S&T managers, unclear allocation of research funds and resources, disturbing factors in research environment and impatience of research personnel. The root cause of these problems is that the traditional S&T management system is improper for the new development pattern.
To give full play to the role of S&T innovation in facilitating economic and social development, efforts must be made to promote the modernization of S&T management system and capacity. The prerequisite is to build a good innovation culture and environment with the scientific value of creation and innovation priority and the scientific outlook on development in the whole society. ① The design and construction of S&T innovation system should be improved for building a vigorous innovation ecosystem. ② The traditional administrative management mode in research institutions should be changed to be suitable to the modern scientific innovation. ③ Elite S&T managers should be selected from scientific research personnel who are familiar with research work. ④ The research resources need to be allocated according to specific scientific goals with consideration to both national strategic target and scientific exploration target, as well as both stable support of institutions and selection by appropriate competition. ⑤ A free, relaxed and harmonious academic research environment and research evaluation system should be fostered to create conditions for scientific discovery.

3.4 Improving the policy system for S&T development

China still lag behind S&T powers especially the United States in the research and development investment, proportion of triadic patents, income from trade of intellectual property, Nobel Prices in Sciences, international authoritative awards in S&T field, as well as world-class universities, research & development institutions and enterprises. China must achieve fundamental breakthroughs and make great strides in the key indicators of S&T innovation ability. S&T policy tools and their combination as a government’s key means for promoting S&T development need to be constantly improved.

1) The scientific S&T planning system and funds input system needs to be improved. The systems should not only reflect the national goal-oriented basic research but also give consideration to the exploratory high-risk basic research for which scientists can choose their interest topics. Both the national strategic demand-oriented research in the key core fields and the market demand-oriented frontier research should be supported. Both the public welfare research concerning national well-being and people’s livelihood and the future strategic reserve research involving national strategic security should be supported. Not only the national competitive S&T projects need to be designed and arranged, but also the national research institutions should be supported to independently arrange research projects according to their positioning.

2) The normative policy system for evaluation of the management and development of national research institutions needs to be formed. We should, according to the characteristics of different institutions and their positioning, evaluate the development of institutions on a five-year cycle (basic research institutions can be evaluated on a longer cycle, as the cycle in RIKEN has been changed to seven years), guide the adjustment and reform or the merging and withdrawal of institutions and maintain their innovation and development potential. The management system of research institutions needs to be constantly reformed for improvement, which is a dynamic process. However, it should be noted that the frequent and aimless reform, which will undermine the stable growth and continuous innovation momentum of institutions, should be avoided. A major problem which is hard to be disclosed in the management of research institutions is the selection of the persons in charge of the institutions. The leadership and management in the same system may vary with different persons in charge. Poor development of some institutions is often attributed to the improper selection of the persons in charge, which is generally considered as a system and mechanism problem. In a specific environment, the development of a research institution is primarily dependent on the person in charge—Cavendish laboratory is a typical example of success. However, we have never seen a review of the selection mechanism and the leader responsibilities that led to the poor development of an institution due to the improper selection. Therefore, it is vital to perfect the selection mechanism of the persons in charge of research institutions.

3) The policy system for training, using and evaluating S&T talents needs to be built up. In the context of international S&T talent competition, China should build and gradually perfect the innovation ability-centered policy system for training, using and evaluating talents, thus implementing a talent classified evaluation mechanism and delegating the evaluation authority. Particularly, the evaluation period will be prolonged so that the role of talents will be less disturbed by the increasingly prevalent excessive evaluation. It is essential to perfect the international cooperation program and the policy of international talent exchange in S&T fields to attract the world-class talents to start their career in China.

Evaluation of institutions, projects and talents targets different objects of S&T activities, for the purpose of guiding the evaluated objects to better play their role of innovation and creation. For highly complex S&T innovation system and main bodies and types of S&T activities, it is improper to establish a unified evaluation system, and the S&T activities should be evaluated by corresponding management main bodies. The simple, quantitative and mandatory evaluation mode should be reformed. Instead, the evaluation methods that are instructive, hierarchical, targeted and qualitative should be built to create a management environment friendly to S&T innovation.

References

4 PwC. China to dominate global economy by 2050, US to fall behind India, Russia to top Europe-PwC. [2019-07-17]. https://www.rt.com/business/376544-china-us-gdp-pwc-2050/.

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