Scientific and technological innovation related to real economic growth

Xiaoning Long
Wang Yanan Institute for Studies in Economics, School of Economics, Xiamen University, Xiamen, China

Abstract

Purpose – Innovation is the fundamental driving force for the long-term sustainable development of an economy. After four decades of rapid economic growth, China is facing crises related to a demographic structure of "aging before getting rich," industrial overcapacity of low-end products and environmental and resources constraints. This paper aims to discuss these issues.
Design/methodology/approach – Based on logical analysis and recapitulation of previous empirical research, this study presents the conclusion.
Findings – Scientific and technological innovation, as strategic support to improve social productivity and overall national strength, must be placed at the center of the country's overall development.
Originality/value – The development model that preys upon cheap resources for extensive growth is unsustainable. Thus, the country needs an urgent strategic switch to drive its economic growth through research and development innovation and original technological advancement.

Keywords Business environment, Real economy

Paper type Research paper

1. Introduction

Innovation is the fundamental driving force for the long-term sustainable development of an economy. After four decades of rapid economic growth, China is facing crises related to a demographic structure of "aging before getting rich," industrial overcapacity of low-end products, and environmental and resources constraints. The development model that preys upon cheap resources for extensive growth is unsustainable. Thus, the country needs an urgent strategic switch to drive its economic growth through research and development (R&D) innovation and original technological advancement. In 2017, the report of the 19th National Congress of the Communist Party of China pointed out that "innovation is the first driving force for development and the strategic support for building a modern economic system." This report proposed to deepen scientific system reform, establish a market-oriented scientific and technological innovation (STI) system with enterprises as the mainstay, enhance industry, academia and research collaboration to support small and medium enterprise innovation and promote commercialization of scientific and technological achievements." Therefore, STI, as strategic support to improve social productivity and overall national strength, must be placed at the center of the country's overall development.

This paper is funded by National Natural Science Foundation of China (NSFC) General Program (71273217); NSFC Emergency Management Project (71741001); and Marxist Theoretical Research and Construction Major Project (2015MZD006).

China Political Economy
Vol. 2 No. 1, 2019
pp. 108-122
Emerald Publishing Limited
2516-1652
DOI 10.1108/CPE-04-2019-0012

In this context we have noticed that, on the one hand, the investment in innovation of Chinese enterprises is increasing year by year. The "Statistical Bulletin on National Science and Technology Funds Inputs in 2016" shows that the R&D expenditures of various enterprises in China amounted to 1,214.4bn yuan, up by 11.6 percent (and 3.4 percentage points in terms of the annual growth rate) year-over-year (YOY). The contribution of enterprises to the growth of R&D funds in the entire society was 83.8 percent, up by 12.7 percentage points YOY, and the status of innovation gradually became prominent. However, the innovative activities of many Chinese enterprises remain at a low level, with outputs mainly focusing on micro-innovation in areas like utility model and appearance design or applied technology development, while lacking cutting-edge and basic research and key technology in strategic areas.

The recent ZTE ban (i.e. a denial of export privileges against Zhongxing Telecommunications Equipment Corporation of China) has sounded the alarm. In April 2018, the US Department of Commerce announced that the Chinese telecommunication equipment supplier ZTE breached some of the provisions of its settlement agreement (by instrument fraud and exportation of equipment to Iran). Thus, ZTE would be banned from purchasing components from US companies within the next seven years. Although ZTE has ranks among the top 500 companies in the world and enjoys the market leading position in China, its hardware equipment, spare parts, layers of operating systems and applications used in its business activities are highly dependent on supplies from US technology companies such as Google, Qualcomm and Texas Instruments. This ban may bring ZTE to the verge of bankruptcy. Given this dilemma of one of the strongest R&D companies in China, other Chinese firms may face challenges in the future. Although the ZTE ban was finally lifted under the condition that China would pay large deposits and meet other requirements, the US-initiated trade war against China has shown signs of further expansion, which may seriously affect the realization of the "Made in China 2025."

This condition shows that if enterprises are unable to implement independent innovation, although the international division of labor may be a "cost-effective" solution in the short term, it may affect the speed and quality of economic growth in the long run due to the lack of competitiveness in high-end technology. Where national interests are at odds, the low-tech countries would merely be at the mercy of the developed ones. This situation means that how to motivate Chinese companies to encourage corporate R&D and innovation at present and in the future is a crucial factor in overcoming short-term technological problems, countering overseas pressure and promote long-term economic growth.

The enterprises and industry sectors involved in the aforementioned discussion are the main battlefields in the transformation and upgrading of China's real economic development at present. These enterprises and industries also highlight the dual challenge in promoting real economic development as the foundation of China's development. On the one hand, the real economy must be transformed and upgraded with high-quality capital, manpower and technological input. On the other hand, not only the overall economy lacks innovation, but the phenomenon of "underweighted real economy and overweighted virtual economy" in the capital and talent sectors also results in a shortage of input in the real economy. Therefore, promoting the development of the real economy is a crucial task.

What is the relationship between the development of the real economy and STI? Premier Li Keqiang clearly stated in the 2017 Report on the Work of the Government that "the real economy, as has always been the foundation of China's development, has a top priority to accelerate the transformation and upgrading," and has enlisted "innovation-driven transformation and upgrading of the real economy" as one of the nine "key tasks." We believe that the interdependence between STI and the development of the real economy is manifested, aside from the reliance of the latter on the former, in their identical requirements for the development environment. Therefore, solving the challenges faced by the real

economy and promoting STI are two sides of the same coin. They invariably involve the relationship between the government and the market to improve the business environment.

This article aims to examine the relationship from the following perspective. Section 2 clarifies the concepts of the real and virtual economies and demonstrates why the fundamental path of the development of the real economy is to transform and upgrade, and then to explain the dependency of real economic development on STI. Section 3 focuses on the long-term and high-risk characteristics of STI to discuss the challenges that may be encountered in the process. This section also posits that the environmental conditions required by STI and real economic development have much in common, namely, a fair, transparent, predictable and stable business environment in the long run. Section 4 proposes strategies to promote STI. Aside from studying the business environment, this section also analyzes and compares the specific effects of various innovation policies based on previous research results. Section 5 provides a brief summary.

2. Transformation and upgrading as the development path

To discuss the relationship between STI and the development of the real economy, we must first clarify the concept of the real economy. The most useful definition of the real economy is that of Liu (2015), who compares the real economy with the virtual economy and defines the latter as an activity that directly generates money from money; correspondingly, the value-added activities generated on the basis of directly creating social wealth constitute the real economy. The concept of the real economy is different from the common "physical" or "sectoral" concept, because the distinction between the real economy and the virtual economy is based neither on whether the production and distribution of the material goods is being conducted nor on the corresponding sector of production, but on whether the value-added activities of monetary capital take goods and services as a medium and ultimately create new wealth. Therefore, activities in non-manufacturing sectors (such as logistics and finance) that can further add value to goods and services are also an important part of the real economy. By contrast, activities in the traditional sectors (manufacturing or agriculture) that are solely for the purpose of asset appreciation and wealth redistribution fall into the virtual economy, such as price speculation on certain agricultural products. The classification of the activities in the real estates is a typical example of how this concept can be applied: the construction of real estate commodities and the provision of property management, to offer the use value of goods and services, create new wealth for society. Thus, these activities belong to the real economy based on the above definition, whereas those solely for real estate speculation, which are intended to earn profit from rising house prices, redistribute wealth without creating new social values. Therefore, those activities belong to the virtual economy.

The distinction between the real and the virtual economy is important because, first of all, it clarifies the decisive role of real economy in China's economic development. As the main force of direct value creation, the real economy is the fundamental driving force for the development of all economies. The virtual economy characterized by "money making money," if overdeveloped, will not only distort the rational allocation of production factors but also cause "exsanguinating (blood drawing)" damage to the development of the real economy, but will also generate economic bubbles arising from price distortions, thereby harboring serious economic and social risks. Therefore, it is crucial to revitalize the real economy as the foundation of development of the overall development of China's economy and society.

The distinction between the real and the virtual economy is also important because it is closely linked to innovation activities. The development of the real economy is bound to create new wealth for society, so the related innovation activities directly contribute toward the growth of social wealth. By contrast, the virtual economy aims to distribute and redistribute

social wealth; consequently, the related innovation activities only directly affect the distribution, rather than adding up, of social wealth. Of course, innovation in the virtual economy may also provide different incentives by changing the distribution of wealth corresponding to real economic activities, thereby affecting the level of these activities and influencing the creation of social wealth. However, this effect is indirect, and it comes into play via real economic activities. In other words, if innovation in the virtual economy does not contribute to real economic activity, such innovation cannot have a positive impact on social wealth creation. Therefore, innovation activities in the real economy are much more important.

The fundamental path toward the development of the real economy in the new era is transformation and upgrading. In the past few decades, the development model has helped China's economy to improve its industrialization and urbanization levels relatively fast. However, in the context of changes in internal and external conditions such as population structure, resource environment, technology level and domestic and overseas markets, the development model characterized by high input, high consumption, high pollution, low output, low quality and low efficiency needs to be transformed into a development model characterized by low input, low consumption, low pollution, high output, high quality and high efficiency. In other words, the transformation is from extensive and extended economic growth to intensive and inclusive economic growth. This condition requires the Chinese economy to shift from low value-added production to high value-added production. In other words, it is necessary to realize the transformation and upgrading of China's economic development.

To achieve this goal, the key is for the production process rather than the industry category to shift from low value-added to high value-added production. Clarifying this point is conducive to overcoming several common misconceptions. The first is that transformation and upgrading means eliminating traditional industries and turning to emerging ones, which would result in blindly chasing new industries and dismissing even the advantageous traditional ones as sunset industries. Although the development of emerging industries is an important way to transform and upgrade the industrial structure, it is not the only way. Traditional industries can still upgrade their product quality through internal R&D innovations, thereby providing new impetus to the development of modern economic systems. The second misconception is that the transformation and upgrading involves reducing the proportion of the manufacturing industry and raising that of the service industry, mainly because the energy consumption of the manufacturing industry and the resulting pollution level are higher than those of the service industry. Of course, the features of energy consumption and pollution determined by industrial characteristics are unquestionable, but as the saying goes, one "cannot give up eating for fear of choking." Thus, withdrawing from the manufacturing industry would be unwise because this industry has an important supporting role in the national economy. The correct approach is to develop and deploy advanced technologies within the manufacturing industry to reduce energy consumption and pollution emissions while increasing efficiency.

The aforementioned tend to generate the third misconception, which argues that the transformation and upgrading must rely on the guidance of government regulations as well as funding and policy support, and in particular, industrial policies. Under the influence of this view, achieving industrial restructuring and upgrading in some places is believed to involve the fast establishment and growth of emerging industries regardless of local objective conditions that may lead to overcapacity. This overcapacity will then drag down the healthy transformation and upgrading of the economy. Some places engage in a "one size fits all" development approach, which requires the added value of the tertiary industry in all cities in a region to reach a certain ratio, even exceeding that of the secondary industry. This condition contradicts the fact that the resource endowments and development advantages of different cities vary; thus, this economic plan is far from reasonable. Although the added value of the tertiary industry outpacing that of the secondary industry

is an important manifestation of the transformation and upgrading of the industrial structure, it is neither a decisive standard nor a unified requirement for all regions and cities. For example, for megacities where education, healthcare, wholesale and other tradable sectors have obvious equal-scale effects, the development of tertiary industries is more suitable. By contrast, small and medium-sized cities are more suitable for developing manufacturing industries because of the advantages of lower land and labor prices.

In fact, the essence of "transformation" of industrial structure is to transform the "type" of driving forces of economic growth, that is, from high input, high consumption, high pollution, low output, low quality and low efficiency growth to low input, low consumption, low pollution, high output, high quality and high efficiency growth, turning extensive growth into intensive growth, rather than simply switching the industries. No inevitable connection exists between the transfer and transformation of an industry. Transferring an industry does not necessarily entail a successful transformation, and likewise, transformation does not necessarily entail transfer. An upgrade of the industrial structure incorporates not only the upgrading between industries, such as the evolution of the industrial dominance from the primary industry to the secondary and tertiary industries, but also the upgrading within an industry itself. In other words, the degree of processing and reprocessing within an industry gradually deepens, achieving technology intensification and continuous improvement of production efficiency. Only by correctly understanding these connotations of industrial structure transformation and upgrading can we avoid deviations in practice.

Based on the requirements of economic development in the new era, an overall transformation and upgrading includes structural changes that have an inter-industry as well as intra-industry nature. In contrast to the inter-industry structural changes, the more important transformation and upgrading is the intra-industry quality improvement, product upgrading and STI. Regardless of the history of China's economic reforms or the economic development of the world's manufacturing powers, the inter-industry upgrading is invariably accompanied by the improvement of intra-industry production efficiency and product quality. Although the emergence of certain technologies has increasingly intensified the competition in the traditional manufacturing industries such as textile, coal and steel, Germany, Japan, Switzerland and other countries maintain their traditional advantages in high-end manufacturing, such as that of precision machine tools, and their top position in the core technologies they have mastered. Recognizing this fact can help cultivate and promote the value of craftsmanship, including enrichment of the traditional spirit of seriousness, responsibility, dedication and meticulousness, thereby advancing mass innovation and entrepreneurship.

To sum up, the fundamental source of economic growth is the continuous creation of social wealth. The long-term driving force of economic growth in a country is the development of the real economy, in which innovation activities constitute the perpetual motion of economic growth. The specific manifestation of effective innovation is the successful transformation and upgrading of the real economy, which is reflected in the structural adjustment between different industry types and within specific industries. To ensure all-round transformation and upgrading in a true sense, enterprises cannot rely solely on government leadership and efforts. A market-oriented approach is necessary. Based on this approach, institutional construction and policy incentives can be formulated and implemented by the government to guide enterprises in making their own choices.

3. The connotation of STI and challenges in STI process

As mentioned, the fundamental path toward the development of the real economy is transformation and upgrading, which depends on STI. Therefore, promoting the development of the real economy necessitates the promotion of STI by solving the

challenges that may be encountered in this process. To fully understand these challenges, we first discuss the characteristics of STI from the concept of innovation. Innovation refers to new ideas, equipment or methods that can help meet higher or potential needs. Thus, innovation is manifested as new technologies, products and processes, or as novel ways of organizing and managing production, or as new marketing and business models. Based on the given definition, the aforementioned features of innovation constitute the features of STI. Innovation can be divided into three types: knowledge, technological and management innovation led by modern science and technology. Specifically, knowledge innovation refers to the original scientific research activities that propose new ideas (i.e. new concepts, ideologies, theories, hypotheses, methods and discoveries). Technological innovation refers to new production technologies and upgrades on existing technologies for practical application. Management innovation refers to the process by which organizations formulate creative ideas and translate them into useful products, services or operation methods, often because of new management elements (methods, tools or models) or combinations of factors that are introduced into the enterprise management system to effectively achieve organizational goals.

Some innovative activities (such as those in the financial, real estate and other sectors, where the only target is asset appreciation via price fluctuations) are not directly involved in providing products or services to the real economy. Innovation activities that do not lead to the creation of new social wealth should be classified as the virtual economy. STI does not include the innovation activities corresponding to this part of the virtual economy and the management innovations thereof. Financial innovation (including corresponding management innovation) and innovation at the macro-level of management, such as institutional innovation, can indeed indirectly influence the level and quality of STI through the incentive mechanism that influences the innovation entities. Ultimately, however, what plays a decisive role in promoting long-term economic growth is STI, just as the healthy growth of a national economy depends on the development level of the real economy in which the activities directly create value.

Compared with other investment activities, innovation activities require greater investment and a longer cycle and involve greater risk. Therefore, higher requirements are imposed on the business environment, particularly for STI. Therefore, compared with other types of innovation, such as financial innovation, the development and realization of STI involves longer cycles. Meanwhile, the success of STI is based on the creation of new social wealth and plenty of innovative behaviors cannot increase productivity and social value. These failed innovations are the costs and risks that innovators must face. By contrast, financial innovation as a virtual economic activity takes the transfer of wealth as a direct goal, so even if new value and wealth are not generated, some participants still benefit from it and become the beneficiaries. This condition continues to provide new impetus for such innovations. However, these innovations must realize their redistribution of wealth in the short term. Therefore, such rent-seeking financial innovations have a short cycle as their living conditions are completely different from those of STI. Some of the financial activities participate in the production and value-adding process of the use value by providing the funds needed for the real economy, and therefore pertain to the real economy. Thus, the corresponding innovation activities should not be classified under financial innovation of the virtual economic activities.

Therefore, STI as a long-term development momentum of the real economy and financial innovation as a virtual economic activity have diametrically opposite requirements for the business environments. STI needs a fair, transparent, stable and predictable business environment so that the return on long-term investment can be assured. The financial innovation in the virtual economy, however, is aimed at the short-term rapid appreciation of assets, and the focus is on the profitable contingent opportunities to be obtained, the

frequency of which can often be positively correlated with the rate of change in the business environment. A fair, transparent, predictable and long-term stable business environment constitutes a necessary condition for the advancement of STI. This condition is consistent with the development requirements of the real economy, but it is not an important prerequisite for virtual economic activities.

STI activities first need to be supported by "public knowledge input," namely, basic research to acquire new knowledge without any specific commercial application. Basic research has obvious public-good characteristics. On the one hand, once new knowledge and technologies generated by basic research are published, the discoverer or inventor faces difficulty in preventing others from using such knowledge or technologies or in profiting from the innovative outputs developed by others using relevant knowledge and technology; this situation is called non-excludability. On the other hand, the use of basic research results is not affected by the increase in the number of users; this situation is called non-competitiveness. Stiglitz (2014) pointed out that the "pace of innovation is related both to the level of investment in innovation and the pool of knowledge from which innovators can draw," that is, to the amount of "public goods" information that researchers can use for free or at low cost. Therefore, promoting STI activities should solve the problem of public goods supply, which may require government intervention.

Furthermore, strong positive externalities are involved in STI activities. Therefore, private supply is often insufficient, and the government may need to intervene through subsidies to boost supply. The positive externalities of R&D innovation activities are manifested in conditions where enterprises have invested substantial resources in innovation activities, but new knowledge and new technologies generated by the innovation process may be used by other enterprises, rendering the social benefits generated by R&D and innovation activities of enterprise higher than the private income it generates. If enterprises cannot fully reap the benefits of innovation, then the incentives will be restrained, thereby leading to insufficient social investment and affecting long-term economic growth. The positive externalities of innovation make the private benefits of innovation lower than the social benefits, so that the innovation incentives of enterprises are not enough to make them choose the best innovation input level in society. To solve this problem, the government often compensates for the market failure by providing enterprises with fiscal and taxation policies such as subsidies for innovation, tax incentives, reductions and exemptions. Financial innovation as a virtual economic activity, however, does not face these problems because it does not produce positive externalities.

STI activities also require investment in the form of external funds. Therefore, STI requires the support of the financial system. Numerous studies have shown that most STI activities are subject to financing constraints, the mitigation of which plays a pivotal role in stimulating enterprise innovation. Due to the prevalence of information asymmetry in financial markets and the particularity of innovative investment, STI financing costs more than general projects (Hall and Lerner, 2010) because of the particularly serious information asymmetry in STI activities. Specifically, because of the inherent uncertainty of innovation activities and the complexity of technology activities, innovators are much more aware of innovation activities than outside investors, that is, a wide information gap exists between innovators that need capital investment and the potential providers of funds. In other words, information asymmetry occurs in the investment process of STI, thereby leading to market failure that hinders the development of innovation.

4. Strategies to promote STI and real economy

As mentioned, the transformation and upgrading of the real economy must rely on STI instead of simple model innovation or financial innovation. In particular, STI can directly affect the production efficiency of real economic activities such as the production and

provision of products and services. Consequently, the same production materials yield higher output. Thus, STI is the decisive factor in determining the total supply. By contrast, business model innovation can be understood as new ways and means to effectively integrate market demand, thereby helping to meet potential needs and achieving higher levels of market equilibrium, while financial innovation aims to help effectively match the key channels of market supply and demand by providing new financial products and services. Specifically, it is manifested in providing more efficient ways to create an exchange platform for capital supply and demand through identifying and monitoring investment projects and redistributing investment risks.

According to the framework of production function, the role of STI is to push up the production possibility curve, whereas the simple model innovation and financial innovation aim to make the economic operation move from within the production possibility curve onto it. Both are indispensable for economic growth, but STI is not only the fundamental driving force for the development of the real economy, but also the basis and premise for financial and model innovation to promote such development. Therefore, the following discussion focuses on how to promote STI. Furthermore, given the commonalities of STI and the development of the real economy, including the need for long-term stable business environment and long-term financial resources, most of the discussion in this section has guiding significance for the development of the real economy.

How to improve the supply of STI is a key issue that all economies need to address. First, clarifying the various challenges faced by STI is necessary, along with planning strategies with a definite purpose. In addition to the features of STI activities described in Section 3, if intellectual property right (IPR) protection is leveraged to promote STI, then monopolistic behavior may occur. Therefore, promoting STI requires addressing these challenges, including typical market failures.

4.1 Streamlining administration and delegating power to lower levels to create a transparent and stable business environment

In view of their long-term and high-risk characteristics, STI activities require a transparent, fair, stable and predictable business environment. The establishment and improvement of law-based protection, such as high-level property rights and contracts, is the best way to achieve this objective. This condition requires real transformation of government functions by streamlining administration and institute decentralization, reassigning economic activities that can be effectively regulated by market mechanisms, and transferring government functions to effectively provide a system to create high-level property rights and contract protection.

Our study finds that the government can boost market competition of STI intermediary organizations by effectively reducing the access barriers to them in the innovation markets, thereby improving the current level of STI. Specifically, the cancellation (at substantial ratios) of administrative examination and approval projects by all provincial science and technology departments has promoted enterprises to apply for invention patents, and also played a role in encouraging enterprises to conduct high-quality innovation. This promotion effect applies mainly to private enterprises and businesses that are subject to high financing constraints. We also found that the cancellation of such projects reduced the cost of patent applications by decreasing the access barriers for patent agents and agencies, further stimulating corporate innovation (Long and Lin, 2018a).

4.2 Provide an appropriate level of IPR protection

IPR protection constitutes an important institutional arrangement for promoting STI activities. Simply put, IPR protection is a system that helps innovators recover their

innovation costs and obtain investment returns by granting them a monopoly on the production and sales of new products for a certain period of time. As a result, innovation is encouraged. The monopoly rights granted are IPR, including patents, copyrights and trademarks, which provide property rights protection for technological inventions, artistic creations and product creditworthiness (goodwill), respectively. As discussed, knowledge products belong to the category of knowledge and information, and they have the characteristics of public goods. Knowledge products can be used by many users simultaneously, i.e. these products have commonality. Second, once the knowledge products are made public, their creators cannot prevent others from using them, i.e. they are not exclusive. These characteristics determine that makers of knowledge products often cannot profit from their sale as the makers of other products do. However, innovative behaviors are time-consuming and costly in terms of manpower and materials. If innovations do not bring corresponding economic benefits, then innovators lose their motivation and the source of innovation will be exhausted.

Therefore, all countries protect intellectual property products, such as technological inventions through laws on patents, copyrights and trademarks. During the period when exclusive rights are granted to the knowledge products, innovators can either obtain monopoly profits by exclusively producing and selling their products, or reaping use fees (royalty payments) by selling the right to use IPRs, or earning transfer fees by selling IPRs to other companies. These and other derivative rights (including pledge rights and mortgage rights) provide innovators with effective incentives to make IPR protection a major means of promoting innovation. Earlier models of relevant economic theories also inferred that stronger patent protection would lead to an increase in innovation speed (Kamien and Schwartz, 1974; Waterson, 1990; Klemperer, 1990; Gilbert and Shapiro, 1990).

On the other hand, IPR protection, while stimulating innovation, also brings about drawbacks of monopoly, such as compromising consumer welfare and hindering future innovation. From a static perspective, monopolistic producers will reduce production and sell goods at a price level far above the cost of production to maximize profits, so that a large number of reasonable market demands are not met[1], thereby resulting in reduced social welfare levels (Nordhaus, 1969). From a dynamic perspective, each successive invention builds essentially on its predecessors, whereas IPR protection can hinder future innovation for various reasons (Scotchmer, 1991; J.E and Maskin, 2009). First, the fees charged by existing owners of innovations can increase the cost of future innovations. Second, existing exclusive licensees of innovations may prohibit others from using existing innovations to maintain monopolistic benefits, thereby reducing future innovation. In addition, because the defined scope of IPR is unclear, existing exclusive licensees of innovation may also use patent thickets to protect their monopolistic rights, thereby intensifying the negative effect on future innovation (Hall and R.H, 2001; Shapiro, 2003) [2]. Therefore, a country needs to determine the level of IPR protection that suits its needs and formulate relevant laws and regulations according to specific conditions of economic development and innovation capabilities. Various industries may also need to deal with different levels of protection.

Studies have shown that compared with the stage of economic development and the ability to innovate, China's current level of IPR protection has much room for improvement. Specifically, a variety of local policy experiments related to improving the IPR protection level have played an important role in promoting innovation. The local copyright free registration system implemented in 2004 by Dehua County in Fujian Province significantly improved the performance and innovation level of local ceramic enterprises, especially those with high dependence on copyright protection (Wang and Long, 2016). In 2012, the pilot implementation of patent enforcement insurance in 20 prefecture-level cities across China increased the patent litigation, patent value and innovation level of enterprises in the pilot areas (Long and Lin, 2018b). Long *et al.* (2018) further provided the following empirical

evidence: a higher level of IPR protection can enable the authorized patents of local listed companies to bring greater market value to the enterprises and thus promote the level of innovation thereof.

4.3 Expanding the universal coverage of incentive policies for innovation

Aside from improving the institutional environment such as property rights protection, the government can also promote corporate innovation through various policy incentives with different levels of coverage. Depending on the level of coverage, financial subsidies or tax incentives can be provided for all innovation activities, or tax incentives or subsidies can be implemented for innovations in specific industries. When selecting the level of policy coverage, governments have to consider not only the fundamentality and externalities of the innovation activities involved but also the possibility of rent-seeking behavior. The following general principles can apply. First, the more fundamental research, the greater the positive externalities; thus, conducting wider-coverage tax benefits or subsidies is reasonable. Second, with greater likelihood of rent-seeking behavior, conducting wider-coverage incentive policy is more reasonable.

Our previous research (Long and Wang, 2015) aimed to quantitatively evaluate the patent incentive policies of local governments in China, and found that these policies have boosted patent applications and authorizations but elicited a decline in the average quality of patents. In other words, policy measures such as fiscal and tax incentives have produced unexpected negative effects, which may result in a phenomenon of "curing the symptoms, not the disease." Although the tax incentives or financial subsidies applicable to the applicant enterprises have the advantages of low cost for short-term implementation and quick policy effect, they may have unanticipated negative effects, including quality degradation caused by information asymmetry in innovative behavior, and acts of corruption and resource waste caused by rent-seeking.

In comparison, the "Patent Box" and other taxation systems applicable to all R&D innovation inputs are tax incentives with inclusive characteristics, which can avoid behaviors such as corruption and rent-seeking and negative effects. However, the inclusiveness of these incentives necessitates substantial adjustments and revisions to the taxation system, rendering high costs for the short-term implementation, which may slow down the policy actions. Therefore, the centennial plan for China's new era of economic development proposes the requirements for seriously exploring the feasibility of the "patent box" policy, which is a tax incentive for IPRs such as patents. Through taxable income reduction and exemption of the enterprises' earnings from intellectual property or products with IPRs, the Chinese government can motivate enterprises to conduct R&D and IPR commercialization. This policy is still in the exploratory stage. However, given the importance of innovation activities in addressing trade disputes, the government should speed up their exploration and implementation.

The experience of the UK, France, the Netherlands and other mature economies should be used as a reference along with China's national conditions to analyze the advantages and disadvantages of implementing the "patent box" policy in China. In the aforementioned mature economies, the "patent box" policy can encourage enterprises to commercialize IPRs, prevent the IPRs of innovative enterprises from flowing abroad and maintain the competitiveness of their own IPRs. Furthermore, the "patent box" policy may result in a reduction in short-term fiscal revenue, an increase in the complexity of the tax system and even international tax competition. Therefore, this policy should be examined and applied cautiously. In addition, in policy implementation, a variety of factors should be considered to maximize the advantages. As the policy is a tax incentive for corporate IPRs, the setting of tax rate and tax base, and the scope of intellectual property covered (whether trademarks and copyrights are involved), should be considered to balance the IPR revenue and tax losses and circumvent possible international tax competition. Finally, the direction of the

"patent box" policy should be guided to encourage corporate R&D and innovation. The government should strengthen the guidance over the "patent box" policy, such as restricting the location and technology source of patents, stimulating enterprises to improve their profitability, beefing up investment in innovation, and avoiding the near-sighted business practice of "acquisition–holding–selling."

4.4 Promoting financial innovation to support finance

Promoting STI also entails resolving the problem of high capital investment requirements which are financing difficulties due to information asymmetry. In China, the challenge is that the financial industry cannot provide effective screening and monitoring services, and corresponding financial innovations cannot provide relevant financial products based on STI, thereby failing to guarantee the capital investment required by STI. Therefore, effective promotion of STI should be accompanied by the acceleration of financial reforms and the healthy development of the financial services industry.

At present, the difficulties encountered in China's economic development are highlighted by two sets of issues. First is the structural imbalance of the real economy, insufficient investment in some real economic sectors and overcapacity in other real economic sectors. Second is the sluggish growth of the overall real economy vs the overheating tendency of the virtual economy. The reason is that the production and service industries that should provide logistics and financial services for the real economy have gradually deviated from their role of social wealth creation and focused on wealth redistribution. The deeper root of the problem lies in the fact that with the development of China's economy and the accumulation of residents' wealth, the demand for investment in assets has grown rapidly, but the supply of corresponding investment products, especially high-quality investment products, has continued to be deficient. In this case, the need for supply-and-demand equilibrium leads to a rapid and continuous increase in the price of investment products, so that the benefits of changes in wealth distribution far outweigh the benefits of wealth creation for a long time.

The solution to China's underweighted real economy and overweighted virtual economy should include various policy combinations and relevant reforms in the financial sector, specifically generating high-quality investment opportunities and projects through STI in the real economy, as well as furnishing more high-quality assets based on and guaranteed by solid economic growth facilitated by financial innovation. These strategies can help the financial industry restore its original role of deploying financial resources and serving the real economy. Such solutions can also reduce asset prices and the virtual economy's preemption of financial resources. Furthermore, these solutions can reduce interest rates, decrease the operating costs of the real economy and support the promotion of STI.

4.5 Recommendations to promote fundamental research and its application

The general challenges faced by science and technology innovation activities and possible solutions are discussed above. In view of the two major types of STI activities, this subsection discusses the specific difficulties encountered in the process of conducting STI, such as basic research and the transformation of achievements and exploring how to solve these difficulties to promote STI activities.

4.5.1 Ways to encourage basic research and innovation. In the field of basic research, the characteristics of scientific research and innovation activities as public goods are particularly prominent. The results of basic research are usually new knowledge and new ideas presented in the form of textbooks, monographs and academic papers. Basic research has enormous value and the potential for widespread dissemination and impact, with significant spillovers over applied innovation and economic growth. Boudreau and Lakhani (cited in Stiglitz, 2014) used theoretical analysis and evidence from experimental economics

to show that academic research, patent systems, open-source technologies and other "technical disclosure" methods involving intermediate processes contribute to the development of subsequent R&D and innovation. Basic research involves a cycle that is much longer than that of other studies, and it is no picnic to reflect the value of each scientist, causing greater difficulty for the creators of basic research results to earn corresponding compensation or economic benefits. Therefore, basic research has typical public-good characteristics, where private supply under market conditions is likely to be insufficient. Thus, the government should focus on subsidizing basic research.

Moreover, with a wide research scope, it is impossible to foresee the prospects and directions of new knowledge and new fields. In particular, innovative research in the true sense often occurs in unexpected fields. As a result, the selection mechanism for predicting the success rate of innovative projects beforehand is difficult to build. In addition, discriminatory preferential policies will also lead to inventors' rent-seeking behavior, i.e. the scarce talent and time resources will be merely used to influence the results of the selection mechanism rather than investing in truly innovative activities. Therefore, government investment in basic research should apply the principle of universal benefit and increase the scope of funding while also moderately reducing the quantity of and funding for talent projects.

In summary, first, support for and investment in basic research should be increased at all levels of government to improve the long-term stable support mechanism for universities, research institutions and scientific research personnel. Second, the universal-benefit financial subsidies must be vigorously promoted, the number of talent projects and reporting costs must be reduced to cut the cost of rent-seeking brought by talent selection. Third, the reform of scientific research projects and fund management must be deepened so that the autonomy of scientific research personnel in using funds can be ensured. This suggestion can benefit the promotion of research and innovation activities.

4.5.2 Measures to promote the applications of fundamental innovations. Unlike basic research, the application of innovations is more likely to bring direct economic benefits to innovators or outcome converters. Thus, government subsidies or interventions would not be necessary. However, several countries have had a history of low conversion rate of results from research projects that are funded by the government. To solve this problem, the US passed the Bayh–Dole Act in 1980, which has achieved obvious results and significantly improved the conversion rate of scientific research. The key to the effectiveness of this Act is to empower the responsible person with the ownership of IPRs, such as patents generated by government-funded research projects.

Since 2000, the Chinese government has successively issued a series of reform on ownership policies that are related to the patents supported by public funds. Since the policy is highly similar to the US Bayh–Dole Act in terms of specific implementation rules, scholars often refer to it as the "Chinese-version BD Act."[3] Using empirical research, we examined the impact of the BD policies of 31 universities of the "985" Project in China on the number of patent applications, authorizations, renewal rates, citations and conversion contract value, with a comparative analysis in relation to the non-BD policies (patent application subsidies, job title promotion incentives, cash award for authorized patents and others) (Long and Yi, 2018). The empirical results show that after the promulgation of the Chinese version of the BD policies, the number of patent applications, authorizations and renewal rates of universities adopting the BD policies have been improved in the long run, whereas the number of citations and value of patent-conversion contracts exhibited short-term growth. Thus, the "Chinese-version BD Act" has, to a certain extent, provided an effective incentive for inventors by granting them partial patent ownership.

However, the incentive role has room for improvement. The incremental reform has left the Chinese-version BD Act with a lag in its effect of improving the number and quality of patents

in colleges and universities. The nature of state-owned assets of university patents has repeatedly become an institutional barrier to the patent-conversion process. Since the inception of the Chinese-version BD Act, the patent conversion income of colleges and universities increased significantly in the short term. However, with the increase in the number of patent conversion cases and the value involved in litigations and disputes over rights, responsibilities and interests have become increasingly apparent. Under the existing school leadership responsibility system, patent conversion needs to be signed and approved by the school leaders before they formally come into force. The lack of a fault-tolerant mechanism may lead the school leaders to bear the political risk of state-owned assets being undervalued. These concerns have caused many conversion projects to be put on hold. The disputes of interests between enterprises, universities and inventors in the conversion of results have become another major obstacle. On the one hand, enterprises have the motive to not realize the distribution of income according to the contract after the project becomes profitable. Universities and inventors are often at a disadvantage with the knowledge and experience of law and business, and cannot win the benefits they deserve. On the other hand, disputes also exist in the distribution of interests between some universities and inventors. According to a survey, the equity acquired by the inventor in the patent conversion is usually held by the university asset management company, and the inventor has no right to transfer or sell it (Chang, 2017).

On February 26, 2016, the State Council promulgated "Several Provisions on the Implementation of the Law of the PRC of China on Promoting the Transformation of Scientific and Technological Achievements," including the exemption clauses aimed at eliminating colleges and universities' concerns about the loss of state-owned assets and further strengthening the independent decision-making power of universities. Specifically, these provisions require the establishment of a collective decision-making system for leading groups on major issues in the transformation of scientific and technological achievements, with a view to removing the decision-making responsibility of unit leaders in the pricing of such achievements due to changes in follow-up values. Therefore, the Chinese version of the Bayh–Dole Act is expected to play a crucial role in stimulating the innovation of university researchers in the foreseeable future.

5. Conclusion

This study has argued that the bedrock of economic development lies in the development of the real economy, whose fundamental path is transformation, upgrading and STI. Given the involved high risks and long cycles as well as the nature of STI as a public good, the STI process needs to address multiple challenges, ranging from maintaining a stable expected return through high-quality business environment, to solving "market failures" including public goods, externalities and information asymmetry through institutional arrangements or policy interventions.

Based on previous empirical findings, this study concludes that the promotion of STI requires the following conditions: a transparent, fair, stable and predictable business environment; high levels of IPR protection; fiscal and tax incentive policies with universal coverage; and financial innovation based on STI and the characteristics of the real economy. These conditions must be aligned with the long-term development of the real economy.

Notes

1. The reasonable market demand corresponds to the demand where the price is above the marginal production cost.
2. The patent thicket phenomenon refers to "a dense web of overlapping intellectual property rights that a company must hack its way through to actually commercialize new technology." This kind

of difficulty in commercialization can be achieved through the jungle, which leads to insufficient use of patents, thereby resulting in the waste of social resources.

3. The "Opinions on Strengthening the Protection and Management of Intellectual Property Rights Related to Science and Technology" promulgated in 2000 decentralized the ownership of university patents back to universities. However, since most Chinese universities are government-owned institutions, the patent results of scientific research projects funded as intangible assets are bound by the regulations governing state-owned assets. The implementation of patent transformation requires the approval of multiple levels of administrative departments. As the aforementioned documents do not give colleges and universities the right to dispose patents, the decentralization of patent rights is mere lip service. In 2002, the State Council promulgated "Several Provisions on the Management of Intellectual Property Rights of Research Achievements in National Research Projects," further liberalizing the independent decision-making power of colleges and universities on the implementation of patents, and explicitly requesting rewards and payments for scientific researchers. This policy is relevant to the core contents of the US Bayh–Dole Act and is therefore considered as the Chinese version of that law.

References

Bessen, J.E. and Maskin, E. (2009), "Sequential innovation, patents, and imitation", *Rand Journal of Economics*, Vol. 40 No. 4, pp. 611-635.

Chang, X. (2017), "Elaborate management and policy recommendations based on university patent transfer: evidence from developed countries", *Science of Science and Management of S.&T*, Vol. 37 No. 5, pp. 27-36.

Gilbert, R. and Shapiro, C. (1990), "Optimal patent length and breadth", *Rand Journal of Economics*, Vol. 21 No. 1, pp. 106-112.

Hall, B.H. and Lerner, J. (2010), "The financing of R&D and innovation", in Hall, B.H and Rosenberg, N. (Eds), *Handbook of the Economics of Innovation*, Elsevier B.V, Amsterdam, pp. 609-639.

Hall, B.H. and Ziedonis, R.H (2001), "The patent paradox revisited: an empirical study of patenting in the US semiconductor industry, 1979–1995", *Rand Journal of Economics*, Vol. 32, pp. 101-128.

Kamien, M.I. and Schwartz, N.L. (1974), "Product durability under monopoly and competition", *Econometrica*, Vol. 42 No. 2, pp. 289-301.

Klemperer, P. (1990), "How broad should the scope of patent protection be?", *Rand Journal of Economics*, Vol. 21 No. 1, pp. 113-130.

Liu, Z. (2015), "Rethinking the interaction between the real economy and the virtual economy", *Study & Exploration*, Vol. 36 No. 9, pp. 82-89.

Long, X. and Lin, H. (2018a), "Effects of patent enforcement insurance on innovation", *China Industrial Economics*, Vol. 35 No. 3, pp. 116-135.

Long, X. and Lin, H. (2018b), "Streamline administration, institute decentralization and enterprise innovation", working papers.

Long, X. and Wang, J. (2015), "The motivation of China's patent surge and its quality effect", *The Journal of World Economy*, Vol. 37 No. 6, pp. 115-142.

Long, X. and Yi, W. (2018), "Does the Chinese version of the Bayh-Dole act promote innovation in colleges?", working papers.

Long, X., Yi, W. and Lin, Z. (2018), "How valuable is intellectual property right protection?: Empirical evidence from patent data of China listed companies", *Journal of Financial Research*, Vol. 40 No. 8, pp. 121-137.

Nordhaus, W.D. (1969), "An economic theory of technological change", *American Economic Review*, Vol. 59 No. 2, pp. 18-28.

Scotchmer, S. (1991), "Standing on the shoulders of giants: cumulative research and the patent law", *Journal of Economic Perspectives*, Vol. 5 No. 1, pp. 29-41.

Shapiro, C. (2003), "Antitrust limits to patent settlements", *Rand Journal of Economics*, Vol. 34 No. 2, pp. 391-411.

Stiglitz, J.E. (2014), "Intellectual property rights, the pool of knowledge, and innovation", working papers, available at: www.nber.org/papers/w20014

Wang, J. and Long, X. (2016), "Can copyright protection improve corporate performance? Evidence from Dehua ceramics industry", *Economic Perspectives*, Vol. 44 No. 6, pp. 26-36.

Waterson, M. (1990), "The economics of product patents", *American Economic Review*, Vol. 80 No. 4, pp. 860-869.

About the author

Xiaoning Long has PhD Degree from Wang Yanan Institute for Studies in Economics, School of Economics, Xiamen University. Long is Distinguished Professor of Changjiang (Yangtze River) Scholar Program of the Ministry of Education, People's Republic of China, and also Doctoral Supervisor. Xiaoning Long can be contacted at: cxlong@xmu.edu.cn