How to Improve the Postprint System for Pure Basic Research in China

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Date: 2023-12-04T00:00:00+00:00

Abstract

With the development of an innovation-driven economy, the role of pure basic research in promoting scientific and technological innovation and technological progress has become increasingly significant. Since the founding of the People' s Republic of China, China has made considerable progress in pure basic research; however, in the new "trinity" development model characterized by the division of labor and collaboration among the three major systems of pure basic research, applied technology, and financial support, pure basic research remains the overall "soft underbelly." The article proposes that to comprehensively elevate the level of pure basic research, it is first necessary to clarify certain misconceptions, then identify the fundamental reasons for China' s relative weakness in pure basic research, and on this basis formulate strategic approaches for its improvement. China' s pure basic research is indeed relatively weak compared to world advanced levels; however, relatively backward pure basic research is not directly related to the so-called "chokepoint" problem. The "chokepoint" problem primarily stems from inadequate technology, insufficient accumulation of tacit knowledge, and inadequate investment in applied technology research and development. The article argues that the fundamental reason for China' s relative backwardness in pure basic research is that China has not yet begun to exert effort in developing genuine pure basic research, which consequently implies tremendous potential. As China' s comprehensive national strength rises, gradually increasing investment in pure basic research within the limits of its capabilities is a wise move that serves the long-term interests of both China and humanity. The article points out that the strategic approach to doing pure basic research well lies in expanding the scale of the "scientific population" and enabling this population to fully utilize their talents. Based on this approach, the article elaborates on specific strategies for fundamentally elevating China' s pure basic research level, centered on meeting the three essential prerequisites of education, management, and "soft infrastructure."

Full Text

Preamble

How to Improve China' s Pure Basic Research System

Citation Format: Yuan R D. How to improve pure basic research system in China?. *Bulletin of Chinese Academy of Sciences*, 2023, 38(11): 1627-1634, doi: 10.16418/j.issn.1000-3045.20230813002.

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Abstract

A major pillar of the new innovation-driven "trinity" development model is pure basic research [1]. As an innovation-driven economy develops, pure basic research has become increasingly significant in promoting scientific and technological progress. Since the founding of the People' s Republic of China, the country has made considerable progress in pure basic research. However, within the new "trinity" development model—consisting of three collaborative systems: pure basic research, applied technology, and financial support—pure basic research remains the "soft underbelly."

This article argues that to comprehensively elevate the level of pure basic research, we must first clarify certain misconceptions, identify the fundamental reasons for China' s relative weakness in this area, and then formulate strategic approaches for improvement based on this understanding. While China' s pure basic research is indeed weaker than world-leading standards, this relative backwardness is not directly causally related to the so-called problem of "being choked at the neck." The primary issue behind technological strangulation is inadequate technology capabilities, insufficient accumulation of tacit knowledge, and underinvestment in applied technology research and development.

The fundamental reason for China' s lag in pure basic research, this article contends, is that the country has not yet begun to make serious efforts in developing genuine pure basic research—yet this also means the potential is enormous. As China' s comprehensive national power rises, gradually increasing investment in pure basic research within the bounds of its capabilities represents a wise decision that serves both China' s and humanity' s long-term interests. The strategic approach to improving pure basic research lies in expanding the scale of the "scientific population" and enabling them to fully utilize their talents. Based on this framework, the article elaborates on concrete strategies centered on meeting three essential conditions: education, management, and "soft infrastructure."

Keywords: middle-technology trap, pure basic research, high-quality development, innovation-driven, three-pronged new development model, scientific population

DOI: 10.16418/j.issn.1000-3045.20230813002

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1. Clarifying Misconceptions about Pure Basic Research

Since the founding of the People' s Republic of China, China' s scientific and technological capabilities have developed rapidly, yet the overall pattern remains unchanged: achievements in applied technology research far exceed those in pure basic research. Moreover, the distinction between pure basic research and applied technology research is often unclear, with applied technological research frequently misidentified as pure basic research.

Pure basic research, also known as pure scientific research, is an activity that seeks to improve scientific theories to better understand and predict natural or other phenomena. Its findings are validated by the scientific community, and once confirmed, they represent innovations and improvements to existing scientific theories, becoming part of scientific knowledge shared by all humanity —making them unequivocal international public goods [2]. For instance, Einstein' s development of special and general relativity represented a major breakthrough beyond Newtonian mechanics, marking another leap in humanity' s understanding of the universe' s natural laws. Alongside relativity, the 20th century witnessed numerous major theoretical breakthroughs: the establishment of quantum mechanics, the proposal of continental drift theory, the discovery of DNA' s double helix structure, the formulation and proof of Gödel' s incompleteness theorems, the development of the Big Bang theory of cosmic evolution, and the discovery and theoretical explanation of superconductivity—all of which have profoundly and positively impacted societal progress. To date, all scientific theories are only relatively true; humanity has yet to discover a perfect scientific theory. The goal of pure basic research is to produce better scientific theories. So far, China' s contributions to human scientific theory have been extremely limited, with very few major scientific breakthroughs achieved by Chinese scientists—a fundamental reality that must be confronted.

It is essential to recognize that there is no causal relationship between the level of pure basic research and the problem of "being choked at the neck." While the United States and Western countries are currently blocking China in certain key technological areas to hinder its progress—a situation requiring urgent resolution —we must not panic and mistakenly attribute the root cause to insufficient pure basic research. China's pure basic research does have problems, but they are not the main reason for technological strangulation. The logic is straightforward: the results of pure basic research contain no secrets; researchers worldwide can access the latest findings. Therefore, even if China fails to produce results in certain pure basic research areas, it can still master the latest achievements through literature review.

"Being choked at the neck"specifically manifests as the inability to independently manufacture certain products, such as high-end chips, lithography machines, or high-precision bearings. The key reason these products cannot be fully domestically produced is the lack of mastery over manufacturing process details and parameters, which involve numerous non-patented trade secrets. Many valuable manufacturing details are not patented but are treated as confidential business secrets by companies because patents require disclosure and have expiration dates, whereas trade secrets can generate profits indefinitely if not leaked. A classic case is Coca-Cola' s formula, which has never been patented and remains a trade secret to this day [3]. Beverage formulas are difficult to reverse-engineer. While China currently cannot fully replicate Coca-Cola' s formula, no one would claim China is "choked at the neck" in the beverage industry, much less attribute it to weaknesses in pure basic research. The millennia-old sword of King Goujian of Yue that never corrodes and the paper-thin Western Han Dynasty plain gauze robe are difficult to manufacture even with modern technology, yet it would be absurd to claim that ancient Chinese from over 2,000 years ago possessed more advanced scientific theories—these are secrets of manufacturing craftsmanship. Some lost techniques simply cannot be replicated. Today' s precision products are similarly difficult to fully reverse-engineer even when purchased and disassembled. High-end chips, lithography machines, and high-precision bearings all fall into this category. For example, the manufacturing process for high-quality steel used in high-end bearings involves how to incorporate rare earth and other elements to improve steel quality—this belongs to the applied technology system, not pure basic research. It involves tacit knowledge. Developed countries' enterprises have accumulated such tacit knowledge over decades or even centuries [4]; it is entirely normal that China has not yet fully mastered certain areas. Breakthroughs should be pursued through applied technology research and development, not by mistakenly blaming relatively weak pure basic research.

Because China has recently faced technological strangulation, it has begun emphasizing pure basic research, but this is misguided. Pure basic research has little to do with being choked at the neck; the primary issue is inadequate technology, insufficient accumulation of tacit knowledge, and underinvestment in applied technology R&D.

2. Reasons for China' s Relatively Weak Pure Basic Research

Objectively speaking, China' s pure basic research remains quite weak compared to world-leading standards. For example, in mathematics—a crucial field for pure basic research—China's level is mediocre. Mathematician Shing-Tung Yau stated candidly in an interview: "Compared to European and American mathematics, Chinese mathematics has never been brilliant." Nobel Prize statistics are also revealing. In the three fields closely related to pure basic research—Chemistry, Physics, and Physiology or Medicine—the top three countries by number of laureates are the United States, United Kingdom, and Germany. To date, only Tu Youyou has won a Nobel Prize in these fields for research conducted in mainland China; even when including all ethnic Chinese and overseas Chinese, the total is only nine individuals.

Why is China' s pure basic research so far behind world-leading standards? The reason is not complicated: China has not yet developed genuine pure basic research. If we compare pure basic research to a sport, China has essentially not yet begun to participate. Take rugby, for instance—whether British or American style, it is barely played in China. If China loses to the United States in rugby, everyone understands why, and no one complains. Rugby is a niche sport in China that started relatively recently; it is unrealistic to expect immediate international success. However, if given sufficient attention with stable investment of human and material resources, progress will come with time. Pure basic research in China is currently a "niche sport." Although research funding has increased in recent years, China' s total R&D investment remains insufficient compared to other scientific and technological powers, especially in pure basic research. In recent years, technological powers such as the United States, United Kingdom, France, and Japan have allocated 12%–23% of their total domestic R&D investment to pure basic research, whereas China allocates only about 6% [5], with much of this not being genuine pure basic research but rather applied technology R&D. Consequently, truly pure basic research receives minimal funding.

Therefore, pure basic research in China represents a "from 0 to 1" challenge, and we are still relatively close to "0." The gap with others is between "having" and "not having." In the long history of humanity, pure basic research is a very recent phenomenon, only about 500 years old; for all of humanity, the "from 0 to 1" transition is not yet complete. Of course, for advanced countries that started much earlier, pure basic research has already reached a high level.

Genuine pure basic research must first be characterized by pure motivation. Pure basic research is not capital-intensive but interest-intensive—it results from researchers pursuing their passions [1]. Therefore, the approach to pure basic research should not be overly utilitarian; it should not be conducted to solve practical problems. Research aimed at solving practical problems is ultimately applied research, not pure basic research. If pure basic research must have a purpose, it is to advance human knowledge and produce international public goods belonging to all humanity, because pure basic research outputs are borderless, public, and freely accessible scientific knowledge. Anything that can be patented or kept as commercial or military secrets is applied, not pure basic research.

If we must set a concrete goal, it might be this: to improve China' s pure basic research level so that at some future point, Chinese contributions to human scientific knowledge increase substantially. If we quantify this goal: 100 years from now, approximately one-fifth of the knowledge in worldwide mathematics, physics, chemistry, and biology textbooks should originate from China, and approximately one-fifth of theorems, laws, effects, formulas, or other scientific terms should be named after Chinese individuals (assuming China' s population represents one-fifth of the world' s total at that time).

3. Strategic Approach and Necessary Conditions for Improving Pure Basic Research

Improving China' s pure basic research requires work in two areas: first, expanding the scale of the "scientific population" so that more Chinese people become interested in and capable of conducting pure basic research; and second, creating conditions for these individuals to pursue their interests and utilize their abilities. Achieving these two objectives requires meeting three necessary conditions.

3.1 Shaping a Matching Education System

Expanding the scientific population most importantly requires shaping a matching education system, particularly basic education from primary to middle school, which is crucial for cultivating scientific interest and capability. The reasons are similar to athletic talent development: interest and ability must be nurtured from an early age. In different sports, because muscle usage differs, a professional skier from childhood might not outperform an amateur swimmer in swimming. To be qualified for pure basic research requires strong interest in scientific research and a rather special combination of abilities—including independent thinking, imagination, and logical reasoning—that must all be cultivated from childhood.

First, **interest** is a crucial driver of scientific research. Interest makes scientists more engaged in their work and facilitates creative thinking. Therefore, cultivating students' scientific interest is essential for developing future pure basic research talent. However, China' s current education system essentially kills this interest. The exam-oriented system overemphasizes standard answers and lacks environments that encourage thinking and exploration. Many students are forced to study subjects unrelated to their interests, losing intrinsic motivation to learn. Moreover, heavy academic burdens leave students without time for autonomous exploration, and many parents and schools also adopt utilitarian mindsets that prioritize scores over interest. Consequently, many students have lost interest in learning by the time they graduate from middle school and enter university, let alone interest in science [6].

Second, **independent thinking ability**. The independent thinking required for pure basic research represents a unique way of using the brain, fundamentally different from traditional human thinking patterns and from the thinking patterns of most people today. The essence of science is anti-authoritarianism —a rational skepticism that maintains a healthy doubt toward all doctrines, including established scientific theories [7]. The Royal Society, which has made enormous contributions to natural science development, has as its motto "Nullius in verba" (Take nobody' s word for it). For the scientific population, new evidence proving their previously held beliefs wrong can cause them to reject their own views from a second ago, let alone from last year or earlier, without feeling any shame whatsoever. This self-negation and course correction is the most distinctive thinking pattern and behavioral mode of the scientific population. One must ask: does the current education system promote or hinder the independent thinking and skepticism that pure basic research depends on? After more than a decade of education system indoctrination, how much of the "scientific population" remains?

Third, **imagination and questioning ability**. Bacon declared "knowledge is power," but Einstein' s assertion that "imagination is more important than knowledge" is more relevant for cultivating the scientific population. While knowledge is important, imagination holds greater reference value. With the rise of large language models in artificial intelligence, problem-solving abilities across disciplines are gradually being automated, and in terms of knowledge itself, the amount human brains can master has long fallen behind what computer systems can systematically archive. Humans are gradually losing their competitive advantage over machines in these areas. In this context, imagination and the ability to ask valuable questions become increasingly important. Yet China' s current education system still focuses on knowledge cramming and cultivating problem-solving abilities, severely lacking in developing imagination and questioning capabilities.

Fourth, **logical thinking ability**. Mathematics is the foundation of natural science, and logic is the foundation of mathematics [8]. Logical thinking ability is also essential for the scientific population. This ability requires time to accumulate and develop—the earlier the start, the better. Beginning in the late 1980s, China' s education system gradually weakened and reduced logic teaching. In 1988, logic content was removed from middle school Chinese language textbooks. Some "experts and scholars" subsequently proposed eliminating logic from normal university curricula. The situation continued deteriorating in the 1990s. At many universities, logic courses changed from required to elective. Most notably, a 1998 document from the former State Education Commission removed logic courses from the core curriculum for Chinese language and literature majors (teacher education track). Today, not only middle and primary school students but even many university students may have never heard of "logic" as a discipline. While cutting logic courses saves some resources, it is undoubtedly detrimental to the development of China' s pure basic research.

In summary, without reshaping China' s education system to cultivate students' scientific interest and abilities in independent thinking, imagination, and logical reasoning from an early age, the idea of expanding the scientific population is unrealistic.

3.2 Establishing a Matching Management System

With a certain scale of scientific population, the next step is to provide them with space to apply their talents and engage in pure basic research long-term and stably. Since the pure basic research system consists of universities and other research institutions, the management methods of these institutions directly determine whether the scientific population can pursue their curiosity and explore cutting-edge scientific questions in a free academic environment.

The biggest problem currently is that China' s entire research management system is still structured to promote applied research aimed at solving practical problems, rather than to foster genuine "interest-intensive"or "freedom-intensive" pure basic research. In the project catalogs of the National Key Basic Research Program released by the Ministry of Science and Technology, truly pure basic research projects are extremely rare [2]. In fact, worldwide, pure basic research is not, to put it extremely, prescribed by institutions (including government and research organizations); the sole driving force behind pure basic research is researchers' interests.

The underlying logic of China' s existing research management system differs fundamentally from that required for pure basic research. Therefore, a specialized management system for promoting pure basic research must be established, distinct from the existing system for applied technology development. China' s new national system can concentrate resources to accomplish major tasks, which is of great significance for tackling key core technologies and catching up with world-leading countries in applied technology, and has proven highly effective. However, to develop genuine pure basic research—to produce new scientific theories and knowledge belonging to all humanity and to see more Chinese names in mathematics and natural science textbooks in the coming years—we must explore and form a management system that enables the scientific population to fully utilize their talents. In this pure basic research management system, whether researchers are granted sufficient freedom to engage in long-term, stable, curiosity-driven scientific exploration not aimed at solving practical problems is a necessary condition for successful pure basic research.

If China aims to catch up with the United States in pure basic research and eventually match its number of annual Nobel Prize winners, Chinese researchers should enjoy the same degree of freedom and decent living standards as their American counterparts. For example, the University of Virginia School of Medicine has a research center studying children' s so-called "past-life memories" (memories from before their current incarnation). American scientists have pursued this alternative topic for over half a century and continue to this day [3]. Under a pure basic research management system, respect for scientists' research freedom and stability of their funding support must reach this level.

3.3 Building Matching "Soft Infrastructure"

After addressing research freedom and funding stability, the next issue to resolve is the salary, benefits, and security status of pure basic research workers. Russian mathematician Grigori Perelman provides an excellent example. Perelman proved the Poincaré Conjecture, one of the seven Millennium Prize Problems in mathematics, yet he refused to accept the Fields Medal and the Millennium Prize (with a total award of over $1 million), arguing that American mathematician Richard S. Hamilton’ s contribution to proving the conjecture was no less than his own and that he should not be the sole recipient. Perelman had previously also declined awards from the European Mathematical Society. He lives an extremely simple material life, subsisting on the simplest black bread, pasta, and yogurt [4].

True members of the scientific population are not seekers of material comfort. The compensation they require need not be extravagant—middle-class income is sufficient. At current price levels, this means an annual income of more than 300,000 RMB in first-tier cities and more than 200,000 RMB in other cities. However, the income and benefit levels must be stable, removing worries about long-term engagement in pure basic research.

China’ s R&D investment intensity (the ratio of R&D expenditure to GDP) has grown rapidly in recent years, reaching 2.55% in 2022 [5], approaching the average level of developed countries. However, in China’ s R&D investment, experimental development funding accounts for a very high proportion, exceeding 80% [6], with most of it used for research infrastructure construction such as laboratories and the manufacturing, purchase, and installation of equipment. The “soft infrastructure” for improving researchers’ , especially young researchers’ , welfare and income is clearly insufficient. For example, the Five-hundred-meter Aperture Spherical Telescope (FAST) built in Guizhou, costing approximately 667 million RMB, is the world’ s largest “telescope.” To maximize scientific benefits, the instrument hopes to operate 24 hours a day after launch. However, its recruitment information shows that resident researchers are offered an annual salary of only 100,000 RMB, with requirements including educational qualifications, willingness to work long-term in remote areas, willingness to work night shifts, and good English proficiency. Such compensation is supposedly already quite good, specially secured for major projects like FAST [7].

This lag in research “soft infrastructure” (salaries and benefits) stands in stark contrast to the massive investments in research “hard infrastructure”(various laboratories and large-scale scientific equipment). While equipment is important, ultimately, results depend on human diligence and wisdom. This unreasonable investment structure is extremely detrimental to improving researchers’ enthusiasm and attracting talent, representing a major obstacle to enhancing China’ s pure basic research capabilities.

The scientific population is passionate about pure basic research and actually has relatively low demands for material enjoyment. Those with both interest and ability for pure basic research typically experience a continuous, peaceful, and profound joy, similar to what Buddhism calls being “filled with Dharma joy.” However, under the current domestic environment, researchers engaged in pure basic research may face various challenges. They may not fully possess the ideal characteristics of the scientific population, and the institutional mechanisms managing them may not fully support pure basic research. They may also feel pressure due to inadequate “soft infrastructure” such as salary and benefits, as well as uncertainty about job stability. This situation may cause anxiety and could lead to undesirable consequences. Additionally, some university management systems may not foster a long-term stable environment for pure basic research. For example, although young scholars may receive relatively good salaries during their appointment periods, the "up-or-out" or even "out-without-up"system may create challenges, reflecting a social Darwinist logic that could have long-term negative impacts.

If China truly intends to improve pure basic research, it must systematically reshape the matching education, management, and "soft infrastructure"systems.

4. Conclusion

After clarifying misconceptions about pure basic research, we find that the fundamental reason for China' s relative backwardness is simple: the country has not yet begun to make serious efforts in developing genuine pure basic research. This article' s strategic approach—expanding the scientific population and enabling them to fully utilize their talents—and the specific strategies built upon meeting the three essential conditions of education, management, and "soft infrastructure" point a way forward for improving China' s pure basic research.

Precisely because China has not yet begun to exert its efforts, the potential in this area is enormous. China has 1.4 billion diligent and intelligent people. If just one ten-thousandth of them are cultivated into a scientific population truly interested in and capable of conducting pure basic research, and if the management system and "soft infrastructure" create an environment for these individuals to utilize their talents, China' s pure basic research level will be completely transformed. Therefore, if China truly decides to improve pure basic research, it can absolutely achieve world-class status. We should be fully confident in the future of China' s pure basic research.

Pure basic research is not conducted to solve practical problems; all research aimed at solving practical problems belongs to applied research. From this perspective, investing human, material, and financial resources in pure basic research indeed does not directly generate economic returns—at least not in the short term. However, in the long term, the development of pure basic research determines the heights human technology can reach. Because pure basic research results belong to all humanity as open and transparent scientific theories and knowledge, government support for this international public good is crucial, in addition to scientists' selfless dedication. As a developing country, China must invest in pure basic research according to its means. Even the United States, a scientific and technological powerhouse, has long adopted a pragmatic, compromise approach to pure basic research rather than idealistic adventurism. The United States invests enormous resources in research based on its economic strength, but most of it is still spent on applied R&D activities. Of course, in pure basic research, both relative and absolute U.S. investment far exceeds China' s current level. On this issue, the trend is clear: as China' s comprehensive national strength rises, gradually increasing investment in pure basic research within its capabilities is a wise move that serves the long-term interests of both China and humanity.

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Responsible Editor: Yue Lingsheng

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