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Definitions, R&D Activities and Industrialization of Biotechnology in China

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Abstract: The general classifications, statistical foundation as well as the definitions of biotechnology in China are described in this paper. The expenditure on biotechnology mainly includes National S&T Programme, National Nature Science Foundation and other funds by some departments. Based on the area of manufacture of biological and biochemical products, we analyzed the research expenditure pattern, outcome and some industrial characters. To realize the comprehensive understanding and improve further the process industrialization, we suggest that statistical base on R&D expenditure and patent should be taken full advantage of and taken as special item in S&T statistic investigation.

Keywords: Biotechnology, bioindustry, definition, classification, S&T activities, industrialization

Introduction

China, as one of the countries with the richest bio-resources and biodiversity in the world, is facing more and more challenges in fields such as human health care, industry, agriculture, food supply and environmental protection.[1] In the new century, it is thought that biotechnology and its related industries will be given the major impetuses of economy. The concept of bioeconomy has been generally accepted worldwide. Therefore, the development of biotechnology is of great

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importance to realize modernization and sustainable development of this country, which will also help to solve many urgent problems.[2] In China, the government, research institutes, and companies have fully recognized the potential impact of biotechnology, and attached much attention to the development of biotechnology and its industrialization.[3]

With significant progress in both the science and the commercial development of biotechnology, there are still many problems that influence or handicap the rational development. Although the number of industrial products produced via biotechnology growth significantly and production scales increased rapidly, a clear, applicable and authoritative definition and its classification have not been established, and a stable, comprehensive and representative statistical route has not been confirmed. It is hard to comprehend and control the biotechnological resources in both research and industry level. In this paper, we try to introduce and discuss some characters of China's recent progress on biotechnology, especially by certain area with solid statistical data.

Definitions

There are different definitions of biotechnology in China, most of which refer to or are learned from the experience of international organizations and developed countries. For example, Biotechnology Industry Organization in U.S defined the biotechnology as "the use of cellular and biomolecular processes to solve problems or make useful products". In Convention on Biological Diversity biotechnology is considered as "any technological application that uses biological systems, living organisms, or derivates thereof, to make or modify products or processes for specific use". China's definitions are basically close to the above, but are combined with more practical conditions in China. Generally, those definitions often have greater scope and more detailed classification.

Two definitions based on government-oriented research can be taken as the authoritative point of view in China. One research funded by the National Developing and Reform Commission (NDRC) proposed that modern biotechnology is based on the progress of molecular biology, including genetic engineering, protein engineering, cellular engineering, enzymatic engineering and zymolytic engineering.[4] The other research supported by the Ministry of Science and Technology (MOST) defined bioindustry as "use of individual cellular and biomolecular etc., combined

with engineer and information technology, to solve problems or make useful products, or reconstruct animal, plant, and microbe into special characters and quality to provide products or services. Bioindustry is based on a complex technical system".[5] In this research, biotechnology was considered as "a serials of technologies about the research, design, reconstruction of biosystem to improve the quality, create the new variety, and provide people with products or services, which include molecular biology, cellular biology, biochemistry, biophysics, information technology etc."

Classifications and Statistical Foundation

(a) Classifications

Based on the definitions of bioindustry, two classifications were proposed (shown in Tables 1 and 2). Classification, keeping in view the practical industrial condition, was proposed and generally used by NDRC's reports.[6] Classification, designed by MOST's investment, is based on the technical developing trends, which divided bioindustry into three sub-industries. Traditional bioindustry refer to the productive processes to animal, plant and microbe by traditional methods. Modern bioindustry refer to putting the last techniques into relevant production, and make the new techniques commercialization and industrialization. Future bioindustry refer to the use of last techniques in the forefront of biotechnology, which are of great commercial potentials and can provide some products without mass production. The scope of classification is similar to the first two parts of classification, and can generally correspond to the actual development in China.

Table 1: Classification Based on Annual Report on Bioindustry in China (2007)

Classification	Main contents
Biomedicine	Medicines and curative methods based on biotechnology
Bio-agriculture	Crop breeding, transgenic corps, bio-pesticide, bio-fertilizer
Bio-energy	Bio-ethanol based on celluloses, bio-diesel oil, Biobutanol
Bio-production	Bio-materials, wood-plastic composites, microbial manufacture
Bio-environment	Precaution and reconstruction to pollution
Service to biotechnology	Contract research organization for biomedicine, etc.

Source: Department of High-Tech Industry of National Development and Reform Commission, Chinese Society of Biotechnology.

Table 2: Classification Based on China Bio-industrial Report

Classification	Sub-classification	Main contents
Traditional Bioindustry	Zymolysis	Amino acid, organic acid, enzyme preparation, brewing, vitamin, antibiotics
	Chinese traditional medicine	Tablet, extraction and other Chinese traditional medicine products
	Health care products	Functional food, nutriment
Modern Bioindustry	Medical biotechnology	Gene medicine, bacterin, biochemical medicine, diagnostic reagent
	Agricultural biotechnology	Transgenic crops, modern breeding, crossbreed, tissue culture, bio-pesticide, bio-fertilizer, forage additive, bacterin for domestic animals
	Industrial biotechnology	Bio-environment, bio-material and traditional industries reconstructed by modern biotechnology
Future Bioindustry	Genome technology	Structural genome technology, functional genome technology, protein technology
	Stem cell technology	Cellular substitution, organism substitution and apparatus substitution
	Organism and apparatus technology	Sustainable material, cellular engineering, organism and apparatus transplantation
	Biochips	Genetic diagnoses, nucleic acid sequence measuring, medicine selection, Bio-information studies, individual cure
	Animal clone technology	Apparatus transplantation between variant individuals, remedial clone, species breeding, medicine based on animal material, saving wild lives in sever danger
	Gene cure	Gene cure for malignancy, gene cure for cardiovascular and cerebrovascular diseases, gene cure for infectious diseases
	Environmental biotechnology	Precaution and reconstruction to water, atmosphere, and solid waste pollution
	Bio-energy	Energy from plants and wastes
	Nano-biotechnology	Diagnoses based on nanotechnology, nano medicine
	Biosensor	Biosensor based on heat sensitivity, field effect, piezoelectricity, optics and sound wave
	Bio-computer	Computer based on protein, DNA and bionic technology

Source: Department of High-Tech Industry of National Development and Reform Commission, Chinese Society of Biotechnology.

(b) Statistical Foundation

Before the statistical investigation on biotechnology was conducted by OECD, a united or jong investigation on biotechnology by the Science and Technology Commission (instead by MOST), National Bureau of Statistics of China (NBSC) and other ministries was carried out in 1990s. In this national survey, the R&D activities and industrialization of biotechnology in more than 40 provinces and independent planed cites were observed.

In 2003, NDRC organized the "Strategies Research on China's Bioindustry Development". MOST also began the work on "Investigation on China's Bioindustry" and published a report in 2004. Regional investigation was also carried out at that time. For example, MOST and Shanghai's Science and Technology Commission organized the "investigation on biotechnology and its industrialization" in 2004, which collected the last progresses on biotechnology in 2003. The purpose of this investigation was to lay the foundation and provide experiences for future biotechnology statistics as well as know the whole conditions comprehensively. The investigation referred to OECD's statistic framework and provided relevant data and information, the result of which is comparable internationally and can accelerate China's engagement to international statistical methods on biotechnology.

Because of the complex and diversity of biotechnology, although many classifications were proposed, most of the data are not easy to be acquired continuously and steadily. So it is difficult to describe China's biotechnology comprehensively by data analysis. But some areas, like manufacture of biology and biochemical products, were brought into the China Statistics Yearbook on High Technology Industry. So the analysis in the next parts is mostly based on the data in this area.

S&T Activities: Based on Manufacture of Biological and Biochemical Products

(a) Main Sources of Public R&D Expenditure

Since the mid-1980s, the Chinese Government has been giving increasing attention to biotechnology. Increasing amounts of funding from both central and provincial governments have been used to support basic research and development (R&D). The expenditure on biotechnology mainly includes National S&T Programme, National Nature Science Foundation and other funds by the Chinese Academy of Sciences, Ministry of Agriculture, etc. For research activities, National S&T Programme

consists of National High-tech R&D Programme (863 Programme), National Key Technologies R&D Programme, National Basic Research Programme (973 Programme), and is the main fund to support biotechnical research.

Biotechnology has been a major component in the two biggest and most important programs: the 863 Programme and the 973 Programme. In 2006, the appropriate funds of 863 Programme is 3.8 billion Yuan, 21.3 per cent of which (0.81 billion) is related with biology and medicine. 28.7 per cent of National Key Technologies R&D Programme fund (2.11 billon) is appropriated to agriculture area, many of which belong to biotechnical research. National Basic Research Programme is another important fund for biotechnical basic research, from which agriculture and health areas obtained 0.11 and 0.15 billion respectively in 2006. In National Basic Research Programme, protein research project and procreation and development research project were established with 0.11 and 0.07 billion expenditures respectively.[7].

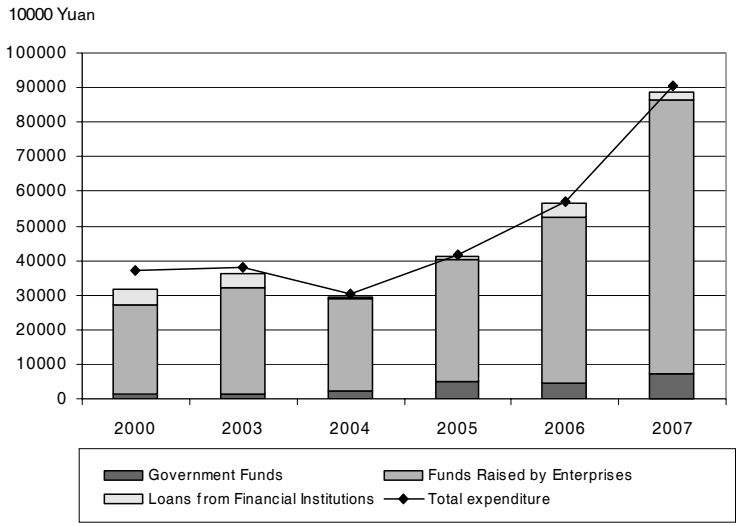
National Nature Science Foundation of China (NNSFC) is another fund sources for basic research of biotechnology. In 2007, Funding statistics for Projects of General Programme, Young Scientists Fund and Regional Fund totalled 3 billion yuan, 35.3 per cent of which (almost 1.1 billion Yuan) belongs to the Life Sciences research. 4,354 projects were funded with an average of 242,800 Yuan.[8]

(b) Analysis on Manufacture of Biological and Biochemical Products

Government funds, funds raised by enterprises and loans from financial institutes are the sources of funds for S&T activities for manufacture of biological and biochemical products. Form 2004 to 2007, the total funds increased from 0.29 to 0.88 billion with annual increasing rate around 40 per cent, which reached to 60 per cent in 2007. Figure 1 shows that funds raised by enterprises hold the largest part of S&T expenditure, almost 90 per cent of funds came from industrial sector. Government funds played a stable source with about 10 per cent of total funds in 2004-2007. Loans from financial institutes have limited effect in China's bioindustry development, the percentage of which was unsubstantial from 1.7 per cent in 2004 to 7 per cent in 2006. The lack of financial support is one of the characters in China's bioindustry, to which more importance has been attached by the central government[9].

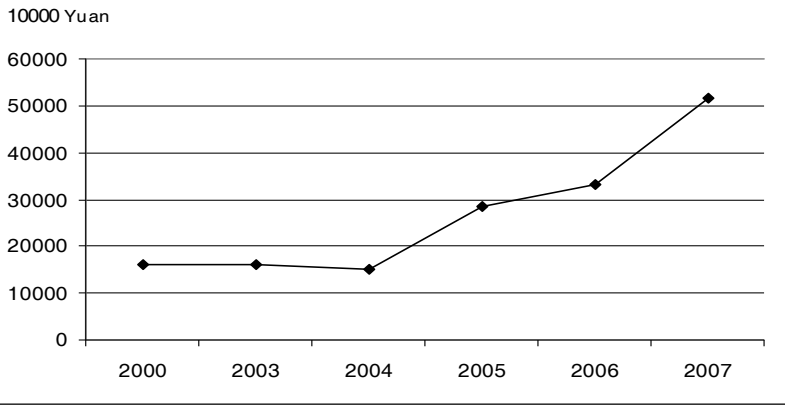
In S&T expenditures, more and more funds were used for developing new products. About 0.15 billion Yuan were invested annually in

Figure 1: Sources of Funds for S&T Activities



developing new products and the funds were not enhanced distinctly from 2000 to 2004. After 2004, the condition changed markedly and the annual average increasing rate is 53 per cent. In 2007, the funds reached the level of 0.52 billion yuan, accounting for 59 per cent of the total expenditures on S&T activities and revealing the accelerating progress of industrialization (Figure 2).

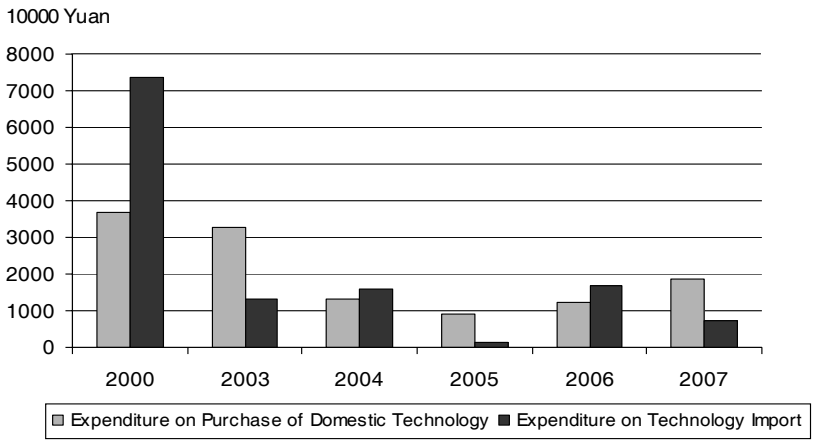
Figure 2: Expenditure for Developing New Products



Source: China Statistics Yearbook on High Technology Industry (2008).

As an important step, technology transfer can reflect the demands of techniques and innovative ability. In China, expenditure on biotechnology import has dramatically decreased from 2000 to 2007. The expenditure on biological and biochemical technology import in medical area in 2007 is only one-tenth of that in 2000 (Figure 3). It revealed that the research foundation of biotechnology has been laid and less technology need to be imported from oversea. The decline of expenditure on purchase of domestic technology shows the similar trends. Although the total expenditure is growing rapidly, the expenses on domestic technology transfer in 2007 decreased to half of that in 2000. It also can be found from the results that research activities were increasing in industrial level.

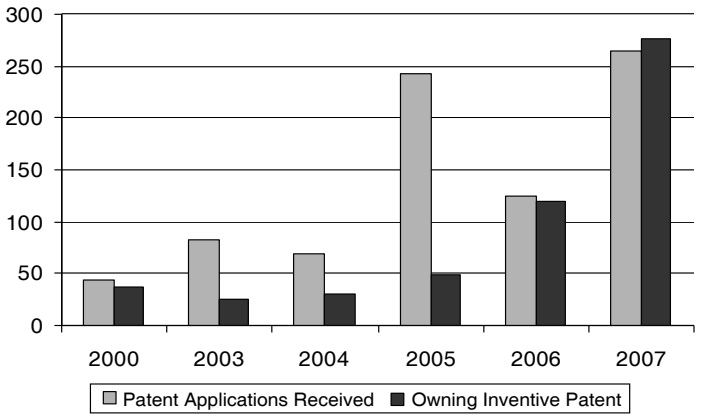
Figure 3: Expenditure on Purchase of Domestic Technology and Technology Import



Source: China Statistics Yearbook on High Technology Industry (2008).

Patent is an important index of S&T activities' outcome, especially in relation to economic development. In the area of manufacture of biology and biochemistry products, patent applications increased greatly from 2005. Figure 4 shows that the owning inventive patents increased rapidly and steadily. From 2005 to 2007, the number doubled from of what it was in the last year.. The increased patents also reveal the industrial progress that is based on the technical advancement.

Figure 4: Numbers of Patent Applications Received and Owning Inventive Patent



Source: China Statistics Yearbook on High Technology Industry (2008).

Industrialization

(a) Policies

Chinese government has already made biotechnology a priority topic for the coming years. *Bioindustry Development Plan for 11th Five-year (2006-2010)* was proposed by NDRC on April, 2007. In the plan, four aspects of developing objects were established. Firstly, a better environment including policy, innovative, standards, industrial organization and bio-safety systems should be built fundamentally. Secondly, the ratio of R&D expenditure to value added of industry should be increased markedly and a series of products should be brought about with sales income above 1 billion. Thirdly, industrial structure should be optimized and upgraded. Finally, the added value of bioindustry should be more than 500 billion, accounting for 2 per cent of GDP. On this condition, the added value of bioindustry should be more than 2000 billion, accounting for 4 per cent of GDP in 2020.

Guiding Options of Jointly Promotion on Financing to China's Biological Industry was proposed by NDRC and National Developing Bank in June, 2007. The guiding options pointed out the main methods to support bioindustry, including provide financing and assurance system, setting

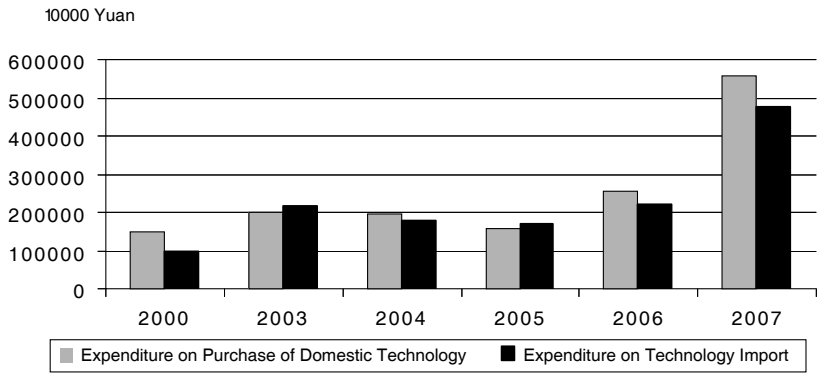
up special funds for bioindustry. Nation S&T Program also provides innovation fund for small technology-based firms, 14 per cent of which (0.12 billon) was invested on biology and medicine area to promote industrialization in 2006.

The era of bioindustry presents both challenges and opportunities to policy makers and society. In the past twenty years, scientific discovery and technological development has occurred rapidly in China. Some of these findings have been published in the international peer-reviewed journals and have been the subject of domestic and international patent applications. In the meantime, China is facing unprecedented issues and challenges arising from new biotechnologies, such as bio-safety, bioethics and intellectual property rights protection. So, many new field of polices need to be investigated, studied and designed.

(b) Progress of Some Characters

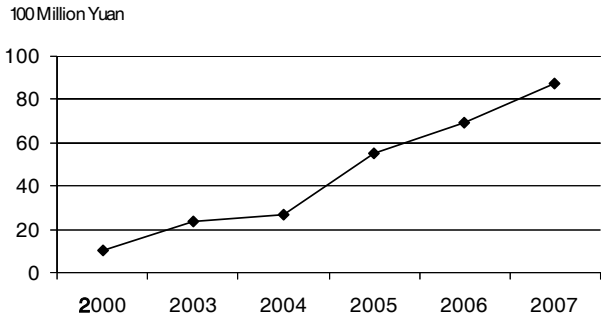
The advancement of biotechnology brings about the economic results. From 2003 to 2006, both the industrial output value and the sales income of new products are around 2 billion Yuan. As the Figures 5 and 6 show there is substantive expansion in industrial output of new products and in the sales income from them. The growth of bioindustry also stimulated exports. The Figure 6 shows that the value of exports increased stably, reaching 0.09 billon Yuan in 2007, with 25 per cent increasing rate annually form 2005.

Figure 5: Industrial Output Value of New Products and Sales Income From New Products



Source: China Statistics Yearbook on High Technology Industry (2008).

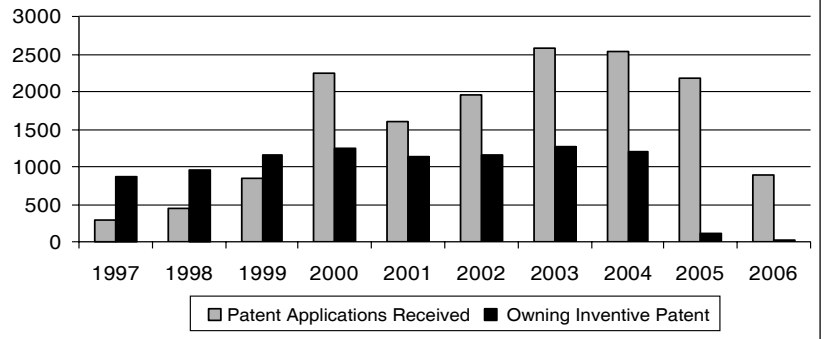
Figure 6: Value of Export of Biological and Biochemical Products



Source: China Statistics Yearbook on High Technology Industry (2008).

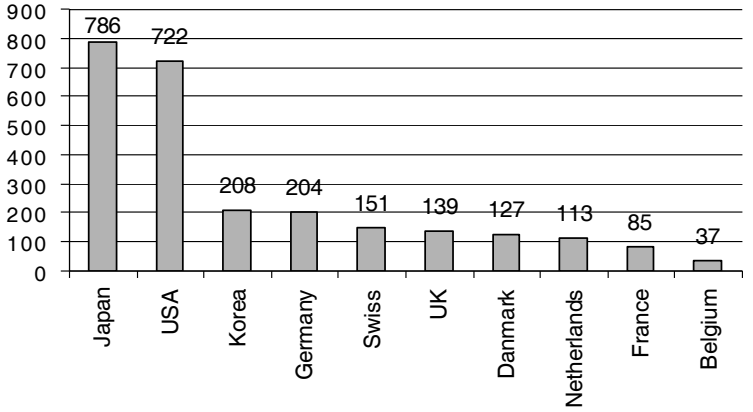
The patent application is a main index of industrial technique competition. From 1998, the applications from domestic organizations increased consistently, while that of oversea organizations is relatively stable. The recent two years data has not been available in the patent database, but the general situation shows that the competition between domestic and oversea organizations has focussed on the intellectual property more and more (Figure 7). For oversea applications, Japan and U.S. are the 2 biggest sources, accounting for almost 60 per cent in the main oversea applications (Figure 8).

Figure 7: Inventive Patent Applications received in China



Source: Annual Report on Bioindustry in China (2007).

Figure 8: Owning Inventive Patents of Main Countries in China from 1977-2006



Source: Annual Report on Bioindustry in China (2007).

(c) Industrial Base

Cluster industrialization is an effective way to realize the new industrial mechanisms. In China, many cities established the bioindustrial base to promote the applications of biotechnology, especially for medicine and biomedical industry. This bioindustiral base aggregated various elements of industrial development and drove China's whole bioindustry. Up to October 2007, the main 12 bases shown in Table 3 accomplished 262.7 billion Yuan of production value, accounting for 52 per cent of total production value of medicine and biomedical industry (507.4 billion Yuan). The annual increasing rate of production values of total medicine and biomedical industry was 25.9 per cent, which was also 5.2 points higher than that of whole high-tech industries.

Suggestions

(a) Taking Full Advantage of Statistic Base on R&D Expenditure and Patent

Based on the statistical situation on biotechnology in China, statistics on biotechnology entirely is difficult to be realized. But, some data can be abstracted from the existing statistical foundation. Most of the R&D data can be found in China's S&T Annual Report, China's high-tech Annual Report. In biology and biochemical medicine area, the data are

Table 3: The Characters of China's Bioindustrial Bases in 2007

Base	Production Value		Profit		Number of factories
	Value (billion Yuan)	Increasing rate	Value (billion Yuan)	Increasing rate	
Beijing	19.2	22%	2.8	43%	200
Shijiazhuang	28	18%	1.6	70%	270
Changchun	21.6	30%	1.6	33%	175
Shanghai	29.3	9%	2.7	51%	370
Guangzhou	22.5	23%	4.7	20%	350
Wuhan	22	18%	3.3	30%	328
Changsha	24.2	30%	2.6	30%	310
Chengdu	35.1	9%	3.7	28%	500
Chongqing	22.6	23%	1.9	23%	513
Kunming	4.3	25%	0.4	19%	155
Qingdao	7.3	26%	1.2	28%	182
Shenzhen	26.6	23%	2.3	28%	752
Total	262.7	21%	28.8	33.6%	4105

Source: Annual Report on Bioindustry in China (2007). Data shown is from January to Octobers.

comprehensive and authoritative. For example, according to International Patent Classification (IPC), patent of biotechnology is available in China's patent database. For other area's R&D data, new statistical table should be added in the national investigation by Bureau of Statistics.

(b) To Establish Special Item in S&T Statistic Investigation

In China, although Bureau of Statistics is entrusted with the responsibility for statistics collection but as biotechnology covers different areas of research which are dealt by various departments, it may be useful if there is a unified design among different organizations so that harmonised frameworks are followed by the different agencies. This would ensure more comprehensive and precise understanding of data and would help draw insights on collaborations and impact analysis.

Endnotes

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