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Biotechnology Industry, Statistics and Policies in Korea

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Abstract: This article introduces discussion on the current Korean bio-industry, its statistical system, R&D expenditure and policies. We also present a brief discussion of non-economic and social impacts of the bio-industry in Korea. In addition, we attempt to estimate trade-related competitiveness. The major findings of the report are as follows: the bio-industry in Korea is made up of mostly dedicated firms based on both modern and single definition. The firms still have diversified lines of production using both biotechnology and conventional technologies. Secondly, biotechnology and bio-industry statistical system is currently well-organized since MKE and KIET took a full charge of the statistical system and data collection since 2002, but need to work on keeping consistency with international system such as OECD suggestion and trade statistics.
The average growth rate of bio-industry over the last 5 years has been 14.4 per cent, more than three times of annual GDP growth in the same period. The major force behind the Korean bio-industry is the synergy created by enthusiastic governmental policy and the entrepreneurship of the research-oriented firms.

Keywords: Biotechnology, bio-industry, patent, trade specialization, R&D.

Introduction

The bioeconomy is a dynamic and unique economic development opportunity for Korea as the country strategically repositions itself for global change and competition. The bioeconomy, as a vehicle for growth for the next generation after conventional manufacturing driven industry, reducing climate change emissions and other less desirable impacts and increasing productivity for the manufacturing industries, is a right choice for Korea. We can enhance its existing agriculture, forestry, manufacturing and biotechnology sectors with value added opportunities presented in the emerging and continuing bio-industrial shift.

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The Korean economy represents an important and growing market for the use and import of biotechnology products. Further, considerable investment has been made to develop an indigenous biotechnology industry. The biotechnology sector in Korea has enjoyed considerable scientific success and has grown to a substantial size mainly due to continuous fund from both the government and the private sector. Success has led to a substantial increase in total sales, employment, private and public R&D, and international trade in recent years. During the years 2002-2007, biotechnology sales almost doubled from the equivalent of US $20.4 billion to US $ 40.0 billion, an annual increase of 14 per cent, as of 2007 US dollar-Korean won exchange rate. Employment of full time equivalent in biotech active firms also has increased from 8,604 (Biotech R&D employees, 5,030) to 20,236 (Biotech R&D employees, 10,178) with an annual increasing rate of 18.7 (15.1) per cent during the same period.

The Korean government has also promised to increase public investment budgets as a type of public R&D, infrastructure, and human resources by 14.4 per cent per annum over the five-year period between 2002 and 2007. The government is firmly committed to the biotechnology sector with a recent announcement by the Ministry of Knowledge Economy (MKE) that US$ 1.35 billion would be invested. This is in addition to state-based R&D projects valued at US$ 9.2 billion and raising another US$ 22 billion through issuing state based bonds to foster the commercialization of next generation technologies, particularly biotechnology. This excludes measures such as establishing world-class research institutions, such as MOGAM Biotechnology Research Centre and POSTECH Biotech Centre.

The leading private firm groups also established their biotechnology firms to pursue the business opportunities. Academic or research institutes' engagement in the bio research is also increasing. Leading firms include: LG Life Sciences, which develops new drugs for the global market and has joint development projects with Parke-Davis & Yamanochi of Japan, and Regen Biotech, Labfrontier, Crystal Genomics, INbionet, etc.

It is estimated that there are more than 800 biotechnology firms in Korea. Out of these biotechnology firms in Korea, 32 per cent are biopharmaceuticals 23 per cent bio foods 14 per cent bio chemicals.

Even though Korea is not a top-tier country in all biotechnology spheres, the number of relevant professional publications in the industry is estimated to rank top 12 in the world. There are nearly 10,000 research and technical personnel working in the industry. This research effort has

yielded a wide array of biotechnological varieties that have gone through field trials and have been cleared for environmental release and put into commercial production.

Korea, along with development of biotechnology industry, has also put a great deal of efforts to establish a consistent data collecting and analyzing system. The biotechnology industry statistics had been managed by Bioindustry Association of Korea (BAK) during 1992 to 2002 as an informal and non-official statistics. Since 2002 MKE has been running an annual biotechnology firm survey. This survey is officially conducted on a voluntary basis and has achieved an overall response rate of almost 100 per cent. The survey has shown a stable and consistent set of annual statistics of biotechnology industry and its activities. Recently the statistical system has been modified at a detailed level of disaggregation and puts more focus on trade statistics.

This article introduces discussion on the current Korean bio-industry, its statistical system, R&D expenditure and policies. We also present a brief discussion of non-economic and social impacts of the bio-industry in Korea. In addition, we attempt to estimate trade-related competitiveness. Finally, as concluding remarks, we present some findings and implications for development of biotechnology industry and further research.

Biotechnology Industry Statistics in Korea

Classification of Bio-industry Statistics in Korea

MKE, former Ministry of Commerce, Industry and Energy, has been running an annual biotechnology firm survey since 2002. This survey is conducted on a voluntary basis in a sense that there is no specific penalty for non-responding firms and it has achieved an overall response rate of near 100 per cent.[1] This survey provides a single definition of biotechnology and uses the Korean Bio-industry classification system. The Korean bio-industry system classifies biotechnology firms into eight sectors: biopharmaceutical, biochemical, biofood, bioenvironmental, bioelectronics, bioprocess and equipment, bioenergy and bioresource, and bioassay, bioinformatics and R&D services. The survey focuses on 'modern' biotechnology.

The major goal of biotechnology industry statistics is to produce statistical information for both bio- and non bio-firms, policy makers, international stakeholders in order to understand current state of bio-industry in Korea and to enhance the industry for the next generation growth engine of the Korean economy.

In building and implementing a statistical classical system, most important to this end was establishing the scope of bio-industry in Korea. The definition of bio-industry in the Korean system is "an industry producing goods and services using biotechnology." That is, the scope of bio-industry is determined by biotechnology itself and changes in accordance with technological innovation. Therefore, it is necessary to understand biotechnology as the currently used term and to systematize its classification to obtain more useful bio-industrial statistics. This process is also linked with the relative significance and substitutability stemming from technological innovation in the knowledge-based economy, legitimate not only for biotechnology but also for other industries capitalizing on new technologies.

To capture an efficient and manageable bio-industry classification system in Korea, the technology classification system was founded, based on which a survey was conducted on the current status of the bio-industry. With the analysis on the survey results, the standard classification system of Korea's bio-industry was set up to facilitate research on the structure of the industry. The technology classification system is useful for analyzing classification indicators as well as the structure of the bio-industry and producing practical statistical data.

This kind of research will enable the government, public and private firms and research institutes to recognize critical issues of the bio-industry by clarifying the status of the real economy relevant to the biotechnology, and to facilitate the analysis on the economic impact of biotechnology, as well as to understand inter-industrial relationships among bio-firms in the perspective biotechnology innovation.

Establishment of the Biotechnology Classification System

The statistics on the Korean bio-industry classified a firm's application field according to the broad criteria of the Korean Bio-industry Classification. There are differences between OECD and the Korea classification in biotechnology applications or bio-industry.

Bio-industry is defined as "products and processes produced with biotechnology" and the technologies currently used in the domestic bio-industry were grouped according to the biotechnology classification system. Based on the biotechnology classification system, key technologies that were primarily used in relevant industrial sectors were screened. The most important principle in establishing the biotechnology classification system was the suitability to the purpose of developing a system. Therefore,

the scope and divisions of biotechnologies were established in order to better reflect the status of the domestic bio-industry.

Technologies used primarily in the bio-industry were the subject of the survey but those forecast to be used in the bio-industry in the near future and expected to have considerable spillover effect were also included to allow flexibility to the survey. The classification consists of three groups of Category I, as shown in Table 1.

The level of technologies in Category I could differ. Despite the difference, however, they were placed in Category I if their impact on the bio-industry was equally substantial.

The technology classification system was established with the participation of experts in firms and industries. The classification system of biotechnology consists of three categories: Category I includes the Chapters A - M at one-digit level, which comprises 13 items as shown in Table 1. Category II includes the sub-sectors of Chapters A-M, A1 - M0, at two-digit level - 68 items. Category III , not in the paper, is more refined than Category II comprising 319 items.

Table 1: Structure of the Biotechnology Classification System in Korea

Value Chains	Purpose of the Technologies	Key Biotechnologies (Category I)
R&D	Biological Material and Cell	A. Genetic engineering B. Protein engineering C. Other macromolecular engineering D. Cell and tissue engineering
	Bioinfornation application analysis	E. Systems biology and and bioinformatics F. Metabolic engineering
Production and Applications	Production	G. Bioprocess
	Biosecurity and sustainable development	H. Bioresource production and utilization I. Envionmental and bioenergy
	Fusion	J. Nanobiotechnology K. Bioelectronics
Evaluation	Safety and efficiency	L. Biosafety and bioefficiency
Others		M. Other biotechnology

Korea's Bio-Industry Classification System and Its Statistical Significance

Korea's statistics on its bio-industry have been published by BAK since 1992. However, KIET (Korea Institute for Industrial Economics and Technology) and MKE took a full charge of data collection, criteria or guidelines regarding the statistics since 2002. Moreover, questionnaires were used in the survey to complement the results of the existing surveys. Based on the results of this survey, the classification system of the domestic bio-industry was re-established to obtain statistical data facilitating the overall analysis of the bio-industry and economy. Korea is following OECD definition of bio-forms which may be summarized as below:

- Firms that utilized biotechnology as a key technology in the R&D stage but used other technology to manufacture products;
- Firms that directly used biotechnology in the manufacturing, production and service (R&D included) processes;
- Firms that used raw materials which was made with biotechnology but produced their products using technology other than biotechnology;
- Firms that produced machines, equipment or plants to be used in the R&D or production process where biotechnology is involved; and
- Firms that purchased and resold the abovementioned products or acted as sales agents on contract terms

Bio-firms are basically classified in accordance with their industrial activities. Industrial activity is defined that any economic activity progressively pursued by economic players that produce, sell or provide goods or services. The statistical units used for the bio-industry are firms. When a firm carries out diverse bio-related activities, the business line of that firm is classified as that of its activity with the highest sales record. Firms that concentrated their key products regardless of sales records are studied separately.

When a firm with manufacturing facilities produces and sells a specific product on orders from another firm or on contract terms, it is classified by that product. When a firm does not directly manufacture a specific product but commissions another firm for production and takes over the final product for sales, it is classified by the final product if the following four conditions are met:

- a firm directly plans a product (concept, design, samples, etc);
- it buys raw materials with its own account and provides them to the contractor;

- it manufactures the relevant products in its own name; and
- it takes over the products and sells them directly in the market.

The Korean statistical system is, in principle, decentralized in that each agency has the responsibilities to collect its statistics relating to its particular field. Hence bio-industry statistics is also managed and operated under the authority with cooperation of separate ministries, with field work of KIET and BAK. With the aim of improving the comparability and consistency of statistics, the authority standardizes bio-statistical terms and classifications periodically. These definitions and modifications in classifying are linked to the Korean Standard Industrial Classification and the Standard Korean Trade Classification, where biotechnology and bio-industry statistics are linked in. Trade statistics in bio-goods and services follow the same broad structure of ISIC Rev 4 (draft version) and selectively choose detailed modifications.

Table 2: Korean Bio-industry Classification

1. Bio-Pharmaceuticals	Industrial activities to produce pharmaceuticals or medical supplies that are used for the diagnostics, prevention, and treatment of human or animal diseases utilizing biotechnology at the stage of research, development, or manufacture (exceptions: medical devices and medical diagnostic devices). 1010 Antibiotics 1020 Anticancer medications 1030 Vaccines 1040 Hormones 1050 Immunotherapeutics 1060 Hemotherapeutics 1070 Growth factors 1080 New therapeutics (ex. gene therapeutics, cell therapy, cloned organs, etc.) 1090 Diagnostic kits 1100 Animal medications 1000 Other biopharmaceuticals
2. Biochemicals	Industrial activities to produce chemicals or substitutes by means of extraction and purification from organisms or biotechnological process (Goods for medical application other than polymeric materials are excluded) 2010 Biopolymers 2020 Industrial enzymes and reagents 2030 Enzymes and reagents for research 2040 Biocosmetics and home & personal care chemicals 2050 Biological agrochemicals and fertilizers 2000 Other biochemicals
3. Bio-Foods	Drinks, foods, and feeds that humans or animals can uptake, extracted from living organisms or biotechnological means are applied at the stage of R&D, manufacture, or production.

Table 2 continued

Table 2 continued

	Edible or inedible animal and plant fats are included. (Products for medical applications are excluded).
	3010 Functional health foods 3020 Amino acids 3030 Food additives 3040 Fermented foods 3050 Feed additives 3000 Other biofoods
4. Bio-Environmental Industry	Industrial activities to provide goods, systems, pollution assessments, and structures for cleaning, restoring, and protecting environment using biotechnology 4010 Microbial treatment agents 4020 Microbe-immobilized materials and equipments 4030 Bioenvironmental agents and systems 4040 Measuring apparatus for environmental pollution (service for pollution assessment) 4000 Other bioenvironmental productions and services
5. Bio-Electronics	Manufacture of medical- or non-medical devices and apparatus making use of bio-informatics, biotechnology, nanotechnology, and electronic technology 5010 DNA chips 5020 Protein chips 5030 Cell chips 5040 Biosensors 5050 BioMEMS 5000 Other bioelectronics
6. Bio-Process and Equipment	Apparatus and plants that utilize living organisms, materials derived from living organisms, or biotechnology for R&D, manufacture, or production process. Instruments and apparatus that are used for research and experiment. 6010 Bioreactors 6020 Biomedical and diagnostic apparatuses 6030 Bioprocess and analysis equipments 6040 Plant and process design 6000 Other bioprocesses and equipments
7. Bio-Energy and Bio-Resources	Industrial activities utilizing organisms or biotechnological processes for obtaining energy sources. Investigation of organisms having novel functions, creation of organisms by breeding and genetic transformation, cultivation, or farming 7010 Biofuel 7020 Artificial seeds and seedlings 7030 Experimental animals 7040 Transgenic animals and plants 7000 Other bioenergy and bioresources
8. Bio-Assays, Informatics Service	Bio-Assays, Informatics Service 8010 Bioinformatics services 8020 Gene analysis services 8030 Protein analysis services 8040 R&D services(ex. drug development services, etc.) 8050 Biosafety and efficacy evaluation services 8060 Diagnosis and preservation services 8000 Other bioassays, bioinformatics services

Biotechnology Industry and Policies in Korea

Brief History of the Korean Bio-industry

Since the early 1980s, the Korean bio-industry began to introduce and develop new biotechnology products for industrial purpose. In 1983, the Korean government enacted Biotechnology Promotion Law to foster young bio-firms. The government, mainly Ministry of Education and Ministry of Science and Technology, helped to establish biotechnology departments and research institutes in Universities from the year 1984. As a public research institute, Korea Research Institute of Bioscience & Biotechnology (KRIBB) was established in 1985, introducing GEC (Genetic Engineering Center).

From the early 1990s, the Korean bio-industry began to produce goods and services in a large scale from private firms. In 1991, the Bio-industry Association of Korea (BAK) was established and 50 bio-industrial companies signed to become members of the new organization. Since then, BAK has been promoting various enterprises to facilitate growth and development of the bio-industry. The Ministry of Science and Technology formally launched Biotech 2000 Program in 1994, speeding up the government-driven biotechnology policies.

Table 3: History of Korean Bioindustry

1980-1989: Technology Development Stage

- Introduction & Development of New Biotechnology
- Enactment of Biotechnology Promotion Law, 1983
- Establishment of Biotechnology Departments & Research Institutes in Universities, 1984
- Establishment of the Korea Research Institute of Bioscience & Biotechnology of (KRIBB), 1985

1990-1999: Product Manufacturing Stage

- Establishment of Bioindustry Association of Korea (BAK), 1991
- Formalizing of Biotech 2000 Programme (MOST), 1994
- Proclaim of Bioindustry Vision 2000 (MOCIE), 1994
- Development of Bioprocess Technology & Launching of Bio-products

2000-Current: Bioindustry Introduction Stage

- Establishment of Korean Bioindustry Development Strategy, 2000
  - Key National Strategic Industry·
- Inauguration of National Bioindustry Action Plan
- Productivity Improvement of Generic Products, Development of New & Modified Bio-products
- Investment Increase in Public and Private Sector

Since the year 2000, coupled with strong government support, the biotechnology firms in Korea began to garner competitive edge in some bio-products and services. The Korean government put a strong effort to

help the industry by entitling the National Strategic Industry and inaugurating National Bio-industry Action Plan. In the meanwhile, the bio-industry has shown a substantial productivity improvement especially in generic products and development of new and modified bio-products. We also witnessed a great deal of increase in public and private sector. The leading private company groups also established their biotechnology companies to pursue the business opportunities. Academic or research institutes' engagement in the bio research became more active.

The historical analysis of the Korean bio-industry is consistent with following articles. Artuso (2002) classified Korea, Taiwan and Singapore by the following common features; (a) political support, (b) government-led funding opportunities for R&D to commercialize inventions and applications, (c) collaboration among federal and/or local governments, the public, universities, and the private sector, and (d) financial and business support for new biotechnology firms, including venture capital financing and establishment of national centers. The report from Rand (2006) also evaluated Korea as the one of the economically and scientifically advanced countries, possessing the capacity to acquire all the 16 significant technologies including biotechnology in the year of 2020.

According to the historical data on the bio-industry in Korea, obtained from the annual bio-firms survey, total sales of the Korean bio-industry, combining domestic sales and exports, has been growing rapidly. The CAGR during the last 5 years is around 14.4 per cent. The major driving force behind the Korean bio-industry seems to be the synergy effect between enthusiastic governmental policies and the entrepreneurship of research-oriented firms.

Table 4: Total Sales of the Korean Bio-industry (2007 millions of US$)

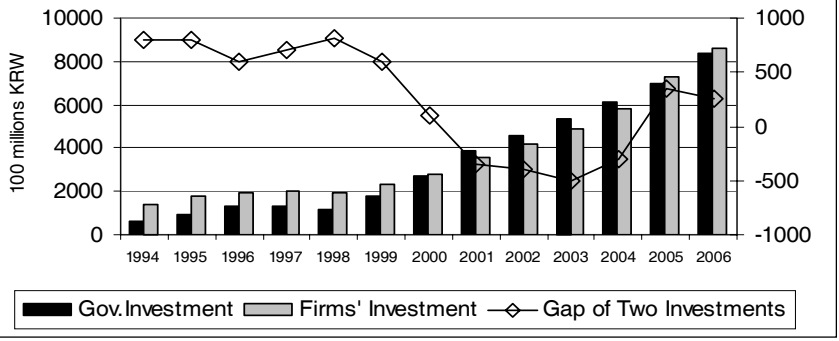
Year	2002	2003	2004	2005	2006	2007	CAGR) (02-07)
Biopharmaceuticals	691	925	1,047	1,200	1,313	1,814	21.3
Biochemicals	122	108	154	199	218	252	15.7
Biofoods	957	989	1,137	1,233	1,463	1,416	8.2
Bioenvironmental	105	99	121	155	175	216	15.6
Bioelectronics	9	8	17	20	28	62	46.2
Bioprocesses and equipment	74	46	49	61	80	91	4.2
Bioenergy and bioresources	46	14	10	17	17	27	-9.8
Bioassay, bioinformatics, etc.	34	47	69	98	105	118	28.0
Total	2,038	2,237	2,604	2,983	3,400	3,997	14.4

In 2007, biopharmaceuticals and biofoods together dominated production by biotechnology firms, accounting for 80.8 per cent and followed far behind by biochemicals (6.3 per cent).

R&D Trend of the Korean Bio-industry

The high growth of the biotechnology industry stems from the government's intensive investment in R&D and social infrastructure. By doing this, the government encouraged firms to invest actively in the biotechnology industry. Figure 1 shows investment expenditures by the government and private firms in the biotechnology industry. As shown in Figure 1, the amount of government's investment increased rapidly at an average of 27.5 per cent per year, greater than that by firms' investment with 17.5 per cent. Furthermore, the government expenditure was nearly the same as the firms' investment. From 2001 to 2004, in particular, public investments exceeded private investment in biotechnology. Here, doubts can be raised as to whether government's investment may cause a crowding-out effect on firms' investment.

Figure 1: Public and Private Investment in the Korean Bioindustry



As shown in Figure 2, there is a sharper fluctuation in the annual growth rates of government investment. We can compare the change in direction of the growth rate in the investment of the two parties. For example, from 1999 to 2000, the growth rate of government investment changed from 44 per cent to 53 per cent, which indicates a plus sign change. Note that there are only the years, 2000 and 2004~2006 when the direction of the two growth rates are reverse. We may refer that government investment could have a reverse impact on the growth rate change in the private investments for the years. In this case, government investment might crowd out private investment by decreasing the growth rate in firms' investment. This can be explained in that, from 2004 to 2006, government investment substituted for firms by investing in areas where firms could play the same roles.

Figure 2: Growth Rates of Public and Private Investment

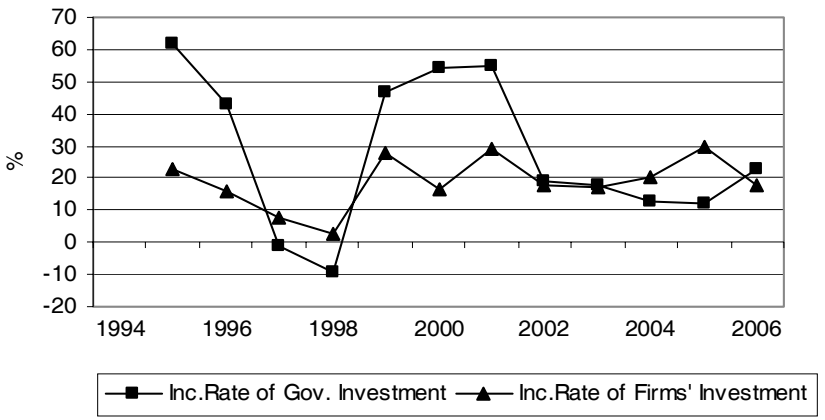


Table 5 shows total public R&D expenditures by periods and major government providers. MEST, which is a new combined ministry of education, science, and technology, is the largest public fund provider during the period 1994~2007, accounting for 44.6 per cent, followed by MKE, .18.9 per cent during the same period. In recent years, especially in 2007, the share of MEST became relatively lower with more emphasis on commercialization of fundamental biotechnologies. Table 6 shows distribution of pure public R&D by biotechnology divisions. Life science accounted for the largest share for both years, followed by health sector.

Table 5: Public R&D Expenditures and Providers (2007 millions of US$)

R&D fund provider	1994-97	1998-'01	2002-06	2007	1994-'07
Ministry of Knowledge Economy(MKE)	18	140	707	193	1058
Ministry of Education, Science and Technology (MEST)	253	564	1335	352	2503
Ministry of Food, Agriculture, Forestry and Fisheries (MAF)	86	111	433	133	764
Ministry of Environment (ME)	10	21	111	140	282
Ministry of Health, Welfare and Family Affairs (MW)	48	95	654	29	827
Public research institutes	0	0	76	100	177
Sum	**415**	**932**	**3317**	**946**	**5610**

Note: Public R&D includes pure research activities, infrastructure, human resource development.
Source: Biotech Policy Research Center, 2008; KIET, Annual Biotechnology Industry Survey, 2008.

In terms of R&D investment, Korea could not invest significant amounts of capital directly because the market is not yet mature and thus, revenues are relatively so small. Due to the relatively short history in biotechnology, the industry may not produce fair amount of rate of return in R&D. The problem of low rate of return from R&D is regarded to stem from less active commercialization from own R&D and technological innovation in biotechnology industry.

Table 6: Distribution of Pure Public R&D Expenditures (2007 millions of US$)

	Life science	Health	Agri. Food	Ind. Process	Bio-fusion	Sum
2007	274	178	101	104	91	748
2008	314	221	107	100	94	836
change, per cent	14.9	24.1	5.7	4.2	2.9	11.7

Note: Pure public R&D includes only research activities.
Source: Biotech Policy Research Center, 2008; KIET, Annual Biotechnology Industry Survey, 2008.

So far, 12 new drugs including a new bio-drug have been licensed from the Korea FDA. Among them, 7 drugs achieved sales of over 10 billion won (around US$8 million) annually. Even though considering the relatively smaller size of market than US, the results are not good performances, compared to the 23 new bio-drugs with sales of over US$1 billion annually in the United States. In the years, 2003-2005, Korean firms obtained FDA 2, 4, and 1 license(s) in the United States in the market launching, phase II clinic, and I clinic, respectively. These figures also reflect the low level of commercialization of developing biotechnologies, compared to new bio-drugs approved ranging from 20 to 40 by the FDA during the years 1999 to 2005, summing up to 230. In the pharmaceutical industry, compared with 602 trillion won of the world market, Korea's market is only 7.8 trillion won in size, accounting for 1.3 per cent. While the largest amount of the sales by firms was 46 trillion won worldwide, the highest sales reached was 0.5 trillion won in the Korean market, or 1.1 per cent of the world market.

While the proportion of the research expenditure to sales is 15-20 per cent in North America and Europe and 12 per cent in Japan, Korea have reached only at 4-8 per cent, resulting from a net profit ratio of less than 5 per cent. While the number of researchers per firm is 500-15,000 persons in North America and Europe and 100-2,000 persons in Japan, the researchers per firm in Korea ranges only 20-300 persons in Korea.

Moreover, the research experience on new drug development is relatively short, around 20 years in Korea, compared with 60 years in North America, 100 years in Europe, and 35 years in Japan.

The biotechnology industry in Korea is in the early stages of development in carrying out R&D investment. In most areas R&D and marketing capabilities including Korea has some weaknesses, compared with advanced countries, especially the United States. In order to improve R&D capabilities, a national R&D system should be revised to provide incentives for cooperation with outside networks. According to the needs of host R&D actors, the evaluation systems used by other R&D actors should be differentiated from those in projects carried out independently. From this point of view, it is important for universities and public institutes to contribute to the industry in two ways: First, they need to focus their research in bio sciences and relevant technologies and, secondly, support commercialization by providing applied technologies under a different system for evaluating R&D outputs.

Firms, Employment, Papers, and Patents of the Korean Bio-industry

The total manpower has increased in the field of biotechnology quite considerable in recent years.

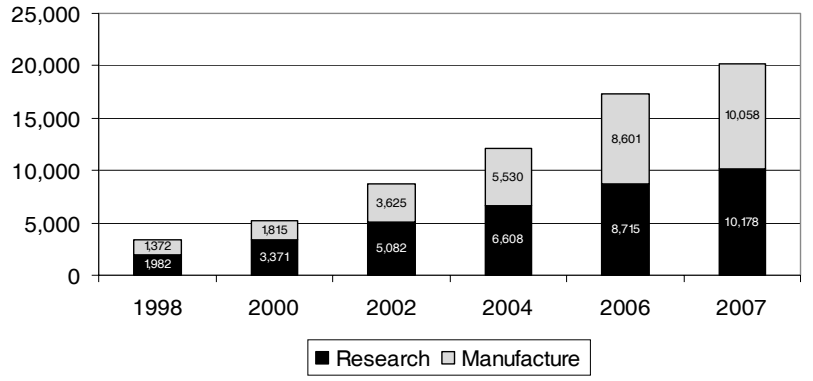
Number of graduates majoring in the biotechnology and bio-engineering, including bachelor, master, and Ph.D., increased consistently reaching 29,256 graduates with annual increasing rate of 2.4 per cent from 2004 to 2007. In 2007, Bachelor degree holders accounted for 66.5 per cent of total; masters, 24.1 per cent; Ph.D., 9.4 per cent (Figure 3).

Figure 3: Graduated Students from Biotechnology and Bio-engineering

The total number of employment also increased rapidly. The biotechnology manufacturing facilities tend to locate in rural areas, near the source of their raw materials and biotechnology services and research centers tend to locate in metropolitan or near the large cities. The jobs associated with the bio-industry offer above average wages. Further, according to inter-industrial analysis, only about small portion of the jobs that can be attributed to a bio-industry facility is created directly at the plant. Many are created when the plant buys supplies and raw materials.

From 1998 to 2007, total employment increased by 22.1 per cent annually; for the periods of 2002 to 2007, by 9.8 per cent (Figure 4). Researchers increased by 19.9 per cent (8.0 per cent for 2002 to 2007) in the same period; manufacturing and service workers at site, by 24.8 per cent (12.0 per cent for 2002 to 2007).

Figure 4: Employment in Biotechnology Industry (Unit Persons)



In 2007, there 834 firms were active in biotechnology in Korea. The largest share of employees worked in the biopharmaceutical sector (40.5 per cent), followed by the biofood sector (24.0 per cent) and biochemical sector (11.7 per cent). Over half of the employees had R&D-related duties (50.3 per cent or 10,178 employees), as shown in Table 7. Average number of employment per firm is 24, ranging from 31 (biopharmaceutical sector) to 14 (bioelectronics).

Thanks to such increase in the human and physical investment, the scientific and industrial outcomes, including professional papers and publications, have risen continuously. The number of SCIE study increased to 4,909 in 2007 by 1.7 times compared to 2002 (2,879) in Phase III, that is 11 per cent per annum (Figure 5).

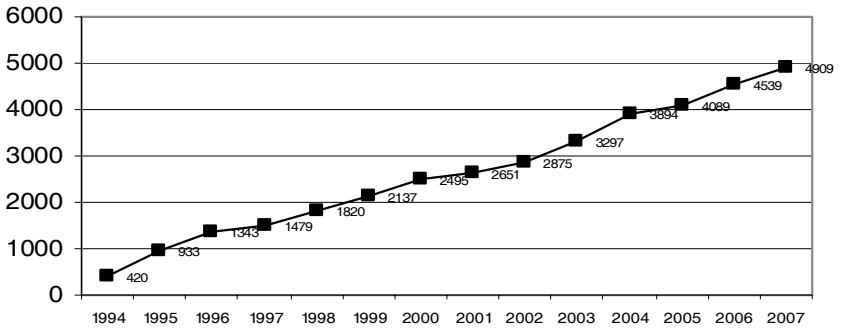
Table 7: Total Sales of the Korean Bio-industry (2007 millions of US$)

Sub-industry	Firms		Employment		
	number	share	number	average	share, per cent
Biopharmaceutical Ind.	266	31.9	8,196	31	40.5
Biochemical Ind.	117	14.0	2,377	20	11.7
Biofood Ind.	188	22.5	4,864	26	24.0
Bioenvironmental Ind.	111	13.3	1,775	16	8.8
Bioelectronics Ind.	21	2.5	304	14	1.5
Bioprocess and equipment Ind.	62	7.4	1,238	20	6.1
Bioenergy and bioresource Ind.	25	3.0	618	25	3.1
Bioassay, bioinformatics and R&D	44	5.3	864	20	4.3
Sum	834	100.0	20,236	24	100.0

Source: KIET, Annual Biotechnology Industry Survey, 2008.

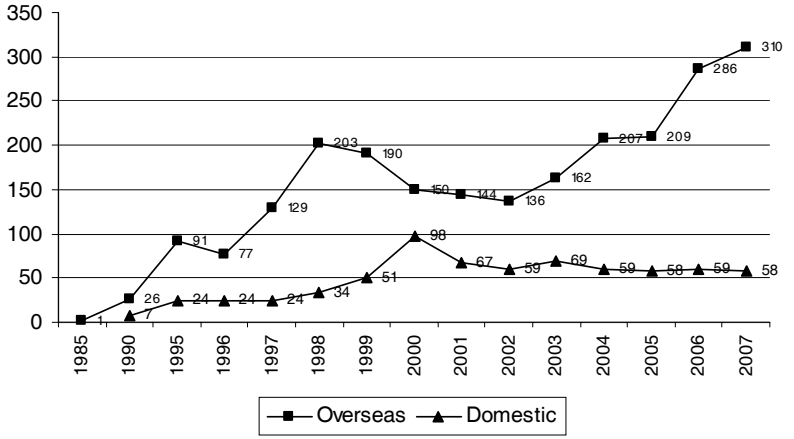
The Korean firms have established their edge in product and process technologies through their focus on R&D. These R&D efforts and human resources, in turn have the potential to provide competitive advantage resulting in improved firm performance. It is the accumulation of knowledge and technological strength resulting from R&D efforts that determines the performance of the firm. Korea focuses on the intermediate results of R&D and human resource development efforts. These can be measured in terms of the number and the quality of patents granted to firms.

Figure 5: Professional Papers of Biotechnology and Bio-engineering



For the initial scratch of the competitiveness review, the number of patents both in overseas and in domestic area, has increased continuously, with slight decline in 2007, as shown in Figure 6. Out of total patent application acquired from overseas, 596 items, the US patents accounted for 18 per cent.

Figure 6: Trend of Patents of the Korean Biotechnology



To better understand the economic inversion and the relative contribution of intangible and tangible assets to innovation, we applied economy-wide and biotechnology industry-specific statistical indicators measuring intangible assets. One embodiment of innovation is patents as explained above, but innovation cannot be measured by a simple patent count. Stated directly, patents are the single most fundamental measure of innovation, but only the overall competitiveness can be measured by including effectiveness of the patents

Technology Specialization (TS), as an index for measuring the competitiveness of the Korea biotechnology and industry, is determined by multiplying a country's number of patents during the period by the current PII (patent impact index). The current patent impact index is a measure of how important a country's patents are based and how often they are cited in other patents, which shows how frequently they are used as the foundation for other inventions. A PII ratio of 1.0 is defined that the country's patents were cited as often as the overall average during certain periods. Table 7 shows patents in US, PPI, TS, and ranks for the relevant periods. The TS was ranked 17th in 1998 to 2001. The ranking

has improved to 15th in 2002~2005 and 13th in 2006~2007, reflecting a gradual gain of competitiveness in the biotechnology.

Table 8: Biotechnology Patents and Competitiveness

Patents			**Patent Impact Index (PII)**		
98-01	02-05	06-07	98-01	02-05	06-07
178	207	170	0.440	0.637	0.645
Technology Specialization (TS)					
98-01		02-05		06-07	
TS value	Rank	TS value	Rank	TS value	Rank
78	17	131	15	109	13

Note: Based on USPS data.
Source: Biotech Policy Research Center, 2008; Korean Patent Office, 2008.

Bio-industry Trade in Korea

The growth in the use of biotechnology in the processes producing of a variety of goods and services has led to questions whether biotechnology-related activity could somehow be reflected in standard statistics classification in most countries as well as OECD and UN ISIC system. In general, industry statistics is classified based on commodities. Therefore, the technology-input goods and services was thought to be difficult to distinguish from those produced without such input. However, with the continuous efforts of OECD and participating countries, the particular case of biotechnology and bio-industry has been quite successfully compiled in conventional statistics system, as has done in Korea

Biotechnology and bio-industry statistics in Korea has been compiled as a distinct activity based on both rules of general statistical system in Korea, such as KSIC (Korea Standard Industry Classification) 8th rev. and SKTC (Standard Korean Trade Classification), a consistent trade statistics of SITC. Trade statistics of bio-industry in Korea is also complied as the above rules.

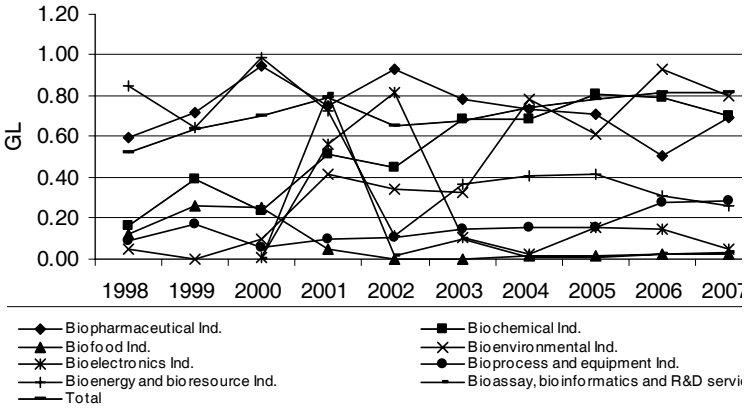
For a simpler comparison, that is either export- or import-oriented for a bio-industry product or service, STSI (Simple Trade Specialization Index) is estimated. For more precise analysis of inter- or intra-industry specialization review, Grubel-Lloyd Index (GL) calculates if the trade between two countries is of an intra-industry or inter-industry nature, that is if countries or regions exchange the same kind of products or not (Figure 7). When the index is equal to 1, the bilateral exchange reveals an intra-industry nature; if the index is 0, the pattern of trade is of an inter-industry nature.

Table 9: Exports and Imports of the Korean Bio-industry (2007 millions of US$)

Import					
	1998	**2002**	**2007**	**98-07 per cent**	**02-07 per cent**
Biopharmaceutical Ind.	84	219	853	29	31
Biochemical Ind.	22	62	92	17	8
Biofood Ind.	4	7	13	14	14
Bioenvironmental Ind.	2	2	6	11	26
Bioelectronics Ind.	0	6	1	14	-31
Bioprocess and equipment Ind.	55	188	130	10	-7
Bioenergy and bioresource Ind.	16	0	4	-15	125
Bioassay, bioinformatics and R&D	0	0	0	-23	42
Total	**183**	**484**	**1,099**	**22**	**18**
Export					
	1998	**2002**	**2007**	**98-07 per cent**	**02-07 per cent**
Biopharmaceutical Ind.	200	190	452	9	19
Biochemical Ind.	242	18	49	-16	22
Biofood Ind.	62	752	1,004	36	6
Bioenvironmental Ind.	0	9	9	76	-1
Bioelectronics Ind.	0	9	38	304	32
Bioprocess and equipment Ind.	3	11	22	27	15
Bioenergy and bioresource Ind.	12	1	1	-29	-12
Bioassay, bioinformatics and R&D	0	3	10	26	25
Total	**518**	**993**	**1,584**	**13**	**10**

Source: KIET, Annual Biotechnology Industry Survey, 2008.

Figure 7: TSI and Glubel-Lloyd Index in the Bioindustry in Korea



Product differentiation with scale economies well explains the exchange of varieties or intra-industry. (GL closes to 1) For the survey periods, sub sectors of bio-industry show quite consistent in trade specialization; biopharmaceutical, biochemical, bioprocess and equipment are net importers, and biofood and bioelectronics are net exporters. GL index for overall biotechnology industry becomes higher, reflecting that the industry is getting more specialized as sub-sectoral level within the industry. Korea has shown a relatively higher specialization in biochemical sector and bio-environmental industry.

For better managing bio-industry trade statistics and policy planning, the government is putting more efforts on regular review for better linking KSIC (ISIC) and SKTC (SITC and HS). The statistical authority and stake holder institutes are closely working together to review better adjustment of list-based biotechnology product and service regarding trade. Recently, group of participating expertise are carefully reviewing SITC (Standard International Trade Classification) and BTN (Brussels Tariff Nomenclature) for maintaining consistent biotechnology trade statistics

It will take some times to include modern biotechnology activities and trade since the conventional industry activities which are based on commodities and services, not on technology itself. Secondly, the biotech firms are still found in many industrial sector in Korea and the firms are engaged in biotechnology as part of its main activity. Therefore, it is not easy task to sort out dedicated bio-tech trade from other.

The statistical analysis such as trade specialization and inter- and/or intra-industry index as shown above indicates the consistency and potential improvement of data collection and trade policy in biotechnology industry. Since the suggested biotechnology classification such as ISIC 4 are widely ranged even in level of classes, experimental analysis of biotechnology trade classification helps to check consistency of bio-data scope and estimation.

Bio-industry activities from cross-border supply, consumption abroad, commercial presence, and presence of natural persons are increasing. Therefore, we are trying to carefully define domestically and to harmonize with international standards. Moreover, for the commercial presence of bio-industry activities, the Korean government attempts to establish consistent statistics compiling system and regulatory policies regarding in-bound and out-bound FDI of biotechnology activities.

Bio-industry Regulations and Policies in Korea

The Korean government has been playing a key role to enhancing solid fundamentals for developing biotechnology industry since 1980s. In 1989, under the supervision of the Advisory Board of Development of High Technology Industry, the Korea Institute for Industrial Economics and Trade established a subcommittee of bio-industry and proposed a bioindustrial development project to understand the concept of the field of bio-industry, and established a vision for bio-industry and a development project for 2000 in 1994. In the late 1990s, the Korean government established a new phase of vision for the field of bio-industry thereby raising investment efficiency and facilitating the development of industrial structure. The Ministry of Commerce, Industry and Energy, with of cooperation of the Korea Institute for Industrial Economics and Trade, proposed an overall picture of the field of bio-industry.

Figure 8: National Science & Technology Administration System on Biotechnology

Ministry of Knowledge Economy (MKE) • Agency for Technology and standards • Small & Medium Business Administration • Industrial Property Office	**Ministry of National Defense** • Agency for Defense Development • Military Manpower Administration
Ministry of Health & Welfare • Food and Drug Administration • National Institute of Health	**Ministry of Environment** • National Institute of Environmental Research
Ministry of Construction & Transportation • National Railroad Administration	**Ministry of Agriculture & Forestry** • Rural Development Administration - Agricultural Research Institute • Forestry Service - Forestry Research Institute
Ministry of Education, Science and Technology (MEST) • National Universities and Colleges • Basic and Leading-edge Technologies • Promotion of Biotechnology-supporting Systems • Education • Assistance of Basic Researchers on Life Sciences	**Ministry of Finance and Economy** • National Tax Service • Customs Service • Public Procurement Service • National Statistical Office

Since 2000, though some of R&D and commercialization are increasingly transferred to private sectors, the government still supports major public policies including developing fundamental biotechnologies, managing research institutes, building bio-infrastructures, and education. The Ministry of Knowledge Economy (MKE, http://english.mke.go.kr/) and the Ministry of Education, Science and Technology (MEST, http://english.mest.go.kr/) are two major ministries. MKE is basically taking charge of applied biotechnologies and industrialization, and development of bio-related renewable energy. MEST plays a key role in basic and leading-edge technologies, promotion of biotechnology-supporting systems, education and human resource development. The ministry also supports basic research on life science and other relevant fields.

The Ministry of Health, Welfare and Family Affairs (MW) is the official body responsible for management and making policies for developing new biopharmaceuticals (http://english.mw.go.kr/front_eng/main.jsp). The ministry is also in charge of clinical trials and safety-related regulations regarding biotechnology. The Ministry of Food, Agriculture, Forestry and Fisheries (MAF, http://english.mifaff.go.kr/main.tdf)'s major tasks include breeding animals, plants , and new food additives, conservation of marine resources, and gene analysis of the marine species. The Ministry of Environment (ME, http://english.me.go.kr/) is the authority for preservation and use of biodiversity, development of waste treatment technology

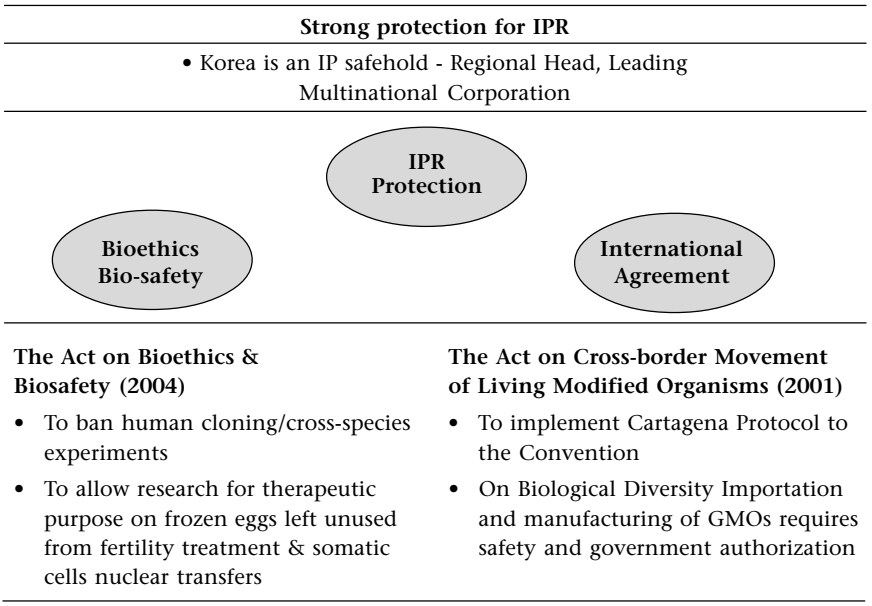
In addition to their significance for economic growth and policy planning, the biotechnology and the bio-industry have a broader impact as they dramatically affect human health and welfare and promote the innovation in the other technologies and industries through the convergence and linkage processes. The ethical, legal, and social implications (ELSI) of biotechnology are important for the reasons described below.

First, biotechnology and bio-industry influence health-care strategies and behaviours, eventually affecting health-care related factors. Secondly, the impact of intellectual property in accessing and using of biotechnology is significant. Accordingly, national competitiveness differences are derived from intellectual property of biotechnologies and bio-industries, which are closely related to the quality of life. Also, cutting edge biotechnology R&D and applications that specifically involve human and participation need acceptance of society. Biotechnology and the bio-industry co-evolve with the society. So how different individuals, cultures and religious

traditions respond to this biotechnology has to be understood. Finally, biotechnology-related-environmental issues such as bio-safety and bio-security have an impact on development and acceptance of biotechnology.

The Korean government has established the required infrastructure

Figure 9: Establishing of Legal and Institutional Frameworks



and introduced laws related to bio-safety, bio-security, and bioethics, in order to facilitate compliance of biotechnology and the bio-industry. However, there is still need for more infrastructure and societal "software" is also required for the ELSI of biotechnology and bio-industry. In IPR, the government has a very strong stance for protection of IPR.

Korea is an IP a safe-hold country and plays the role of regional head, and is a leading figure in the area, especially taking into account increasing multinational corporations.

In bioethics and bio-safety, the government implemented the Act on Bioethics & Biosafety in 2004. The act bans human cloning/cross-species experiments. However, it allows research on frozen eggs left unused from fertility treatment and somatic cells for therapeutic purpose. In accordance with international agreement regarding biosafety and ethics, Korea enacted the Act on Cross-border Movement of Living Modified Organisms in 2001. The act is for implementing Cartagena Protocol to the Convention on

Biological Diversity. In addition, importation and manufacturing of GMOs requires government authorization and biosafety regulations.

Major Government Strategic Projects under Progress

The Biotechnology Transfer Center helps build smooth system for transferring technology by the domestic bio-venture companies. They also facilitate closer interaction between domestic and foreign bio-related technical firms and thereby activate the technology transaction market and enlarge the scale of technology market. The Center has various initiatives which are being summarised as following:

The Bio-Industry Specialized Production Manpower Development Project is to re-educate the professional production manpower on site utilizing the infra such as the pre-established equipment and manpower at the 9 regional Bio Centers throughout the nation, and thereby enhance the technical power of Bio-Industry and diffuse such atmosphere down to the local territories. (Promotions Status; 2, 112 persons for site worker level and 871 persons for preliminary manpower since 2002).

The Bio-medicine/Bio-internal Organ International Standards Infrastructure Building Project operationalises the research club as the decision making and policy organization to lead the countermeasure guideline in supporting the proposal for bio-medicine international standards. The guidelines are in the draft form but they reflect the urge to get domestic technology close to the international standards.

The Site Training Project for the Unemployed in Science & Engineering Field is to provide hands-on experience to unemployed students majoring in bio engineering. The training is also supplemented by the courses of theory and further practice in the professional institute equipped with the test and practice apparatus and give them the chance to have the practical experience through the site training in bio industry (Promotion Status: supported 49 job offering companies, 136 job seekers and 46 companies that wants trainee).

The Small Business Administration Technology Research Association Project is to organize a consortium among the representative agency association, several interested companies and universities for carrying out the research for joint project aiming bio venture enterprises, and thereby joint development of the primary high-tech technology that cannot be developed independently through the cooperation on project basis by the specialized venture enterprises. (Pomotion Status: 17 companies and 7 universities participated for 4 year since 2003).

The BIT Industry Technology Roadmap programme is to derive the strategic product and core technology by predicting the future demand in industrial field where Bio-Industry BT can be incorporated technically, and establish the technological plan suggesting the best strategy to accomplish this target. Distinctively from the existing roadmap it focused on the development of products and technology to establish the Next - Generation Growth Engine (a comprehensive roadmap) incorporating the methods of technology development, manpower demand prospect, infrastructure set up and international cooperation inevitably required to develop the prosperous new products.

Concluding Remarks

As is evident, the foregoing discussion has provided a general review of biotechnology and the bio-industry structure related policies and future role of this in the Korean economy. The major findings of the report thus far are as follows: the bio-industry in Korea is made up of mostly dedicated firms based on both modern and single definition. The firms still have, in some degree, diversified lines of production using both biotechnology and conventional technologies. Secondly, biotechnology and bio-industry statistical system is currently well-organized since MKE and KIET took a full charge of the statistical system and data collection since 2002, but there is need to ensure uniformity with international systems, such as OECD, for comparable policy suggestions and trade statistics.

According to the historical data set on the bio-industry in Korea, obtained from the annual bio-firm survey, the Korean bio-industry has been experiencing rapid growth. The CAGR over the last 5 years has been 14.4 per cent, more than three times of annual GDP growth at the same period. The major force behind the Korean bio-industry is the synergy created by the supportive governmental policy and the entrepreneurship of the research-oriented firms. There are wide variations in value addition within the bio-industry. In Korea, bio-pharmaceuticals, as a highly technology-oriented industry, has the highest share of sales, employment and R&D and are the second highest in exports. The sector, with stringent competition and industry diversification depending on development stage, will play a major role for a while. However, in future, there is very strong potential in bio-food and bio-resources in cooperation with Asian countries. The government must consider a shift in its major policy role from enhancing overall bio-industry development to more R&D intensive approach for fundamental technology development and implementation of efficient regulatory system for IP and biosafety for long term competitive edge in the wider global context.

Endnotes

[1] The Korean biotechnology industry statistics is implemented to provide relevant information for enhancing biotechnology industry, planning biotechnology policies, keeping consistent standardization of biotechnology industry scope and definition, and finally helping international comparison.The statistical survey is based on Statistics Act 3, Article 3, Verification No. 11515 as a general statistics category, and is implemented annually.

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