Survey on Biotechnology Capacity in Asia-Pacific

Opportunities for National Initiatives and Regional Cooperation

RIS
Research and Information System for Developing Countries

United Nations Educational, Scientific and Cultural Organization

Japan Funds-in-Trust

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List of Abbreviations

ABAC	Australian Biotechnology Advisory Council
ABIDI	Asian Biotechnology, Innovation and Development Initiative
ABS	Access & Benefit Sharing
ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
AFMA	Agriculture Fisheries Modernization Act
AIST	National Institute of Advanced Industrial Science and Technology
AIT	Asian Institute of Technology
ANZBPF	Australia-New Zealand Biotechnology Partnership Fund
AP	Asia-Pacific
AP	Associated Press
APEC	Asia-Pacific Economic Cooperation
ASEAN	Association of Southeast Asian Nations
ASX	Australian Stock Exchange
BAEC	Bangladesh Atomic Energy Commission
BAI	Bureau of Animal Industry
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agriculture University
BBTV	Banana Bunchy Top Virus
BC	Biosafety Committee
BCC	Biosafety Core Committee
BCCs	Biotechnology Cooperative Centers
BCSIR	Bangladesh Council of Scientific and Industrial Research
BCT	Biotech Core Team
BERD	Business Enterprise Expenditure on Research and Development
BET	Biotechnology Eligibility Test
BFAD	Bureau of Food and Drugs Administration
BGI	Beijing Genome Institute
BIF	Biotechnology Innovation Fund
BINA	Bangladesh Institute of Nuclear Agriculture
BLC	Biotechnology Liaison Committee
BMO	Biosafety Management Office

BLRI	Bangladesh Livestock Research Institute
BPI	Bureau of Plant Industry
BRRI	Bangladesh Rice Research Institute
C.P.	Charoen Pokphand Group
CARDI	Cambodian Agricultural Research and Development Institution
CARP	Council for Agricultural Research Policy
CAS	Chinese Academy of Sciences
CFR:	Institute for Crop and Food Research Limited
CGIAR	Consultative Group on International Agricultural Research
CIA	Central Intelligence Agency
CIAP	Cambodia-IRRI-Australia Project
CIMBAA	Collaboration for Insect Management for Brassicas in Asia and Africa
CLMV	Cambodia, Laos, Myanmar and Vietnam
COEs	Centers of Excellence
CPB	Cartagena Protocol on Biosafety
CR	Contract Research
CRO	Contract Research Organisation
CSIR	Council of Scientific and Industrial Research
CVL	Central Veterinary Laboratory
DA	Department of Agriculture
DBT	Department of Biotechnology
DENR	Department of Environment
DOH	Department of Health
DoHA	Department of Health and Ageing
DOST	Department of Science and Technology
DOST ITDI	Department of Science and Technology, Industrial Technology Development Institute
DOST PNRI	Department of Science and Technology, Philippine Nuclear Research Institute
DPR	Department of Plant Resources
DSIR	Department of Scientific and Industrial Research
DST	Department of Science and Technology
ECER	East Coast Economic Region
EDB	Economic Development Board
EMB	Environment and Management Bureau
FAO	Food and Agriculture Organisation
FDD	Fruit Development Directorate
FDI	Foreign Direct Investment
FPA	Fertilizer and Pesticide Administration

FRST	Foundation for Research, Science and Technology
GDP	Gross Domestic Product
GEAC	Genetic Engineering Approval Committee
GEF	Global Environment Fund
GERD	Gross Expenditure in R&D
GM	Genetically Modified
GMB	Ganges-Meghna-Brahmputra
GMOs	Genetically Modified Organisms
GMS	Greater Mekong Subregion
GSK	GlaxoSmithKline
HEI	Higher Education Institution
HRD	Human Resource Development
IAA	Indol Acetate Acid
IAAS	Institute of Agriculture and Animal Science
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
IAG	Institute of Agricultural Genetics
IAS	Institute of Agricultural Sciences
IBT	Institute of Biotechnology
ICABIOGRAD	Indonesian Center for Agricultural Biotechnology and Genetic Resources Research and Development
ICAR	Indian Council of Agricultural Research
ICGEB	International Centre for Genetic Engineering and Biotechnology
ICMR	Indian Council of Medical Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information Communication Technologies
IFT	Innovation Fund for Technology
IIF	Innovation Investment Fund
IISc	Indian Institut e of Science
IMI	Infant Mortality Index
IPM	Integrated Pest Management
IPR	Intellectual Property Rights
IRRI	International Rice Research Institute
ISAC	International Scientific Advisory Committee
ISS	Institute of System Science
ITI	Information Technology Institute
JETRO	Japan External Trade Organization
JFIT	Japan Funds-in Trust

KEI	Knowledge Economy Index
KRDL	Kent Ridge Digital Lab
LDCs	Least Developed Countries
LMOs	Living Modified Organisms
MABIC	Malaysian Biotechnology Information Centre
MAF	Ministry of Food, Agriculture, Forestry and Fisheries
MARD	Ministry of Agriculture and Rural Development
MAS	Marker Assisted Selection
MBC	Malaysian Biotech Corporation
MBIO	Malaysian Bio-Industry Organization
ME	Ministry of Environment
MEST	Ministry of Education, Science and Technology
MEST	Ministry of Environment, Science and Technology
MFSC	Ministry of Forest and Soil Conservation
MIRCEN	Microbial Research Centres
MITI	Ministry of International Trade and Industry
MKE	Ministry of Knowledge Economy
MMI	Maternal Mortality Index
MNC	Multinational Corporation
MOA	Ministry of Agriculture
MOST	Ministry of Science and Technology
MOSTE	Ministry of Science, Technology and Environment
MOSTI	Ministry of Science, Technology and Innovation
MoU	Memorandum of Understanding
MRST	Ministry of Research, Science and Technology
MW	Ministry of Health, Welfare and Family Affairs
NARC	Nepal Agricultural Research Council
NARS	National Agricultural Research Systems
NAST	National Authority for Science and Technology
NAST	Nepal Academy of Science and Technology
NBB	National Biodiversity Board
NBF	National Biosafety Framework
NBFSL	National Biosafety Framework for Sri Lanka
NBP	National Biotechnology Policy
NBP	New Biotechnology Policy
NBRA	National Biotechnology Regulatory Authority
NBS	National Biotechnology Strategy

NCA	National Competent Authority
NCB	National Council for Bio- safety
NCB	National Committee on Biosafety
NCBP	National Committee on Bio-safety of the Philippines
NCBT	National Commission for Biotechnology
NCER	Northern Corridor Economic Region
NEA	Nuclear Energy Agency
NFP	National Focal Point
NIB	National Institute of Biotechnology
NIBGE	National Institute for Biotechnology and Genetic Engineering
NNSFC	National Nature Science Foundation of China
NRC	National Research Council
NSCC	National Stem Cell Centre
NSF	National Science Foundation
NSTB	National Science and Technology Board
NSTP	National S&T Programme
NTFBD	National Task Force on Biotechnology Development
NZAID	New Zealand Aid Programme
NZTE	New Zealand Trade and Enterprise
ODA	Official Development Assistance
OECD	Organisation for Economic Cooperation and Development
OGTR	Office of the Gene Technology Regulator
PAEC	Pakistan Atomic Energy Commission
PAL	Pharmaceutical Affairs Law
PCASTRD	Philippine Council for Advanced Science and Technology Research and Development
PCT	Patent Cooperation Treaty
PPP	Public-Private Partnership
PPP	Purchasing Power Parity
PTTC	Platform for Translational Research on Transgenic Crops
RASFF	Rapid Alert System for Food and Feed
R&D	Research and Development
RITM	Research Institute for Tropical Medicine
SAARC	South Asian Association for Regional Cooperation
SBI	Singapore Bio Innovations Private Limited
SCORE	Sarawak Corridor of Renewable Energy
SDPC	State Development and Planning Commission
SPS	Sanitary and Phytosanitary Measures

SRI	Sericulture Research Institute
STRP	Scientific and Technical Review Panel
SWOT	Strength Weakness Opportunity Threat
UGC	University Grants Commission
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Programme
UNESCAP	United National Economic and Social Commission for Asia and the Pacific
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organisation
UPLB	University of the Philippines at Los Baños
USAID	United States Agency for International Developement
USPTO	United States Patent and Trademark Office
WTO	World Trade Organization

Foreword

UNESCO, with its science mandate, is the primary advocate within the United Nations system for mobilizing scientific knowledge and shaping science and technology policy in support of sustainable development.

In the Asia-Pacific region, in the last 30 years, many countries have identified biotechnology as an important priority area for development. Some of its early promises have been realized, with biotechnology-based products and processes developed for addressing problem in agriculture, environment and health, and have successfully moved from the research laboratories into commercialization. Biotechnology-based industry is coming into its own, with several companies performing well in the stocks market.

At the same time, a deeper understanding of the safety and ethical issues linked to biotechnology is emerging, with many countries establishing biosafety regulations, and participating in global trade meetings addressing safety issues, especially for food items.

However, the biotechnology revolution continues, and there are still many potential benefits from the application of biotechnology that are anticipated. Likewise, the corresponding safety and ethical issues remain a major concern. World-wide, the number of players and stakeholders is increasing, with more and more developing countries joining the efforts to deliver biotechnology-based products and processes that would improve productivity and efficiency, and make them more competitive on the global economic arena.

If nations are to effectively mobilize biotechnology for sustainable development, it is important to track such developments, analyze how national capacities in biotechnology are improving, and organize the information as a basis for planning the future. Thus, UNESCO Office, Jakarta engaged the expertise of the Research and Information System for Developing Countries (RIS) based in India, to initiate the publication of the Asian Biotechnology Report, which gives a snapshot of biotechnology capacity, describing current institutional and human resources, programmes and priorities of selected countries in the Asia-Pacific region in the field of biotechnology.

We acknowledge the support of the Japan Funds-in Trust (JFIT) for the preparation and publication of this report, in line with the implementation of the JFIT-UNESCO Science Programme on Global Challenges in Asia and the Pacific Region.

We hope that this report will be the start of a regular assessment of the state of biotechnology in the region, for the benefit of researchers, scholars and policy-makers everywhere.

Biswajit Dhar
Director-General, RIS

Hubert Gijizen
Director, UNESCO

Executive Summary

The Asia-Pacific region is endowed with a very rich cultural and natural heritage along with huge ethnic and linguistic diversity. The region has economies in different stages of growth and encompasses countries belonging to high-income level (Singapore and OECD countries such as Japan, Republic of Korea), upper middle income level (such as China, Malaysia, and Thailand), lower middle income level (such as India, Pakistan, Indonesia, and Vietnam) and low income level (such as Bangladesh, Cambodia and Nepal). However, as a region, the economic growth of Asia-Pacific over the last few decades has been impressive. Estimates by various international organizations such as World Bank, UNESCAP, and ADB have reinstated the Asia-Pacific's future growth potential. The ADB (2013) estimates that the regional growth will pick up to 6.6 per cent in 2013 and reach 6.7 per cent in 2014. This is a distinct improvement on 2012, when growth stood at just over 6 per cent. UNESCAP (2013) mentions that economic growth in the developing Asia-Pacific economies is expected to increase to 6 per cent in 2013 from 5.6 per cent in 2012. Among Asia-Pacific countries, it is also been observed that the real GDP growth rate has been around 5 per cent since 2010 (UNESCAP, 2013). This is a good sign in the post-recession period. This is also indicative of the fact that these economies have become resilient over a period of time. The developing economies of the East Asia and Pacific region grew by 7.5 per cent in 2012, which is higher than that of any other region (World Bank, 2013).

With the emergence of knowledge economy, there has been a rise in the technology-intensive trade globally. The percentage of high-technology in manufacturing export of some of the countries of Asia-Pacific (AP), such as the Philippines (46.35 per cent), Singapore (45.16 per cent), Malaysia (43.39 per cent), and China (25.81 per cent), have been highest among countries worldwide. Similarly, the increasing investments on R&D from abroad in some of the Asia-Pacific countries, e.g. China (US$ 73. 83 billion), India (US$ 30.94 billion) and Singapore (US$ 9. 83 billion) in 2012 highlight the importance of this region in the globalization of R&D. The region has largely transformed itself to the technology-driven economic powerhouse with rapid adoption and diffusion of new technologies. Among these new technologies, biotechnology with its wide ranging applications is considered as a major technology that can further economic and social development.

Biotechnology is a technology that has enormous implications for countries in the Asia-Pacific as it has wide ranging applications in agriculture, health and industry. For many countries in the region, agriculture is a crucial sector in terms of contribution to GDP, employment, livelihood and food security. For a region endowed with rich biodiversity and forest resources, biotechnology offers enormous scope in overcoming declining productivity in agriculture, developing varieties that are more suited to biotic and abiotic stresses, increasing the potential for value addition and reduction in use of pesticides. Although many countries in the region started using biotechnology in the early 1990s, the use of biotechnology has been uneven on account of various factors, and as a result they are unable to make the best use of the benefits of biotechnology revolution.

In this context, this *Survey Report on Biotechnology Capacity in Asia-Pacific: Opportunities for National Initiatives and Regional Cooperation* is an earnest endeavour to map the state of development in biotechnology-related areas in 18 countries of the region, particularly with respect to their current institutional framework, intellectual capacity and capability in terms of human resources and physical infrastructures, and programmes/policies.

The Survey has found that there exist some vital commonalities in all the high-income level countries of the region such as Australia, Republic of Korea, Japan, and Singapore. All of these countries have definite well-placed long-term national plans/strategies and budget to promote R&D in the country in emerging technologies which includes biotechnology. Australia's National Biotechnology Strategy, Republic of Korea's National Bioindustry Action Plan, Japan's BioStrategy 2002 and Singapore's Biopolis Hub, etc., are some of the initiatives undertaken in these countries to harness biotechnology. The gross expenditure on R&D (GERD) in these countries is above 2 per cent and the R&D human resource is above 4000 per million people, which is quite a contrast to the situation in other sets of countries. The physical infrastructure in the form of research centres and universities involved in the area of biotechnology R&D in these countries are of world-class quality. These advanced capacity and capability do get reflected in their high paper publications and patents in biotechnology area. In these countries, it is also observed that the main focus is on tapping economic gains that accrue from biotechnology and use technology to maintain or gain competitive advantage in high-technology and the major players are private biotechnology-led industries. The thrust areas are pharmaceutical, services and industrial biotechnology sectors. Interestingly, in all these countries the share of agriculture in the GDP is below 10 per cent.

Countries belonging to middle income level such as India, China, Malaysia, etc., have shown a special interest in tapping the advantages that biotechnology offer for addressing various societal challenges such as food security, healthcare as well as for promoting biotechnology-led industries in the field of health biotechnology and in niche areas like forestry to capture domestic and global market share. The major promoter of biotechnology R&D is government. The use and scope of biotechnology in these countries is wider as it has role in all the sectors such as agriculture, services and industry. However, the GERD in these countries is less than 1 per cent with an exception of China, which has its GERD above 1 per cent but below 2 per cent. The number of researchers per million people is also lesser than that of the high-income level countries of the region but they are trying to catch up.

Countries belonging to the low income level category such as Bangladesh, Cambodia and Nepal are basically agriculture-driven economies. In these countries, the GERD is very low and the number of R&D personnel is quite low. The physical infrastructure to carry out biotechnology R&D is in nascent stages.

Thus, this Survey has found that as far as the contours and direction of biotechnology in the region of Asia Pacific are concerned, there are stark differences among the countries, which is much reflective of the differences that exist between the countries in terms of income levels and the capacity of the respective national innovation systems. There are some countries which have well-established institutional framework in place to foster and promote developments in biotechnology. They are having both intellectual capacities in terms of skilled human resources as well as infrastructural capacity in terms of knowledge generation centres and industries to explore and leverage the potentialities of biotechnology for both economic and social development. At the same time, there is another set of countries, which have practically very low level of exposure to the biotechnology and its advances, owing to lack of capacity. Nevertheless, as the member countries of the Asia Pacific, they should not be left out. And in this, regional cooperation can play a significant role.

While the continued support of the state for biotechnology is necessary, the importance of strengthening national innovation systems need not be over-emphasised. For countries that have a weak and under-funded innovation system in agricultural research, optimum utilisation and benefiting from agricultural biotechnology will be difficult. In medical biotechnology, many states have realised the importance of supporting research in basic life sciences and have invested heavily in supporting it or in developing the right capacity. Development of biotechnology clusters is becoming an important phenomenon in some countries. The biotechnology clusters and regional initiatives in some countries are expected to add momentum to development of biotechnology in AP. Thus, biotechnology in AP is entering a crucial phase and the path ahead is full of many opportunities and challenges.

Lack of credible statistics on human resources in biotechnology and non-availability of comparable data on human resources and capacity for human resources development in the region make it difficult to estimate the gap between supply, demand and need. The development of human resources should focus on development of capacity and skills at different levels in biotechnology. The human resources potential in this region is an asset that is waiting to be tapped, given the high literacy rates and the increasing enrollment in higher education in many countries.

While initiatives supported by agencies like UNESCO have been useful in setting up specialized centers and build capacity, the need for setting up such centers in many countries in the region is obvious. One potential strategy could be to set up regional centers with support from UNESCO, UNIDO, FAO, etc., so that these centers assist in capacity development in different aspect of biotechnology in countries. Similarly, bi-lateral and multi-lateral agreements in cooperation in Science and Technology can have components for capacity building in biotechnology. We have repeatedly pointed out the need for systematic data collection and development of relevant indicators in biotechnology. This is all the more valid in case of human resources development.

Regulation of biotechnology has emerged as an important issue. Most of the nations in Asia Pacific are either signatories to the Cartagena Protocol or have taken steps to implement it in the national regulatory framework. In this area, i.e. regulation and biosafety, capacity building is vital and there is ample scope for regional and multilateral collaboration. A well-developed and coherent regulatory framework is essential for development of biotechnology industry in any country. Countries should realize this and ensure that appropriate framework is put in place as early as possible. Although collaboration in developing regulatory framework and capacity is welcome, ultimately the framework should be credible and relevant to the needs of the country implementing it.

The Asia Pacific economies are attempting to enhance their technological options for ensuring food, nutritional and health security in the region through strategic initiatives in biotechnology. Though these responses may place them on a higher trajectory for tapping all the benefits of this frontier technology, however, many Asia Pacific countries still have to make additional efforts for capacity building so as to enable their institutions and enterprises to take maximum advantages offered by this technological revolution. This is amply clear from our survey, as indicated in the country reports, that most of the Asia Pacific economies have identified biotechnology as a promising technology and have started developing a policy or national strategy for it. At the same time, Asia Pacific economies also have to build capacity at the level of policy formulation process especially in terms of analysing policy implications of technology trends and corrective measures required at the global level so that access to biotechnology remains feasible especially for the developing economies.

There are several Asia Pacific economies which are just at the first generation technologies (like Indonesia, Bangladesh, Pakistan, Philippines and Sri Lanka) and in some even they are not well entrenched or widely applied (like Lao PDR, Nepal, etc.). In some countries tissue culture is still a major application and they are yet to adopt GM technologies in a big way. It is hoped that in future the bottlenecks that constrain the growth will be addressed resulting in faster growth in biotechnology.

Our studies on the state of biotechnology in different countries point out that biotechnology capacity is unevenly developed. In some countries the initial momentum seems to have been lost and no major changes in policies have occurred although there have been incremental improvements. Countries like India, China and Korea have created milieus that are conducive for growth of biotechnology and the strong hands of the states are visible in this. But in most of the small economies in Asia-Pacific the thrust is lacking and this has resulted in less than optimum utilization of biotechnology for national development. Countries like Singapore and Malaysia have identified niche areas for faster growth of biotechnology and this is paying dividends. Thus, the overall picture is that despite hiccups and constraints biotechnology will continue to grow in all the countries in the region.

The key recommendations that emanate from this survey are as follows:

- The countries in the Asia-Pacific region should take measures including adequate financial support, to enhance the productivity of the national innovation systems. The linkage between the national innovation system and agricultural research systems They should perform technology assessments taking into account the resources, structural constraints and capacity to innovate and engage in advanced research in biotechnology.
- Approaches like development of biotechnology clusters as in South Korea, and special incentives and plans as in India and China can be adopted by the AP countries to give a thrust to biotechnology. States can learn from Singapore and South Korea on formulating policies to stimulate investment in biotechnology.
- These countries and UN agencies should promote South-South cooperation for joint R&D and wider diffusion of biotechnology. The lessons from South-South cooperation in health sector biotechnology should be applied in such cooperation in other sectors of biotechnology.
- Developing regional networks in biotechnology should be given importance so that technological gap among countries can be minimized. Regional cooperation in implementation of regulatory regimes should also be encouraged.
- There is need for more support from multilateral agencies including UN agencies for strengthening institutional capacity, developing regulatory regimes and enhancing capacity of the National Agricultural Research Systems in biotechnology.
- These countries should encourage growth of Small and Medium Enterprises in biotechnology and promote biotechnology entrepreneurship.
- They should promote commercialization of research by universities and research institutes, and, Public-Private Partnerships in biotechnology taking in to account the access to knowledge and the need to balance public and private interests.
- The countries in the Asia-Pacific need to strengthen their innovation systems, develop more coherent frameworks in regional collaboration and do a SWOT analysis of the biotechnology sector to sustain the biotechnology revolution in the region and enhance its relevance and sustainability.
- In our view the states, various stakeholders, international agencies have their tasks cut out in this. The challenge before them is to harness biotechnology for development and use it to enhance their competitiveness and capability for innovation. The coming decades will be crucial for development of biotechnology in Asia-Pacific and timely measures and positive action can make all the difference.

Chapter 1:
Biotechnology in Asia-Pacific

1.1 Economic Growth in Asia-Pacific

Asia-Pacific as a region has been of great significance since centuries. It has been a home to various civilizations. The rich cultural and natural heritage along with ethnic and linguistic diversity bestows a unique character to this region. The region has economies with diverse income-levels. Economic growth of Asia-Pacific over the last few decades speaks of its resurgence. A White Paper on Asian Century by the Australian Government (2012) truly mentions that Asia's transformation into the world's most dynamic economic region has been a defining development of our time. The rapid transformation of some of the Asia-Pacific economies over the past four decades has been unparalleled in the history of economic development. These rapidly transforming economies have often been described as "miracle economies" (UNESCAP, 2013).

Estimates by various international organizations such as World Bank, UN ESCAP, ADB, IMF, etc., have reinstated the Asia-Pacific's future growth potential. The ADB (2013) estimates that the regional growth will pick up to 6.6 per cent in 2013 and reach 6.7 per cent in 2014. This is a distinct improvement on 2012, when growth stood at just over 6 per cent. UNESCAP (2013) mentions that economic growth in the developing Asia-Pacific economies is expected to increase to 6 per cent in 2013 from 5.6 per cent in 2012. Among Asia-Pacific countries, it is seen from Table 1.1 that the real GDP growth rate has been around 5 per cent since 2010. This is a good sign in the post-recession period. This is also indicative of the fact that these economies have become resilient over a period of time.

The developing economies of the East Asia and Pacific region grew by 7.5 per cent in 2012, which is higher than that of any other region (World Bank, 2013a). Similar viewpoint has been expressed in recent UNESCAP survey (2013), which attributed the highest real GDP growth to Asia-Pacific region.

Futuristic projections about the region's economic growth and prosperity are very much promising. The region is set to continue its rapid growth into the next decade. Asia will change the shape

Table 1.1: Real GDP Growth Rate for Asia-Pacific Countries

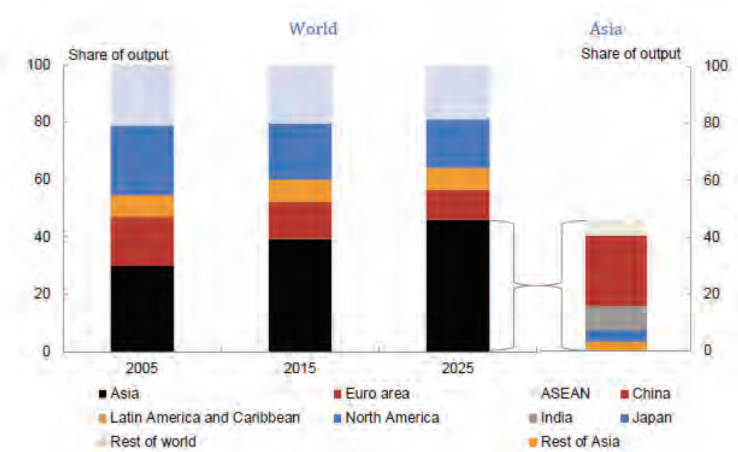
Country/Year	2009	2010	2011	2012 (estimate)	2013 (forecast)
Australia	1.3	2.6	2.5	3.6	2.5
Bangladesh	5.7	6.1	6.7	6.3	6.0
Cambodia	-2.0	6.0	7.1	7.3	7.0
China	9.1	10.4	9.2	7.8	8.0
India	8.0	8.4	6.2	5.0	6.4
Indonesia	4.5	6.1	6.5	6.2	6.6
Japan	-6.3	3.9	-0.6	2.0	2.5
Lao PDR	7.6	7.9	8.3	8.3	8.1
Malaysia	-1.7	7.2	5.1	5.6	5.0
Nepal	3.8	4.0	3.8	4.5	4.0
New Zealand	0.1	0.9	1.5	2.5	2.3
Pakistan	1.7	3.8	3.0	3.7	3.5
Philippines	1.1	7.6	3.7	6.6	6.2
Republic of Korea	0.2	6.1	3.6	2.0	2.3
Singapore	-0.8	14.8	5.2	1.3	3.0
Sri Lanka	3.5	8.0	8.0	6.2	6.5
Thailand	-2.2	7.8	0.1	6.4	5.3
Vietnam	5.3	6.8	5.9	5.0	5.5

Source: UNESCAP (2013).

of the global economy. Fast-growing Asian economies will be the engines of world economic growth as their share of global output rises (Figure 1.1).

The main drivers of Asia-Pacific economic growth are its robust domestic demand, greater trade with its neighbours in the region and supportive fiscal and monetary policies. This is also confirmed in recent World Bank Update (World Bank, 2013a). Continued sluggishness in the United States (US), euro area, and Japan

Figure 1.1: Share of World Output Growth



Note: Unit based on (GDP, PPP, 2011 prices).

Source: Australian Government (2012).

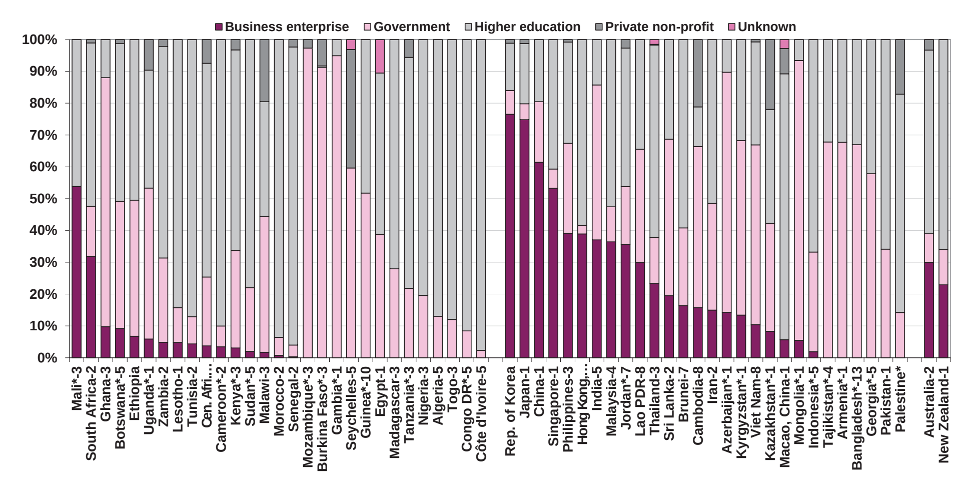
suggests that Asia-Pacific must continue to shift toward more domestic demand and trade with emerging markets. Together, the major industrial economies are expected to manage 1.0 per cent growth in 2013 and 1.9 per cent in 2014. The further narrowing of the region's current account surplus—from 2.0 per cent of gross domestic product (GDP) in 2012 to 1.9 per cent in 2013 and 1.8 per cent in 2014—indicates that the shift to internal sources of growth is progressing (ADB, 2013). As far as FDI is concerned, South Asia has experienced rising inflows of FDI and portfolio investment, falling in line with the global trend of increased shares of FDI flowing into developing countries (World Bank, 2013b). Asia-Pacific remained the leading regional destination for FDI in 2012, with 3740 projects tracked, increasing its global market share to 31.72 per cent. In last two years, there were more than 1.5 Million jobs created due to these FDI, with total capital expenditure of US$ 411.63 Billion.

With the emergence of knowledge economy, there has been a rise in the technology-intensive trade globally. The percentage of high-tech net imports and exports in some countries of Asia-Pacific, such as Malaysia, Singapore and China, are highest among countries worldwide. Similarly, the increasing investments on R&D from abroad in some of the Asia-Pacific countries, highlights the importance of Research, Development and Innovation (RDI) (Global Innovation Index, 2012).

The skilled human resource availability is a pre-requisite for carrying out RDI. It is the basic foundation for building strong and productive avenues for a country's socio-economic growth.

In this regard, the Asian region had about 40 per cent of total world share of researchers. However, in terms of researchers per million inhabitants, Asia, as a whole, had only 660 researchers, in comparison to North America's 4653 and EU's 3059 (UNESCO, 2010). The breakdown of researchers in the Asia-Pacific region shows that in Republic of Korea, Japan, China and Singapore, the major percentage of researchers by sector of employment, belong to business enterprises. In case of India, Pakistan, Indonesia and Malaysia, they are

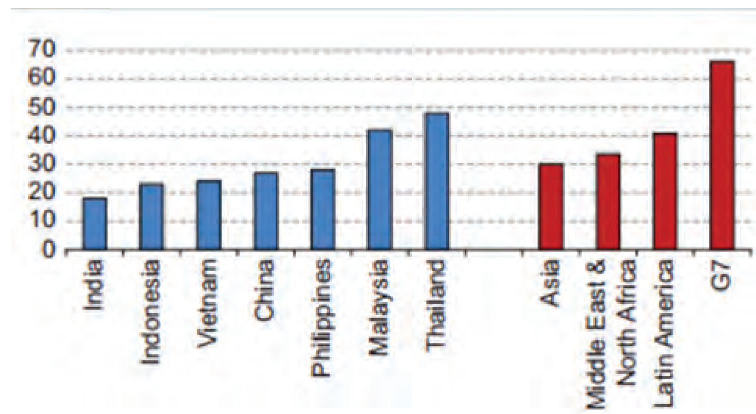
Figure 1.2: Breakdown of Researchers in Africa, Asia and the Pacific



Notes: -1 = 2009, -2 = 2008, -3 = 2007, -4 = 2006, -5 = 2005, -6 = 2004, -7 = 2003, -8 = 2002, -10 = 2000, -13 = 1997.
* = based on HC data.

Source: UNESCO (2012).

Figure 1.3: Tertiary Education Enrollment



Note: Unit used is (in % of eligible age group).
Source: IMF (2013).

concentrated in Higher education sector (UNESCO, 2012) (Figure 1.2).

Higher education, being one of the main driving sources for carrying out RDI in many countries of Asia-Pacific, should be given special focus. However, it is found that tertiary education enrollment in Asia-Pacific countries is not satisfactory (Figure1.3). It is even lower than Middle-East and North African and Latin American countries (UNESCO, 2012).

Capital investment on R&D is another very important factor behind the development of a country's or region's sound infrastructure.

In terms of global investments on R&D, Asia's share of world R&D expenditure was 33 per cent in 2009, which was higher than both that of North America (32.7 per cent) and Europe (28.5 per cent). As far as Gross Domestic Expenditure on R&D as a percentage of GDP is concerned, Asia had invested 1.6 per cent of its GDP on R&D compared to 2.7 per cent in North America and 1.8 per cent in Europe in 2009 (UNESCO, 2012). Japan, South Korea, Singapore and Australia are among the top 20 countries worldwide in terms of GERD (Global Innovation Index, 2012) (Figure 1.4).

R&D funding pattern in Asia-Pacific countries show that both government and business enterprises play a major role, though there are country-wise variations. In countries like Malaysia, Japan, Republic of Korea, China and Singapore, the major contribution comes from business enterprises. However, in countries like India, Sri Lanka, Vietnam, Indonesia and Pakistan, major share belongs to government. Interestingly, in Lao PDR, funding from abroad is maximum (UNESCO, 2012).

After an assessment of the status of Asia-Pacific in terms of macro-economic indicators as well as on the very vital R&D data, it is found that the major impediments which can hold Asia-Pacific's promising growth can thus be poor infrastructure, lack of skilled human resource, low investment, lack of regional technology-collaborations and trade barriers. World Bank (2013a) categorically says that for sustaining and increasing inclusive growth in the medium-term, the underlying productive capacity-human and physical-has to be increased, and that means, first and foremost, investments both in infrastructure and in skills. Since the Asian financial crisis, investment in physical capital has declined significantly in most of middle-income EAP (East Asia and Pacific). On average in the past decade, the levels of investment have remained below the median for all middle-income countries (27.6 per cent of GDP in 2000-11) - in the Philippines (20.4 per cent of GDP), Malaysia (23 per cent), Thailand (26 per cent) and Indonesia (26.3 per cent). In the Philippines, lagging infrastructure development is a long-standing impediment to private investment. And in Indonesia, where aggregate investment has now recovered to its levels in the mid-1990's, the public investment ratio remains among the lowest in the region and infrastructure gaps are cited in most business surveys as major constraints to greater private activity. IMF (2013) has calculated the status of middle-income emerging economies in Asian region along five broad categories: economic institutions, trade structure, infrastructure, demographics (old age dependency ratio, as projected by 2020), and macroeconomic factors (investment, capital inflows). Compared with others in the region, it found that India, the Philippines, and Thailand are exposed to a larger risk of growth slowdown stemming from subpar infrastructure. Improving economic institutions is a further challenge for India and the Philippines, as well as for China and Indonesia.

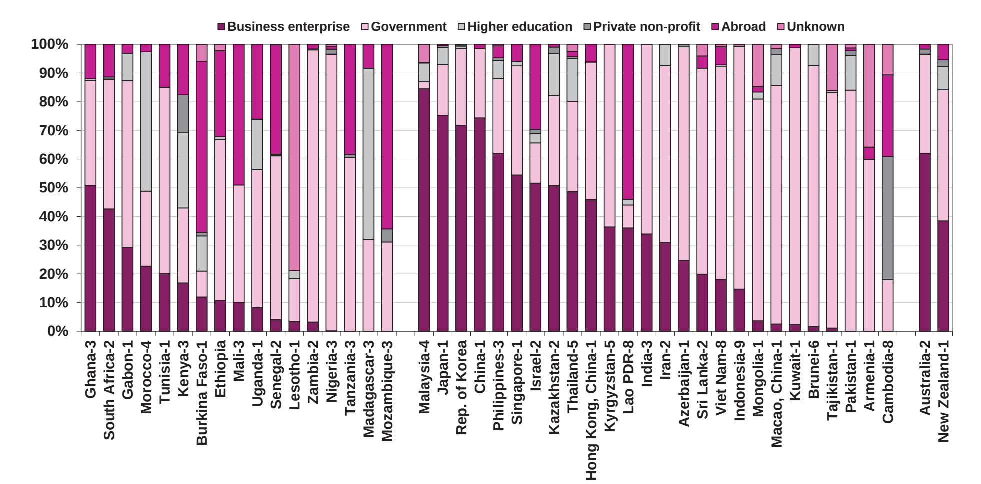
Given the drivers and advantages that Asia-Pacific hold in itself, it is not surprising that this region will continue to be the engine of global growth. Though, there is need to take care of certain barriers that may laggard its forward movement.

1.2 Asia-Pacific and Biotechnology

Asia-Pacific (AP) has achieved remarkable economic success in last few decades. This has happened as AP has largely transformed itself to the technology-driven economic powerhouse with rapid adoption and diffusion of new technologies. Among these new technologies, biotechnology with its wide ranging applications in agriculture, health and industry, is considered as a major technology that can further economic and social development.

At a larger level, the effects of such revolutions have generally occurred in three main stages.[1] First, technological change often raises productivity growth in the innovating sectors; second, falling prices encourage capital deepening and, finally, there can be significant

Figure 1.4: GERD by Source of Funding



Notes: +1 = 2011, -1 = 2009, -2 = 2008, -3 = 2007, -4 = 2006, -5 = 2005, -6 = 2004, -8 = 2002, -9 = 2001.

Source: UNESCO (2012).

reorganization of production around the capital goods that embody the new technology. One of the important features of the biotechnology revolution has been the expansion of the biotechnology industry across the developed countries, particularly by transnational companies (TNCs) and market oriented penetration of new product and processes in the AP countries and other developing countries. The adoption of ICT has catalysed the diffusion of biotechnology. These countries have strengthened their strategies for commercialization of biotechnology leading to a many fold growth in the AP biotechnology industry.[2]

In most of the AP economies the State has played a catalytic role in the adoption and development of the technology. Since most of the AP economies adopted the export led growth model, adoption of new standards and technology was duly rewarded through the various programmes of the governments. Hobday (1995) has shown how various economies followed specific educational and investment programmes to gain technological competence and not through the other established route of substantial government subsidies to promote “leapfrogging” into high technology industry.

As we would see in the forthcoming chapters, AP is all set to make a major global impact in biotechnology. As the country reports would show, most of the AP economies have realised these pre-conditions for technology development. Accordingly in biotechnology sector, a similar trend is emerging with countries developing their strategies in which state plays an important role as a catalyst and facilitator and are also making use of cluster and regional innovation cluster models for fostering innovation.[3] Many economies within AP are pursuing a pro-active strategy for development and adoption of biotechnology.[4] Several developing countries in AP, including People’s Republic of China, Singapore, India, Indonesia, Malaysia, the Philippines and Thailand have begun to invest heavily in biotechnology.[5] They are closely following the OECD members in AP, viz. Japan and South Korea in terms of investments and allocations. In some countries the second and third generation biotechnology is in place and these countries are part of the global biotechnology revolution.

However, most of the AP countries are assessing potential advantages with biotechnology and its impact on the trade and economy and this technology is capital-intensive and requires many pre-conditions for its development. This is a major challenge for most of the economies in the region. Since biotechnology development is more with-in the private sector, it is highly proprietary in nature.[6] The evolution of harmonized intellectual property rights regime, through the WTO, has further intensified the magnitude of challenges that these economies are facing.[7] This has further constrained the space available to the developing countries for relevant policy formulations.

The dilemma is on allocation of scarce physical and financial resources between overall developmental goals versus R&D for innovation and adoption of technologies. Further, the challenges range from the growth prospects of the industry to a stronger regime of intellectual property protection. Food insecurity, malnutrition, communicable and non-communicable diseases are major problems, which need immediate attention. At another level, questions are being asked about the long-term implications of genetic engineering on the environment, with focus on biosafety issues.

Biotechnology is needed and should be given priority not just because it is a cutting edge technology but because it can be part of the broader development strategy and can help countries in achieving developmental objectives. Biotechnology’s role in agriculture is not confined to GM crops.[8] However, linking biotechnology with developmental goals and measuring its impacts or contributions are not easy. There are conceptual and methodological issues and there are also issues of technological choices and alternative options to achieve the same objective. The developments in Asia Pacific indicate that the linkages are not clear and often claims are contested.

Since biotechnology programme objectives need to be very clear, the developing countries might even have to plan for manpower with super-specialization to attend the high priority areas defined by the relevant public policy. An attempt is being made in Table 1.2 to capture these different attributes in one matrix to determine the position and direction of biotechnology policy in different countries. This is specifically attempted for agricultural sector but may be extended to others with change in biotechnology attributes and policy targets.[9] The factors determining economic cost would largely remain the same. The matrix consists of the major crops in a given developing country on the vertical axis, while the aggregate cost values for R&D, IPR protection, biosafety enforcement, infrastructure, distribution cost and cost for human resource development all on the horizontal axis. These costs may be involved in introducing any of the biotechnological traits such as pest resistance, drought resistance and productivity improvement etc. in the ordinary varieties of different crops listed on the vertical axis. These crops are generally important for food and nutritional securities or exports of developing countries.

1.3 Biotechnology Prospects in Asia-Pacific

Biotechnology encompasses many applications and technologies that range from biopesticides to mapping genome of plants and animals to marker assisted selection.[10] In smaller economies where

Table 1.2: Biotechnology in Developing Countries: Matrix for Assessing Technology Direction and Cost of Adoption

	Biotechnology Traits (Economic Cost)	Productivity Improvement (RPBIDH)	Pest Resistance (RPBIDH)	Drought Resistance (RPBIDH)	Enhancing Shelf Life Value (RPBIDH)	Reducing Post Harvest Losses (RPBIDH)	Nutritional Improvement (RPBIDH)
Food Grains (Cereals, Rice, etc.)							
Non-Food grains (Oilseeds, Fibres)							
Plantation crops (Tea, Rubber, Coffee)							
Others (Sugarcane, Tobacco, etc.)							

Notes: Economic Cost constitutes: RPBIDH. R: R & D Allocation; P: Patent (IPR) Protection; B: Biosafety Enforcement; I: Infrastructure; D: Distribution Cost; H: Human Resource Development.

Source: Chaturvedi (2002).

the need for technology is critical, to increase food productivity and for proper utilization of bio-resources the technological options have to be carefully studied and bio-resources should be harnessed accordingly.[11] The economies which have benefited from Green Revolution have to build upon and go beyond Green Revolution to sustain the growth in agricultural productivity and to ensure that such growth is environmentally sustainable and is affordable.

Non-GM technology offers opportunities for this in agriculture and in forestry as many Non-GM applications can be adopted for use by small and marginal farmers on a massive scale and as these are not controversial applications, their rapid diffusion can be facilitated easily. The experience in Asia indicates that countries should use them both as a precursor to GM technology in agriculture and to supplement it so that the countries can choose relevant and economically viable applications instead of relying on one application to meet multiple goals. We are of the view that as at least half a dozen countries in Asia-Pacific have proved that non-GM technologies can be applied widely in agriculture and forestry with success, there is scope for South-South collaboration in this.

The countries need a Technology Assessment in sectors like agriculture and forestry vis-à-vis their capabilities so that action plans can be designed for technology transfer and capacity building. Successful examples from Asia in applying tissue culture, in vitro germination and plant production on a mass scale and introduction and multiplication of exotic germplasm prove that these are appropriate technologies that can be used to meet multiple goals like enhancing livelihood options for small and poor farmers, meeting commercial needs, increasing productivity.[12] Sri Lanka has used tissue culture technology developed in the lab for transfer to small and marginal farmers who are now producing quality bananas for export markers like Japan.[13] Malaysia has used tissue culture in forestry extensively. By tissue culture propagation 12 species are commercially produced.[14] Having pointed out the application of biotechnology in forestry, we would like to point out that at present regulation of biotechnology in forestry is under-developed, particularly the GM forest tress.

Many countries have regulations for agricultural crops, covering fruit tress also. But regulations for use of GM in forestry are found lacking and the capacity to implement them even if there are regulations is another issue. While the regulatory frame work for agricultural biotechnology is useful its application or extension to forestry is beset with problems. This is because while there are fundamental differences between agriculture and forestry, unlike agricultural crops, forest trees have long time frames in growth and utilization and longer life spans. Besides this they are wild resources and are part of forest ecosystem which is complex than agri-ecosystem.[15] Thus while forestry sector as such is well suited for deployment of biotechnology biosafety and long-term impacts on the deployment in ecosystems have to be studied carefully and suitable regulatory frameworks should be developed.

However to realize the full potential of appropriate biotechnologies in agriculture and forestry it is essential that various technologies are promoted and given the importance they deserve. Some technologies like biopesticides, tissue culture may appear to be mundane and less attractive in terms of technological challenges while some like marker assisted breeding are well known but are under applied.

We suggest that the countries should develop a portfolio of appropriate technologies and develop specific plans for their use in different sectors in such a way that these technologies complement each other in achieving the overall objectives. One way to do this is to examine which technologies have worked well and under what circumstances and assess whether the successes can be replicated. Another issue here is the development of capability to absorb these technologies when they are imported /introduced and adapt them for local needs. Using appropriate technologies widely and wisely, instead of relying only on GM plants in agriculture will help the developing countries in acquiring the skills needed for development and diffusion of GM plants.

In this context, it is important to point out that Marker Assisted Selection (MAS) is an appropriate technology that is under-utilized although it has huge potential and is also an appropriate option.[16] But as FAO (2011) points out it is still expensive when compared to other approaches.[17] MAS has been used in India to develop "HHB 67 Improved", a pearl millet hybrid with resistance to downy mildew disease. Genomics and genomics-derived molecular markers are also playing an important role in the characterization, study and preservation of wild populations, such as fish and forest tree populations.[18] Tripathi (2013)[19] made following observation as far as India is concerned:

1. Most of the breeders in India (except few big institutes and seed companies) do not have access to marker technology. A good number of them even do not know how MAS can help in breeding. Those who work on MAS should proactively discuss with breeders to understand the requirements of breeders and to make them aware about the technology.

2. Most of the publications on marker identification are from those groups which themselves do not have the mandate of breeding and varietal development/ release. Lot of effort is needed to convert the findings of a publication into mature technologies. The current regime of "publish or perish" does not provide enough incentives to these researchers in this direction.

3. The cost economics of MAS is currently not very attractive to seed companies.

Apomixis is another technology whose potential is cited in the literature but that that has not seem to be fully used.[20] P. Kaushal *et al.* have called for synergies between plant breeders, geneticsists and molecular biologists to work together for harnessing its potential in India.[21] It is suggested that potential of such technologies should be studied further and explored. Although Apomixis was claimed as plant breeders dream it has not made much head way in terms of practical application. The Apomixis Consortium is a PPP initiative with CIMMYT, Syngenta, Australian National University, Limagrin and Pioneer Seeds as partners. It is expected that it will take few decades for technological capacity to emerge.[22] In 2009 it was reported that a break through was achieved in 2009 that would enable plant breeders to develop apomictic crops although it is expected that about 15 years will be needed to make them available for farmers.[23] George Frisvold, Kathryn Bicknell and Ross Bicknell point out that if this technology is made available in rice it can result in huge welfare gains and can be used to develop varieties that would benefit poor and marginal farmers.[24] But it has been pointed out that apomixis can result in adverse impact on genetic diversity as apomixis mechanism may spread to wild populations.[25] Thus as of today the widespread application of this technology seems to be at least 10-15 years away. Its potential in developing countries is enormous. If it succeeds it could become a new technology that would reduce the dependency of farmers on seed companies for seed.

1.4 Definition of Biotechnology and Statistical Measurement

In the AP region, there are many economies which have invested heavily across various sectors of biotechnology. For example, Singapore had created a Biomedical Science Investment Fund of US$ 600 million and invested US$ 20 billion in research and industrial parks as against US$ 15 billion in South Korea.[26] However, we do not have precise numbers on public investment with statistics to assess returns on their financial expenditures, impact of policies on foreign direct investment and even on regulatory policies, etc. The importance of evidence based policy making is extremely important, especially for developing countries with limited resources, so as to ensure optimum utilization of resources and reasonable prioritisation of R&D expenditure. It is in this context, AP requires a clear policy on definition of biotechnology and its measurements, both for assessing its impact on domestic economy and also for identifying complementarities for best possible utilization of resources. It is for this, that AP economies would have to place their biotechnology numbers together. In this context, the efforts at the Working Party of National Experts on Science and Technology Indicators (NESTI) of OECD, assume major importance. To maximize comparability of both public and business sector biotechnology statistics, a definition of biotechnology was developed by OECD with the help of an expert group.[27]

This is in two separate categories one is a one-line definition and the other gives details of various sectors covered under biotechnology. The one-line definition is, "The application of science and technology to living organisms as well as parts, products, models thereof, to alter living or non-living materials for the production of knowledge, goods and services." Although the single time definition defines the purpose of biotechnology, the list based definition is essential for identifying modern biotechnology. The OECD report (Biotechnology Statistics 2012) includes data for countries which used the same definition of biotechnology.

Once collection of statistics is undertaken, the next point is how convergence should be achieved in terms of methods of collection, authentication and curing of data across countries. What actually should be given? Whether the OECD definition is enough to articulate our developmental needs and policy perspectives? We do not say that it is not appropriate. But beyond OECD what is that topping, value addition, what other parameters we should have. For example, inclusion of biofertilisers into the definition of biotechnology is a major policy dilemma. Whether there is a scope within the OECD definition for that? If we do not include such industries, sometimes the policy-makers say that the pure recombinant DNA industry is very small, so, why are you spending? There are many perspectives possible on this.

Related issue of importance is to focus on what all are the indicators which should be selected for this exercise and what may be the best modality to collect them. It would be best to have the statistics collected through a governmental agency or it should be collected by somebody else who will cooperate with the government at a close level.

In the AP context or in the context of developing countries in general, we need to be very cautious of the definition so that large number of developing countries may join this initiative with comparable numbers. The OECD effort and the interests of developing countries would have to be consciously harmonised. While harmonizing with OECD definition and the indicators, one should see what is OECD Plus, the plus for AP countries. One crucial difference is that there is lot of public funding and that there is a lot of potential, as has been rightly identified in several studies about biotechnology applications. One thing was also clear that in developing countries agri-food sector occupies the centre-stage for policy makers because of obvious concerns related to food security and other public policy concerns in the agricultural sector.

1.5 Framework of the Study

This study would highlight some of these issues and related issues, in light of national and regional efforts for capacity building in the realm of biotechnology, across various sectors. After tracking down the dynamics of economic growth in AP, with a focus on recession, we looked into the issues in measuring and assessing impacts of biotechnology. Chapter 2 would look into the interplay of various economic sectors with technological advancements in the region. This chapter also culls out broad trends in the biotechnology capacity across the AP economies with comparative tables and supporting write-up. The following chapters provide country specific details. This report would try to understand Biotechnology in Asia Pacific from the national innovation systems approach. It attempts to identify and analyze the role of major organizations or actors in biotechnology in the individual countries. These actors include government, universities, research centres and firms. As far as methodology is concerned, this report makes use of Scientometrics and Patent Analysis. Scientometrics (Bibliometrics) helps in finding out the top performing institutes/universities of a country. For the purpose of present study, we have used Thomson Reuters' Web of Science Database for carrying out Bibliometrics and Thomson Innovation Patent Database for carrying out Patent Analysis. Due to ambiguity in searching criteria for Biotechnology-related information, we have applied Web of Science's own research category 'Biotechnology and Applied Microbiology' while searching the country-specific data in the period 2001-2012. Similarly, for Patent information, we have used OECD's Biotechnology International Patent Classification codes, while searching in Thomson Innovation database, with inventor's country address as one field in the period 2001-2012.

While studying the innovation systems and firms capacity to produce, factors like capacity to learn and adopt, capacity to absorb technology and the linkages between firms and institutions are assessed for their potential to innovate, dynamically respond and to form new alliances. One of the factors that hamper the study of innovation systems in biotechnology in Asia is the lack of reliable statistics. Although this is not an issue that is unique to Asia, the time has come to address this now on an urgent basis on account of the following:

Lack of data hampers objective analysis of the policies and plans implemented so far and comparing the outcomes with costs and whether the benefits are commensurate with the costs.

- The strengths and weaknesses of the existing innovation systems cannot be studied in the absence of reliable statistics.
- As countries are investing more and more in biotechnology they should have data to identify priorities, undertake Cost-Benefit Analysis and evaluate alternative investment options.
- As of now most studies rely on data from government or from one or two sources and assessments based on them have limitations because the data often lacks reliability and classifications are not clear. For example, in assessing the availability and deployment human resources in biotechnology unless the differentiation between manufacturing and R&D is made clearly, it is not easy to link the R&D outcomes (papers, patents, etc), budgets with the resources deployed there in.
- In the absence of data it is difficult to arrive at the contribution of

biotechnology sector to the economy and society and within the sector, and, the contributions of sub-sectors. Since application of biotechnology is not limited to a single industry absence of quality statistics makes it difficult to understand the contribution of biotechnology in terms of value addition, resource allocation and utilization. To give an example bio-informatics involves use of informatics and ICTs but value addition in bio-informatics occurs on account of application of knowledge in biological sciences also. If export earnings from bio-informatics are clubbed with ITES or classified under IT services the picture that emerges from this is misleading. In such cases the value addition from application of knowledge in biological sciences and the cost and contributions of persons trained in bio-sciences is not adequately accounted for.

- Robust and reliable statistics can serve both short-term and long-term needs as biotechnology is an emerging industry.

In our view while reliable statistics is an essential but that alone is not sufficient. It is suggested that an Innovation Survey on biotechnology in developing countries is also undertaken. The survey can be done jointly by a network of institutes working in science and public policy studies. The survey will have both quantitative and qualitative aspects and will supplement the current literature on National Innovation System (NIS). It will be based on a methodology that will be applied uniformly. The survey is expected to bring out information and analysis that can supplement what is available. Such a survey will be of relevance and use to policy makers, academics and industry. It can supplement similar studies done by other agencies in various other sectors like UNCTAD in the realm of ICT.

There are reports from The International Service for the Acquisition of Agri-biotech Applications (ISAAA), Asia-Pacific Consortium on Agricultural Biotechnology, which give details about the growth of agricultural biotechnology in the region. However, these attempts do not include the innovation dynamics that cannot be captured in mere numbers. There is a need to understand the numbers and go beyond them to get the underpinnings of the dynamics of forces that shape biotechnology in AP.

In this context, initiative of launching Asian Biotechnology, Innovation and Development Initiative (ABIDI) in January 2007 at New Delhi assumes significance. This was hosted by RIS with support from the Government of India, Department of Biotechnology. At this, some-AP based think-tanks, research institutions, agencies and governments came together to launch an exercise for data collection and for evolving a common approach on definition of biotechnology. The Second meeting of this group was organised at Kathmandu, in March 2009, which was hosted by the Government of Nepal, Ministry of Agriculture.[28] In the meeting issues related to collection of statistics, using a common methodology to collect data and analyze them was discussed. The OECD experience was also debated. Many participants agreed that there was an urgent need to bring in coherence and clarity in data collection, information sharing and analyze the data and in using them for policy purposes. There were further discussions on this in the 5th ABDC held at Kandy in December 2010 and in 6th ABDC in 2012 at Hyderabad.

Realizing the importance of this RIS has proposed to undertake a study, to begin with, on sectoral innovation and indicators for biotechnology in India. This issue of indicators and innovation system was also discussed in the 6th ABDC held at Hyderabad in October 2012. There is a broad consensus that much needs to be done in AP in this as OECD survey does not cover many countries in AP. Hence, there is a case for collecting statistics on biotechnology in countries in AP and also to develop indicators.

1.6 Summing Up

Asia-Pacific is an economic power-house and is home to some of the countries that are moving fast in the biotechnology revolution. Although the countries have invested heavily in biotechnology, particularly in agri-biotechnology and medical biotechnology there are issues like technology assessment and, making the best use of resources including human resources.

AP is a major source for global economic development and is also one of the fastest growing markets in the world. The high growth achieved during the past decade may not be sustained at the same level in the coming years. Still countries in AP will continue to achieve significant growth. The fiscal stimulus provided in the current global economic crisis and slow down is likely to provide an impetus for economic revival and growth. The lessons learnt from the 1997-98 financial crisis are important for countries that bore the brunt of that crisis. Although AP has done commendably in terms of economic growth, in terms of Human Development Index there is a lot to be done. The variation across countries in this indicates that the gap among countries has not been bridged by the economic growth. Hence, it is important that biotechnology strategy should strive to achieve developmental goals also. Linking biotechnology with broader goals in other sectors is vital for enhancing credibility and acceptability of biotechnology.

Capacity building is an important issue that deserves more attention now. Some countries (e.g. New Zealand, Korea, Singapore) have explicitly identified biotechnology as a source of economic development and have tried to integrate that into the overall development strategy. But as all countries are not equally strong and capable in all sectors, it is sensible to identify areas of potential growth and focus on niche areas than spreading the resources thin by trying to do anything and everything in biotechnology. In most countries biotechnology is strongly supported by the state. Many countries have invested heavily in creating infrastructure, offered incentives to industry and start ups and have expanded the capacity in human resources development. While the state supported measures are necessary, they themselves may not be sufficient to spur biotechnology revolution. Countries would need to do a SWOT analysis of their biotechnology strategies and reorient their strategies.

The collection of statistics, measuring the biotechnology sector and other issues in analyzing the data deserve more attention now. Some of the countries (e.g. Japan, South Korea) are members of OECD. OECD had come out with definitions and methodology for data collection and analysis. This exercise was started on a small scale and had proved that it was possible to apply the definitions and methodologies in many countries which were in different stages of development. So countries in AP can undertake a similar exercise and collect statistics periodically and analyze them. Such an exercise will go a long way in assessing the trends and impacts of biotechnology through indicators.

The developing countries of Asia-Pacific are major contributors to the global food economy. This region produces 46.2 per cent of the world's cereals, 37.2 per cent of tubers and root crops, 44.5 per cent of pulses, 50 per cent of vegetable oils, 44 per cent of fruits, 68 per cent of vegetables, 40 per cent of milk, and agriculture is a key source of livelihood as 53.1 per cent of its 3.6 billion people are engaged in agriculture.[29] Asia benefited much from Green Revolution and it has helped Asia to escape from famines and the disastrous consequences of famines. Having successfully used Green Revolution the countries in Asia are now engaged heavily with biotechnology and this engagement goes beyond agricultural biotechnology.

Strong economic growth, coupled with fast growing market and better capacities in human resources, infrastructure and capabilities in R&D, and state support are some of the factors that favor biotechnology revolution in AP. Despite the variations among countries in using biotechnology and in development of biotechnology strategies, biotechnology has come to stay and will play an important role in socio-economic development in AP. The question now is what the strategies to make it more relevant are and how to ensure that the momentum is maintained.

Endnotes

1 Khatri, Yougesh and Houng Lee (2003). "Information Technology and Productivity Growth in Asia". *IMF Working Papers 03/15.* Washington: IMF.

2 See Chaturvedi and Rao (2006). The various presentations made in 5th ABDC and 6th ABDC.

3 Cooke, Philip, Carla De Laurentis, Franz Tödtling, Michaela Trippl (2007). See also Wong (2011) for country specific case studies.

4 See Chaturvedi and Rao (2006). The various presentations made in 5th ABDC and 6th ABDC.

5 Ernst and Young (2008).

6 Dutfield (2008).

7 Reichmann and Maskus (2005).

8 Chaturvedi, S. and K.R. Srinivas (2013). "Genetically Modified Crops: Policy Logjam". *Economic and Political Weekly*, Vol. XLVIII, No. 14: 19-23.

9 Chaturvedi (2005).

10 FAO (2011).

11 *ibid.*

12 Jawahir L. Karihaloo and Oswin Perera (2010). "Agricultural Biotechnologies in Developing Countries: Options and Opportunities in Crops, Forestry, Livestock, Fisheries and Agro-industry to Face the Challenges of Food Insecurity and Climate Change (ABDC-10)," Guadalajara, Mexico, 1-4 March 2010.

13 See 6th ABDC Presentation and the Country Chapter in this report.

14 *ibid.*

15 FAO (2011). *Current Status and Options for Forest Biotechnologies in Developing Countries.*

16 J. David Reece and Ejnavarzala Haribab (2007). "Genes to feed the World: The Weakest Link?" *Food Policy,* 32, pp. 459-479.

17 FAO (2011). p. 42-43.

18 FAO (2013). Working Group on Biotechnology, E-conference on Genomics in Food and Agriculture.

19 *ibid.*

20 See E. Albertini *et al.* (2010). Apomixis in the Era of biotechnology in E.C. Pua, M.R.Davey (eds) *Plant Developmental Biology,* Vol 1. Heildelberg: Springer for an overview. Available at:http://www.plantsciences.ucdavis.edu/Symposium/2007/presentations/Koltunow-TSB.pdf

21 See P. Kaushal, S. N. Zadoo, D. R. Malaviya and A. K. Roy (2005). "Apomixis Research in India: Past Efforts and Future Strategies". *Current Science,* Vol. 89, No. 7, 10 October, pp. 1092-1096. Available at: http://www.iisc.ernet.in/currsci/oct102005/1092.pdf

22 Apomixis Consortium Characterization of the Functional Components required for Apomixis in Maize Dr. Matt Hodges (2009). http://www.cgiar.org/www-archive/www.cgiar.org/pdf/pscnov2009/5.2%20Matthew%20Hodges%20-%20Apomixis%20Consortium%20Master.pdf

23 See http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=4286

24 George Frisvold, Kathryn Bicknell, and Ross Bicknell (2005). "A Preliminary Analysis of the Benefits of Introducing Apomixis into Rice". Paper presented at the 2005 NZARES Conference. http://ageconsearch.umn.edu/bitstream/98515/2/2005-23-preliminary%20analysis%20of%20the%20benefits%20of%20introducing%20apomixis%20into%20rice.pdf

25 Hakan Ulukan (2009). "A New Alternative for Plant Breeding". *Journal of Biological Sciences,* Vol. 9, No. 8, Pp. 788-795. Available at: http://www.agri.ankara.edu.tr/fcrops/1289__APOMIXIS.pdf

26 Chaturvedi, S. (2005). "Evolving a National System of Biotechnology Innovation: Some Evidence from Singapore". *Science, Technology and Society*, Vol. 10, No. 1, 105-127.

27 Chaturvedi, S. (2007). "Asian Biotechnology Information and Development Initiative for Biotechnology Assessment and Policy Relevant Indicators". *Current Science*, Vol. 92, No. 6, 719-721.

28 For details please visit www.ris.org.in

29 FAO-RAP (2009). *Selected Indicators of Food and Agricultural Development in the Asia-Pacific Region 1998-2008.* Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific, Bangkok.

Chapter 2:

Expanding Contours of Biotechnology Revolution in Asia-Pacific: An Overview

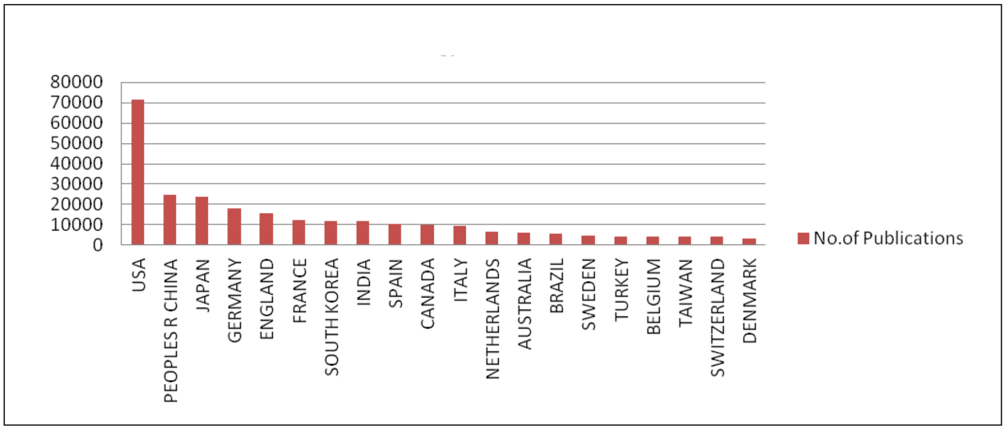
Biotechnology is a technology that has enormous implications for countries in the Asia-Pacific as it has wide ranging applications in agriculture, health and industry. For many countries in the region, agriculture is a crucial sector in terms of contribution to GDP, employment, livelihood and food security. For a region endowed with rich biodiversity and forest resources, biotechnology offers enormous scope in overcoming declining productivity in agriculture, developing varieties that are more suited to biotic and abiotic stresses, increasing the potential for value addition and reduction in use of pesticides.[1] Although many countries in the region started using biotechnology in the early 1990s the use of biotechnology has been uneven and as a result they are unable to reap the benefits of biotechnology revolution.

The AP economies would have to think of relying more on path dependency model as technological convergence emerge as a major policy option with the increasing use of information and communication technologies in life sciences. The birth of nanobiotechnology is one of the developments that have significant implications for humankind[2] particularly for the AP economies as several of them have invested heavily in ICT. The advance areas of biotechnology research like mapping of the genome of crops like rice, using information from human genome project and multiplying tissue culture results all require application of ICT. For countries in the Asia and Pacific, the implications of this convergence will be immense. The Rand Corporation report points out the technological capabilities of some countries in Asia to apply and benefit from this convergence.[3]

2.1 Biotechnology in Asia: Deep Roots and Expansion

Biotechnology has established firm roots in developing countries. Although they were not the pioneers in biotechnology in its scientific or technological aspects, many factors have helped their growth and sustainable expansion in developing countries.[4]

Figure 2.1: Top 20 Countries Publishing in 'Biotechnology and Applied Microbiology' (2001-2012)



Source: Thomson Reuters' Web of Science Database, 2013.

Out of top 20 countries, publishing in the research area 'Biotechnology and Applied Microbiology', five belong to the Asia-Pacific region. In fact, China, Japan, South Korea and India figure among the top 10 nations (Figure 2.1).

But among developing countries in the world, countries in AP have opted for biotechnology with more enthusiasm than countries in Africa or South America. One factor could be the success of the state led industrialisation in Asian countries which propelled countries like South Korea and Taiwan to reap the benefits of export led growth and enabled them to acquire capacity to innovate in biotechnology.

There is a new dynamism in biotechnology in Asia. Factors like government policies, the increasing capabilities for innovation, the availability of trained and skilled human resources have contributed to this dynamism. What is remarkable is that both large and small economies are contributing to that dynamism. In many country countries there are specific policy frameworks and regulations for biosafety as indicated in Table 2.1. While countries like India, China, South Korea, Japan and Singapore are emerging as global players, smaller economies are focusing more on applying appropriate biotechnology in different sectors like agriculture, forestry, health and industry. Thus within Asia there is a significant diversity in applying biotechnology and particularly in agriculture and forestry sectors which is important because it negates the perception that most biotech in agriculture is just Genetically Modified plants. On the other hand many countries are not trying to anything and everything in biotechnology. Rather biotechnology

Table 2.1 Global Biotechnology Industry at a Glance (2005)

	Global	US	Europe	Canada	Asia-Pacific
Revenues ($m)	84872	68400	13352	2692	3970
R&D Expense ($m)	31806	30000	6309	915	488
Net Income (loss) ($m)	-694	-3600	-2645	-722	-6
Number of Companies					
Public	798	386	181	82	149
Private	3616	1502	1563	322	615
Total	4414	1888	1744	404	764

Source: Ernst & Young (2008). Beyond Borders Global Biotechnology Report.

policies and programmes have foci and are directed towards areas/applications that are important and that match with the countries capabilities, available resources and potential. For example, Singapore has identified life sciences and medical biotechnology as key areas where as for many other countries the priority areas are agricultural biotechnology and human health applications in biotechnology like vaccine rather than mapping genomes or stem cell research. But as we will see later, while by and large biotechnology programmes and policies have succeeded, there are weaknesses in the programmes and policies.

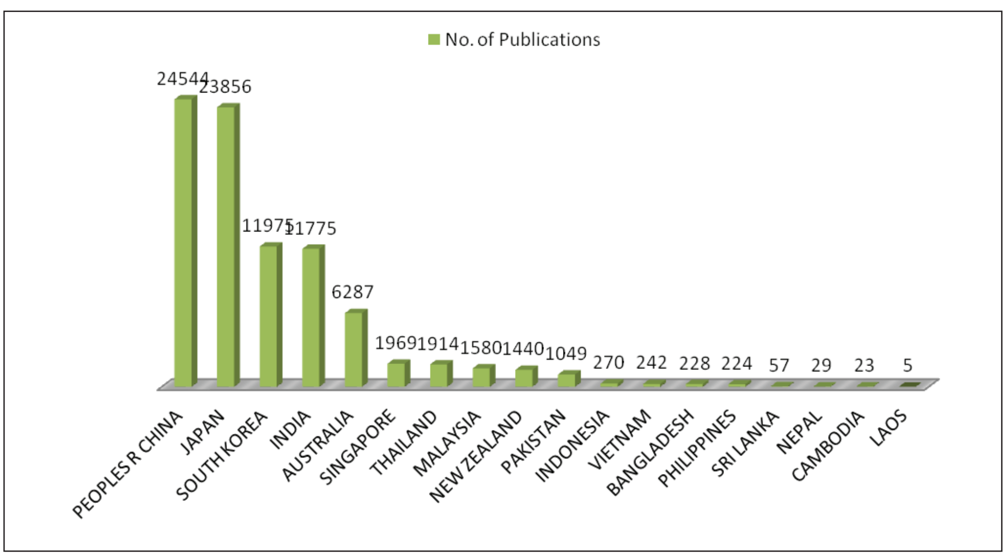
The economies in Asia are witnessing fast growth and by all indications the investments in scientific research and development in Asia is on the increase.[5] Today Asia can compete globally in some niches although it has a long way to go in terms of catching up with USA and Europe in many aspects.[6] Never the less, it has taken less than two decades for some countries in Asia to catch up in terms of key indicators and hence we can be sanguine about the potential of Asia to catch up in biotechnology and emerge as a major player in global biotechnology in terms of investments, innovation and publications within a decade or two.

2.2 Countries, Capabilities and Trends

No discussion on biotechnology in Asia can be complete without discussing the emerging developing economies – China, South Korea and India. These three countries have achieved remarkable growth in the recent past. In last decade these three countries have significantly increased their budgetary allocation to biotechnology. This is a part of the general trend of these countries of investing more on S&T, becoming technologically more sophisticated, and acquiring the capacity to do research in frontier areas.[7]

Among the countries in Asia-Pacific, China, Japan, South Korea, India and Australia are the top countries with high publication activity in research area 'Biotechnology and Applied Microbiology' (Figure 2.2).

Figure 2.2: Countries Publishing in 'Biotechnology and Applied Microbiology' (2001-2012)



Source: Thomson Reuters' Web of Science Database, 2013.

A recent editorial in the Nature Biotechnology pointed out, today China publishes more biotechnology papers than the USA, though in terms of impact they do not rank as high as those from the USA.[8] Moreover as China plans to increase its spending in R&D from 1.5 per cent of GDP now, to 2.5 per cent of GDP by 2020, there will be a quantum leap in terms of funding, taking into account the projected growth in GDP. In case of Korea the average annual growth in biotechnology has been 14 per cent during last three years while the total investments in biotechnology zoomed to $4856 million in 2008 from $ 2038 million in 2002.[9] The biotechnology in Korea is a well diversified, while biopharmaceuticals contributes significantly in both volume and value. Singapore is focusing on biomedical industry and drug development, clinical trials, support to research in life sciences have been identified as major thrust areas. By identifying a single sector within biotechnology as the focus and by giving importance to the related sub-sectors Singapore biotechnology policy is a strategy driven policy that gives a prominent role to state in regulations, incentives and in identifying priorities.[10]

In West Asia biotechnology is taking roots in agricultural biotechnology with tissue culture and molecular markers as main applications and countries like Iran and Turkey have the capacity to produce GM crops based on home grown technologies.[11] Vietnam is another country that is hitching to the biotechnology bandwagon with $10 million investment in 2010.[12] Sri Lanka and Nepal have ambitious plans for biotechnology as formulated in the respective national plans for biotechnology development. Malaysia is another country that has been promoting biotechnology in a big way particularly in agriculture and forestry.[13] The biotechnology policy in Malaysia gives incentives for Foreign Directive Investment in biotechnology besides giving special status to designated units.[14] Malaysia is considered as a 'fast follower' in biotechnology and the state has formulated many innovative plans like Technology Acquisition Fund (TAF) to promote the biotechnology in Malaysia. According to Banji Oyelaran-Oyeyinka and Padmashree Gehl Sampath,

"There is a clear consensus in the policy framework that following the developments in biotechnology in the frontier countries, whereby success depends in strengthening links between basic life science and applied research, the development and commercialization of biotechnology related R&D will depend to a great extent on building specific scientific infrastructural capacity, which evidently requires sustained financial investment."[15]

Biotechnology Business Accelerator Programme (BBAP), grant of BioNexus Status to qualified companies that makes them eligible for privileges are some of the innovative mechanisms used by the state to promote and to attract investments in biotechnology. The National Biotechnology Policy, a 15 year plan, was launched in 2005 with the objective that by the end of the third phase in 2016, biotechnology industry would be established as a global business.

Thailand's Biotechnology Policy framework 2004-2009 had six specific objectives with the ultimate goal of sustainable competitiveness, healthcare for all, equitable income distribution, and a self-sufficient economy. The framework offered incentives for biotechnology units and Thailand identified emerging 'Healthcare centre of Asia' as a major objective.[16]

Since the formation of Biotechnology Board in 1983 the Government of India has been a strong supporter of biotechnology in all sectors and in the recent years significant steps have been taken in capacity building and in expanding the areas of research in biotechnology.[17] Most countries in Asia have by now formulated or revised their National Policy/Strategy for biotechnology and are also giving importance to biosafety regulations (see Table 2.1).

Jawahir L. Karihaloo and Oswin Perera point out that 17 countries in the region have one or more ministries dealing with biotechnology research in agriculture while 11 have research programmes on applying biotechnology in agriculture while 21 countries are either parties to the Cartagena Protocol on Biosafety or have ratified it.[18]

This is not surprising given the fact that biotechnology in Asia has grown on account of strong support from the state which is also a major player in R&D in S&T. Thus while biotechnology in Asia is driven, to a remarkable extent, by strong state support and favorable policy frameworks, the industry has also been playing an active and responsive role by investing heavily in biotechnology. The state's hand is more visible in biomedical innovation in Asia and the hand is not a wavering hand but a firm one backed by a brain. In the words of Wong, the Taiwanese state through 'the right mix of public policies aimed at facilitating technology innovation and knowledge-based interventionist strategies' and recognising that 'cutting edge technologies can no longer be borrowed; rather they must be created', which means a change in state direction and an investment in, or access to, basic science support the biotechnology.[19]

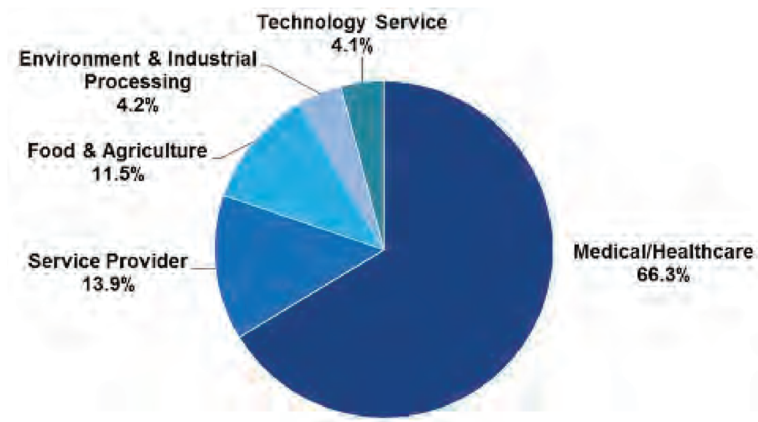
The role of developmental state in biomedical innovation in Asia illustrates that Asian nations are trying to evolve their own models of incentivizing biotechnology without relying too much on the market to play the pre-dominant role and are keen to develop strategies for growth of the industry, identifying areas of priority.[20] The emerging technological South in the Asian context will also be a technological South with a strong focus on biotechnology.

Our contention is not that state guided development is the best model or the only mode that works in Asia, given the fact that there have been some problems with the Taiwanese experience as well as some of the national policies and strategies.[21] Rather we are pointing out that the state in Asia is playing such an important role with the full understanding of the importance of biotechnology and this is a pragmatic step. The earlier experiences with Green Revolution and industrialisation spearheaded by promotional policies of the state indicate that the states' role in promoting biotechnology in Asia should be seen more as a journey taken in a well treaded path than as a radical rupture in policy.

In Asia, biotechnology started gathering momentum in the 1980s but the progress was uneven and in some countries the initial gains were not used to take it forward while in some countries the identified potential was under-utilized on account of many reasons including under-investments in NARS.[22] But in the last decade there has been a positive trend and now the countries seem to have come out of that stagnation stage and are moving ahead in different paces. The task in the coming years would be to avoid faltering again and keep up the momentum so that the national level plans are actualised. For that countries would need to take many measures, supplemented with support from outside in capacity building, regulation and development of human resources.

A positive trend is that of increasing emphasis on science, engineering and technology in bilateral cooperation with African countries by developing countries in Asia.[23] Biotechnology offers much scope in this science diplomacy initiatives and this can result in projects that benefit both countries. As we will see later, health biotechnology is a sector that has rich scope for South-South collaboration within Asia and between countries in Asia and Africa and Latin America.

Figure 2.3: Global Biotechnology Market-Segment Wise



Source: Enabling Technologies Roadmap Study For The Department Of Innovation, Industry, Science & Research, Australian Institute of Commercialization, December 2011, p. 61.

2.3 Technology and Industrial Growth Strategies

Globally the biotechnology industry is dominated by firms in North America, particularly the USA and Canada (Table 2.1) and Europe. Table 2.1 indicates the AP region is a distant third in the global biotechnology industry. In all parameters North America is leading. The share of AP in the global revenue is less than 10 per cent. Thus, the industry in AP has a long way to go when compared to the USA or Europe. Canada is also doing well in terms of all parameters.

The global biotechnology market value in the period 2005-14 is depicted in Table 2.2. It projects that the total market value would be around US$ 318 Billion in 2014, which is very promising for the countries in Asia-Pacific (Table 2.2).

There are many segments in the biotechnology which are marketed. These are technology service, medical/ healthcare, service provider, food and agriculture and environment and industrial processing.

Figure 2.3 shows that medical/ healthcare followed by bio-services segment is dominating the global biotechnology market.

As discussed earlier, with ongoing economic turmoil, investments in

Table 2.2 Global Biotechnology Market Value, 2005-14 (US$ Billion)

Global Biotechnology Market Value, 2005-14 (US$ Billion) YEAR	US$ Billion	Per cent Growth
2010	219.1	9.1
2011	239.5	9.3
2012	262.1	9.5
2013	288.2	9.9
2014	318.4	10.5
CAGR: 2005-09	10.2 per cent	
CAGR: 2009-14	9.6 per cent	

Source: Enabling Technologies Roadmap Study for the Department of Innovation, Industry, Science & Research-Australian Institute of Commercialization, December 2011.

R&D and innovation are crucial and therefore AP economies would have to continue supporting R&D and innovation policies across key growth areas for AP economies. This may require intensive R&D collaborations among member countries. There are several studies which have demonstrated that a large share of industrial growth in the OECD countries have come from technological innovation.[24] This is evident through new technological capabilities leading to changes in products and processes coming through the learning and translation of good practices.[25]

Some countries in the AP region have evolved policy measures (see Table 2.3) and are investing heavily in this and are competing with other major players like the USA and Europe for their share in the global market. We find that governments in Korea, Singapore, Japan, India and China are investing heavily in biotechnology. In India many states have either a biotechnology policy or are encouraging special biotechnology zones, modeled after Information Technology Parks. The use of clusters and regional clusters for developing biotechnology in Korea and Japan, for example, is based on the success of clusters like Silicon Valley.[26] In India the emergence of Bangalore as a major hi-technology cluster with electronics, software, ITES, biotechnology and biopharmaceutical industries is a much cited and studied phenomenon.[27]

The research suggested that industrial technological development should not be viewed as a process that can be promoted easily and quickly by investing in new equipment or buying imported technology. It requires conscious investments by firms in their own technology capability. Technology capability being defined above refers to the skills, knowledge and experiences needed to operate imported technology efficiently. The research also found that enterprise in newly industrialised countries in East Asia had built up relatively good technological capabilities in a spectrum of industries compared to international standards

Table 2.3: Evolution of Biotechnology Policy in Asia-Pacific

Australia	**National Biotechnology Strategy**	**2000**
Bangladesh	National Biotechnology Policy	2006
Cambodia	No national policy as such	
China	First policy in 1990, most programmes are under 863 plan	1990
India	First Policy in 1983 later the National Biotechnology Strategy in 2007	1983
Indonesia	First policy in 1990, Subsequent Policy in 2004	1990
Japan	Bio-Strategy in 2002 – focus on 4 sectors	2002
Korea	National Bio Industry Action Plan	2004
Laos PDR	No National Policy	
Malaysia	National Biotechnology Policy	2005
Nepal	National Biotechnology Policy	2006
New Zealand	National Biotechnology Strategy	2003
Pakistan	There is no comprehensive National Strategy	
Philippines	No Comprehensive National Strategy	
Singapore	No specific National Biotechnology Policy, Biotechnology promotion as part of the Economic Strategy with thrust areas	2006 Science& Technology Plan
Sri Lanka	Policy finalized in 2011 – Implementation in progress	
Thailand	National Strategy with specific objectives in 2003	
Vietnam	No national strategy	

Source: Authors' compilation based on various sources and country chapters.

Table 2.4: Biotechnologies with a High Probability of Reaching Markets by 2030

Agriculture	Health	Industry
Widespread use of marker assisted select (MAS) in plant, livestock, fish and shellfish breeding	Many new pharmaceuticals and vaccines, based in part on biotechnological knowledge, receiving marketing approval each year	Improved enzymes for a growing range of applications in the chemical sector.
Genetically modified (GM) varieties of major crops and trees with improved starch, oil and lignin content to improve industrial processing and conversion yields.	Greater use of pharmacogenetics in clinical trials and in prescribing practice, with a fall in the percentage of patients eligible for treatment with a given therapeutic.	Improved micro-organisms that can produce an increasing number of chemical products in one step, some of which build on genes identified through bioprospecting.
GM plants and animals for producing pharmaceuticals and other valuable compounds.	Improved safety and efficacy of therapeutic treatments due to linking pharmacogenetics data, prescribing data and long-term health outcomes.	Biosensors for real-time monitoring of environmental pollutants and biometrics for identifying people.
Improved varieties of major food and feed crops with higher yield, pest resistance an stress tolerance developed through GM, MAS, intragenics or cisgenensis	Extensive screening for multiple genetic risk factors for common diseases such as arthritis where genetics is a contributing cause.	High energy-density biofuels produced from sugar cane and cellulosic sources of biomass.
More diagnostics for genetic traits and diseases of livestock, fish and shellfish	Improved drug delivery systems from convergence between biotechnology and nanotechnology	Greater market share for biomaterials such as bioplastics, especially in niche areas where they provide some advantage.
Cloning of high-value animal breeding stock.	New nutraceuticals, some of which will be produced by GM micro-organisms and others from plant or marine extracts	
Major staple crops of developing countries enhanced with vitamins or trace nutrients, using GM technology	Low-cost genetic testing of risk factors for chronic disease such as arthritis, Type II diabetes, heart diseases and some cancers	
	Regenerative medicine providing better management of diabetes and replacement or repair of some types of damaged tissue.	

Source: OECD (2009).

and that this was a major factor in their rapid export growth and technological upgrading.[28]

Within the biotechnology sector one comes across different sectoral experiences. Japan and the USA are competitors in high-technology sectors and have their respective strengths in innovative capacities and catering to the global markets and also in basic research. But the growth paths and trajectories of biotechnology industry in the USA and Japan are very different. Venture capital played an important role in the USA while in Japan, the biotechnology firms were mostly spun out from industrial conglomerates. Right from the beginning, biotechnology patents in the USA were broadly focused while in Japan scope of patentability was narrow and broad claims were disallowed.[29] Thus, the biotechnology industry's evolution in the USA and Japan is a study in contrasts.[30]

The biotechnology industry in Korea did not follow the path of the industry in the USA and without the state's support and guiding role, the industry would not have reached this stage. In India, the state support for the industry was vital for its growth and diversification. In fact over the years the Indian government had continued and increased its support to the development of biotechnology by investing in infrastructure, human resource development, various incentives for commercialisation, schemes for applied R&D and by a consistent policy framework. In all these cases the linkages with other sectors were established and biotechnology fitted well within the overall industrial development strategy. In other words, the hand of the state directed the rapid development of biotechnology. But in case of most countries in AP this did not happen. Even when the state wanted to direct and set the direction for the industry to grow, biotechnology did not grow rapidly. In fact there were many false starts that were followed by stagnation or incremental growth. While potential applications were identified and some promising beginnings were made, the pace did not gather momentum to reach the next stage but faltered along the way. We analyse this elsewhere. But the point we want to emphasise is that, biotechnology is not an inappropriate technology, nor is a technology that will become irrelevant rapidly. In fact it is a technology that can enable leap frogging.

By and large, in most countries, the application of biotechnology varies from sector to sector. For example, in Japan there is limited application of agricultural biotechnology while industrial biotechnology has received major attention. Similarly, in Korea and Singapore medical biotechnology has attracted major attention of policy makers. In Thailand, it is agricultural biotechnology which has emerged as very important for increasing exports of agricultural products. In case of India and China, cross-sectoral priorities are being addressed through biotechnology. To what extent all these ambitious objectives will be achieved and whether Japan could repeat the miracle it did in automobiles and electronics in biotechnology is not yet known. It is well known that even Europe is struggling hard to keep the pace with the USA in biotechnology and is trying its best to catch up with the USA.[31] But in a globalised world, it is possible to identify niches and increase the competitive advantage in them. Similarly, it is also likely that advantages like cheaper labor cost, availability of trained human resources and extensive state support will help the countries in AP to overcome some of the factors that inhibit their growth. Realising this, countries like Korea, Singapore and New Zealand are welcoming influx of human resources in biotechnology, while India and China are relying both on numbers and in the quality of human resources.

Most countries have evolved attractive policies to attract FDI investment in biotechnology; relaxed norms of equity ownership and a whole range of incentives are offered. In terms of investment and R&D the region lags behind both the USA and Europe, and Canada is another competitor. The E&Y survey indicates that in terms of R&D expenditure, both in absolute terms and in proportion to the turnover, the USA is leading and the AP region lags behind. It is true that the biotechnology sector in the USA is not a profit making machine and historically biotechnology industry has continued to incur loses. But what would sustain, the momentum are the innovative products and the confidence in the industry. Does this mean that biotechnology industry in AP will always lag behind and remain in the third place? It need not be so. Because the experience shows that the first mover advantage is not permanent and countries do catch up and reduce the gap to reach the higher rungs in the ladder.

In medical biotechnology the success of Korea in vaccines is a case in point. Korea developed and successfully commercialised Hepatitis B vaccine. This is a product development that resulted in a cheaper vaccine that could compete globally.[32]

While biotechnology has firmly established itself in AP, more has to be done for ensuring its rapid expansion. In context of new technologies particularly, biotechnology, most of the national initiatives are focused on the issue of innovation system and the capacity to adapt and absorb technology as the deficiencies of earlier models of linear technology transfer are emerging as major impediments in the technological and thereby economic growth. Thus, technology can no longer be viewed as tools, techniques and processes that should be transferred and applied but seen as an important component of a broader framework of technology transfer and application, particularly in LDCs.[33]

The importance of evolving the regional plan for capacity development in the realm of biotechnology would have to be strongly embedded in the national strategies of various AP economies. Some states give incentives and concessions to biotechnology industry, encourage FDI and develop special clusters or biotechnology zones for integrating research, commercialisation and technology development. Japan's approach is a classic example of using regional clusters and drawing on the capabilities of Centers of Excellence to support biotechnology. Singapore's BioPolis is another example of technology facilitation by the state. Investment in this way helps in stimulating further investment in a high-end technology sector by the private companies. In fact Singapore has further invested billion of dollars in health biotech as indicated in the county chapter to retain it as a key industry as part of the strategic plan on biotechnology.

South Korea too is using the concept of clusters for biotechnology. India is another country that is investing heavily in biotechnology infrastructure and enhancing the capacity of its universities and research centers. The country chapter indicates that number of such clusters and investments therein have increased significantly. It is also establishing Centers of Excellence through newly announced National Biotechnology Strategy. In all these countries the linkages with other innovative sectors are established. Thailand is another country that has a policy with specific goals and linkages. Hence one can reasonably expect that these measures will bear fruit in the medium term while in the long term countries have to re-work and adjust the policies and strategies taking into account the global trends, the national biotechnology landscape and the goals achieved and gaps remaining (if any). Compared to Africa and Latin America, biotechnology in AP is more wide spread and well entrenched. But there is no case for complacency as the progress is uneven and many countries have a long way to go. More importantly the innovation potential of Brazil, and South Africa and some other countries in Africa and LA cannot be under estimated. The possibility of Brazil and South Africa emerging as potential competitors in some sectors cannot be ruled out. Regional clusters can play an important role in development of and sustaining the biotechnology industry, but, as recent research shows, non-local sources of knowledge are also equally important.[34]

In our view, these national plans and strategies should be studied for their effectiveness. Since biotechnology is more than 15 years old in many countries, the time has come to evaluate the experience so far and find out what has worked and what has not. Obviously, there is no magic plan that would deliver results every where. But a comprehensive study of experience so far vis-a-vis the expectations will be of immense use for national governments, international agencies and funders. We suggest that such a study while focusing on biotechnology should also try to address broader and relevant issues.

While the number of firms cannot be the sole indicator of the biotechnology industry, it does give an idea. In many countries industry is in nascent stages while in some there is a well diversified biotechnology industry. As the individual country reports indicate the trajectory of biotechnology development is not uniform. Some countries have made rapid progress in the last decade while some have not been able to do so. For example in India, China, and Korea the industry has not only grown rapidly in terms of numbers and also has become a diversified industry. Table 2.5 provides some ideas about the status of the industry.

2.4 Agriculture Biotechnology

The achievements of agriculture biotechnology in AP are mixed. The productivity in agriculture has increased but gaps remain. More importantly biotechnology, has succeeded in enhancing productivity and yields in some crops like cotton, but in crops like rice, the results are not expected soon. Some of the predictions made in 1980s and the expectations that biotechnology would be the next Green Revolution that would transform the agriculture and enormous gains in productivity are being keenly awaited. There is fast expansion in global R&D share of developing countries, which has expanded from 45 per cent in 1981 to 56 per cent in 2000.[35] According to IAASTD (2009), China and India account for 31 per cent of total agriculture R&D expenditure by the developing countries. Most of this expenditure has focused on agricultural productivity and quantitative gains. The rise in budgetary allocations by China and India is an outcome of growing government participation in the agriculture research related activities. The

Table 2.5: Industry Size/No. of Firms

S.No.	Country	No. of Firms	Description
1	Australia*	527 Dedicated 384	Majority in health biotechnology
2	Bangladesh		Nascent Stage
3	Cambodia		Industry in nascent stage
4	China		Mostly in public sector
5	India	325	Majority in biopharma sector
6	Indonesia		Industry in initial stages
7	Japan*	523	Market size $19.5 billion
8	Korea*	885 Dedicated 325	
9	Laos PDR	None	
10	Malaysia	65	
11	Nepal		Nascent stages
12	New Zealand*	369 Dedicated 135	
13	Pakistan		Industry in nascent stages
14	Philippines	24	
15	Singapore		Well developed
16	Sri Lanka		Industry in nascent stages
17	Thailand	200	
18	Vietnam		No biotechnology industry

Sources: Authors' compilation based on various sources and country chapters and OECD (2012).

commercialization strategies proactively engaged private sector entities atleast for the first generation biotechnology development. As is clear from Table 2.6, total public agriculture research expenditure in China went up from US$ 1049 million to US$ 3150 million in the period 1981-2000 and in case of India from US$ 533 million to US$ 1858 million in the same period. Here the data is adjusted for inflationary changes at the dollar value of year 2000.[36] This had Chinese share in the global total at 14 per cent while India stood at 8 per cent. The share of Asia-Pacific as a whole in the global agriculture R&D increased from 20 per cent to 33 per cent in the period 1981 to 2000. In the same period, share of Latin America and Caribbean declined from 13 per cent to 11 per cent and for Sub-Saharan Africa from 8 per cent to 6 per cent.[37]

Several of the developing countries, in fact, have now embarked on the path of employing the second generation of biotechnologies. The ability to use stem cell research is a case in point. Many of these developing countries were earlier being advised to attempt simpler techniques of plant tissue culture, meristem and organ culture in order to achieve rapid vegetative propagation.[38] The global synergies, appeared to have helped in bridging the so-called gap between North and South over biotechnology. In India itself now there are seven lines of stem cell on which research is on by a private firm. In Singapore, a public research institute has finished the gene sequencing of fugu fish, which has homologies to human genome. In China also Beijing Genome Institute (BGI) has full genomic knowledge about a rice variety.

In agricultural biotechnology Thailand strives to use biotechnology to move up the ladder in value addition and in increasing exports. In Malaysia the continued support for biotechnology is evident from the importance given to it in the Eight Five Year Plan and the increase in budgetary allocations. In Thailand and the Philippines, commercialization in agricultural biotechnology remains as a major challenge. In the Philippines, the less controversial technological choices like biofertilisers and biopesticides have been given due importance. Bangladesh's strategy also addresses similar approach towards agriculture biotechnology. But in many other countries, particularly in LDCs, the linkages are weak or biotechnology is not well integrated in the overall development framework.

What needs to be pointed out is that at least, some governments have realised that biotechnology in their countries should become a global industry and that would be possible only if the necessary infrastructure for research centers and institutes is developed. Although this race to globalise and do world class science research and innovation is welcome, it is possible that in that case the real applications of biotechnology may end up with products and services that cater to global markets or industries in advanced countries than with products that cater to the needs of small and medium farmers or health needs of the poor. Hence it is suggested that an assessment of the policies and programmes can be done to identify how best they can meet the needs of groups like small and medium farmers.

In case of agricultural biotechnology, this is all the more obvious because varieties cannot be developed in one place and simply be planted all over the region. Traits that confer specific benefits have to be incorporated into varieties and hybrids that have some advantages and are more suited to meet the local/national needs. This leads to the question of the capacities and capabilities of National Agricultural Research Systems (NARS) in using biotechnology and their capacity to develop transgenics for crops that are important for a particular country. Recent research raises some questions about the role of public sector in this and the scope for developing new strategies.[39] It is well known that while Green Revolution was led by public sector, gene/genomics revolution would not be so.[40] One of the options then would be to promote more collaboration with international research centers. But the budget for such centers is not increasing and the CGIAR system itself has not been well funded now. The countries can use bilateral assistance to strengthen NARS and use this to support biotechnology research. This will work only if the assistance is on a long-term basis because biotechnology research needs support for many years to establish itself and reach the critical stage. Hence in our view, the time has come to review policies on NARS and study the linkages between NARS and biotechnology in AP region.

Involving users, i.e. farmers, and developing appropriate products for them is important. Agricultural biotechnology can be a tool for empowerment if the needs of the farmers are assessed and technology is applied to solve real world problems. The Cassava Biotechnology Network is a successful example of the new approach in which farmer is not a recipient of charity or is offered something for free. Rather the innovation is developed to overcome some of the problems farmers face in cultivating and using Cassava. Tissue culture techniques were taught to farmers including women and they were encouraged to use their traditional knowledge about the local varieties and choose the best from them for reproduction. The technology was made available and local materials were used. As a result farmers set up units to produce high quality Cassava stakes and these were not unaffordable.[41]

At the outset, some very basic prepositions would have to be raised about the additional inputs being expected from biotechnology, which are other than the traditional techniques already available. Since most of the countries have witnessed Green Revolution, there is already a decent R&D set up and network of extension agencies is working. It is equally important to identify possible areas of research where blending of the two streams of technologies can be achieved. The hybridization techniques and other agricultural practices may well supplement the biotechnology methods.[42] This would not only augment the technical capabilities but would also help in reducing the capital cost which generally goes up with adoption of biotechnology. Thus the biotechnology revolution in agriculture will have to be both an evolution and revolution in AP. It will build upon the Green Revolution even as it strives to overcome some of the problems that have resulted due to Green Revolution and the pressures on resources like land, water on account of increases in population, urbanization, deforestation and industrialization. When the potential impacts of climate change are also taken into account, the challenges ahead become very evident.

2.5 Medical Biotechnology

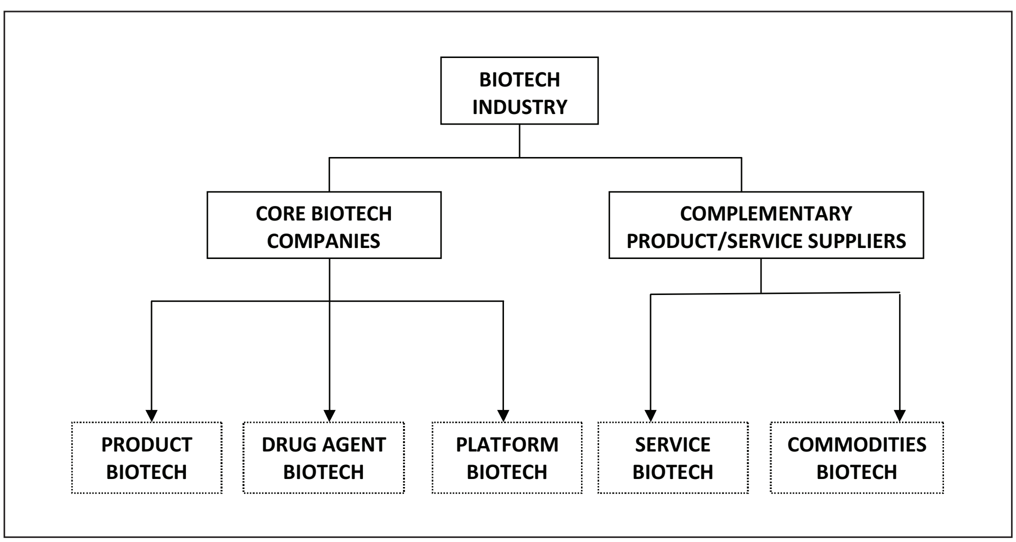
Medical biotechnology is becoming an important application of biotechnology, thanks to developments in life sciences and ICTs. But not all countries in AP are capable of investing in a big way in medical biotechnology although the innovations in this can be applied widely. Korea, India, Japan, Singapore and China have given importance to medical biotechnology. Thailand is another country that is giving importance to this sector but its main focus is on integrating this with medical tourism. Medical biotechnology industry can be broadly classified as two sub-sectors, one dealing with biopharmaceuticals, new drugs and the other diagnostics, bio-devices. Biopharmaceuticals is a growth industry in Asia. With some of the key patents going off the patent protection in the next decade, the competition in the biopharmaceutical market has really intensified.

Medical biotechnology in the post-genomic life sciences involves using knowledge from different disciplines; and hence the medical biotechnology industry needs firms with specialised functions and expertise in particular domains. They are broadly classified into two types – Core biotech companies, and, complementary/ product service suppliers. The taxonomy is as below (Figure 2.4).

As there is a need for different competencies, it is not necessary that single firm should do all the related activities. This gives enormous scope for outsourcing including Contract Research (CR). In fact some countries in AP have a competitive advantage in doing contract research and in conducting clinical trials. Given the knowledge intense nature of medical biotechnology and the need to integrate different domain knowledge to develop new products, the availability of trained human resources is a key factor for development of this sector. Recognising these, countries in AP has invested heavily in training and development and in establishing centers of excellence or specialised research institutes. Japan, for example, has many Centers of Excellence (COE) on specific technologies. Singapore has established BioPolis to act as a global hub for bio-medical technology and life sciences research. India and China have strengthened their R&D system besides setting up many institutes for biotechnology and genomics research. Several strategies are adopted to woo the talented persons as Singapore announced fellowships while New Zealand relaxed immigration norms for professionals in biotechnology.

Although medical technology is relatively a hi-technology industry, it offers immense scope for development of diagnostics, vaccines and other health products including bio-generics that would meet the needs of the people in AP countries. Unlike agricultural biotechnology, in this sector, the private firms are the major player and private sector investment in R&D is higher than that of public sector. The synergy between public and private sector in this is important. The public sector can focus on basic research while applied research and commercialization can be done by private sector. In some applications like

Figure 2.4: Medical Biotechnology Classification



Source: See the earlier report (authors' design).

stem cell therapy some countries in AP are competing well with the USA and Europe. For example, India has emerged an important country in the global stem cell landscape.[43] Korea is progressing despite some set backs on account of fudged results. In medical technology there is enormous scope for public-private partnerships to develop products, offer services and commercialise technologies. India can combine medical tourism with development of biomedical technology.

For many firms in AP region in biopharmaceuticals the advantage lies is in lower cost of production than in innovation. Although AP region can boast of many pharmaceutical firms that can produce new drugs and perform R&D for drug discovery, in terms of revenue and R&D expenditure the USA and Europe based firms are much ahead. Similarly, in medical biotechnology innovation using genomics the USA is the front runner. Countries like Japan and Singapore are also trying to catch up with the USA in this.

A factor that could affect the diffusion of innovations in this sector is IPRs. Stronger IPRs can become a barrier in technology development and transfer. So it is essential that public policies to promote technology in this sector should strive to strike a balance between the incentives for innovation and accessibility and affordability of the innovations. As the Korean example of vaccines indicates, the need for a pragmatic approach is obvious. Public policies that strive for the golden mean in promoting innovation, ensuring access and affordability, and incentives for industry to invest are essential. It is up to each country to craft a specific innovation policy in this sector. A country can identify a sector like biopharmaceuticals or CRO and craft an innovation policy for that sector. CROs can be encouraged to move up in the ladder of value addition and work with public sector universities.

In our view, countries in AP need to do a SWOT analysis and identify areas where they can compete well and explore niche areas where they have distinct advantages. The scope for setting up agencies to promote regional innovation activities and partners hips can be explored.

Table 2.6: Total Public Agricultural Research Expenditures by Region, 1981, 1991 and 2000

	Agricultural R&D Spending			Shares in Global Total		
	1981	1991	2000	1981	1991	2000
	(million 2000 international dollars)			(per cent)		
Asia & Pacific	3047	4847	7523	20	24.2	32.7
China	1049	1733	3150	6.9	8.7	13.7
India	533	1004	1858	3.5	5.0	8.1
Latin America & Caribbean	1897	2107	2454	12.5	10.5	10.7
Brazil	690	1000	1020	4.5	5.0	4.4
Sub-Saharan Africa	1196	1365	1461	7.9	6.8	6.3
West Asia & North Africa	764	1139	1382	5.0	5.7	6.0
Developing countries, subtotal	6094	9459	12819	45.4	47.3	55.7
Japan	1832	2182	1658	12.1	10.9	7.2
USA	2533	3216	3828	16.7	16.1	16.6
Subtotal, higher-income countries	8293	10534	10191	54.6	52.7	44.3
Total	15197	19992	23010	100	100	100

Source: IAASTD (2009).

2.6 Regulation of Biotechnology

Biotechnology regulation is a contentious issue. There are different models of risk assessment and regulations. There is no single model that can be considered as universally applicable and valid for all technologies for all time to come. Counties which swear by science and technology do not follow same norms of risk assessment or adopt uniform regulatory regimes.[44] Although the differences between the USA and Europe in agricultural biotechnology are well known, what is important is that countries in Europe do not apply the same norms in health sector biotechnology or in agricultural biotechnology. This is not an unexpected phenomenon, because countries have evolved different styles of regulation over the years in consonance with their administrative and political frameworks. Countries in AP thus need not simply ape the USA or Europe and should strive to develop regulatory regimes that are suited to their needs. But in a world of globalised science and technology, the regulatory convergence is not likely to occur even when the same sciences and technologies are applied. In other words, while science and technology may be universal, regulatory regimes will not be universal, nor will be based on the same principles of risk assessment and regulation. So even when countries have ratified Cartagena Protocol it is not necessary that all those countries will have identical regulatory regime. There are three broad models of regulation – 'liberal science-based regulation', 'precautionary science-based regulation', and 'social values-based regulation'. States shape policies on agricultural biotechnology regulation by incorporating parts of these models in many ways.[45]

In the decades to come, developing an appropriate regulatory framework will be a major challenge for countries in AP because of the nexus between trade and bio-safety on one hand, and, the issues raised by technological convergence and new technologies like nanotechnology on the other hand. For example, risk assessment of nano-particles is a major issue and as of now there is no universally applied methodology in this. When nanotechnology is being applied in medicine new issues will arise like regulating nanobiotechnology medical devices. Similarly, in agricultural biotechnology while old issues like labeling of GM products will continue new issues like regulation of health-foods, neutracails, and plant derived vaccines will have to anticipated. By and large, there is no resistance to agricultural biotechnology in AP as in many countries in Europe. But this does not mean that there is 100 per cent acceptance for GM food. The controversy over export of rice with traces of GM from the USA to Japan and the subsequent rejection is a pointer. In fact if countries begin to apply either labelling or criteria like 1 per cent or 2 per cent GM is allowed, the implications of these for trade are important. Hence it is essential that countries are prepared well to face the regulatory and trade challenges. The US- EC tussle over GM food is likely to continue as both parties are committed to their positions. This dispute shows that when two economic superpowers take different positions in such issues it also divides many other countries in to either of the groups. As both the USA and the EC are large export markets as well as major exporters of food, developing countries need to tread carefully in this. The dilemmas and possible options before developing countries are highlighted in Box 2.1.

Another issue is that of complying with Carategna Protocol and its implications for trade in GM foods. A country that opts for a very strict compliance coupled with labelling norms may find that it is too expensive to implement if the volume and value of trade and production of GM foods is too little to warrant such a strict compliance and norms. In such cases

Box 2.1 : Biosafety and Trade Conflicts: The US-EU Dispute and Its Relevance for Developing Countries

The transatlantic divide between the EU-USA on GMO food issue shows so signs of resolution. On the contrary, it looks like both parties will continue to live with the stalemate without changing their positions. In Europe, there is no significant development in support of GM food and the resistance continues unabated. While WTO Dispute Settlement Mechanism is the right forum to resolve trade disputes, the GM food issue has become more than a trade issue. The stakes are too high. There are parallels to another dispute between the EU-USA, the dispute over hormone treated beef. In both cases both parties assert that their regulations are based on science and are their respective policies perfectly justifiable in terms of adherence to science based decisions and protecting human health.

What are the implications of this dispute for countries in AP and how they should use this dispute to understand the linkage between regulatory regimes and global trade norms under WTO? The USA and the EU are export markets for agricultural products and both are engaged in capacity building activities in many countries. By and large, they try to emphasis on the merits of the respective regulatory regimes. The absence of a coherent and global trade rules in this gives leeway to countries to develop regulatory regimes modeled after, but not necessarily identical to that of, the USA or the EU or develop their regulatory regimes based on best practices followed elsewhere. For example, in applying precautionary principle, there is much to learn from both and adapt that suit national needs and contexts. Similarly, in deciding over product vs. process distinction in regulation countries can identify which model is more appropriate to them and what are the costs and benefits to them.

The reality is that the dispute between the USA-EU on GM foods is not likely to end soon. At the core of the dispute are the differences in regulatory regimes and perceptions about GM food. Although this is prima facie a trade dispute, it is also dispute about limits of regulatory harmonization at a global level. Based on a detailed analysis on the genesis of this dispute and the implications of the same, two scholars draw five lessons from it. Which includes:

1) "The transatlantic GMO dispute does not represent a deep civilizational divide, but it is real, and deeply entrenched."
2) "Deliberative decision-making is a hothouse flower, which has seldom bloomed in the intense politicisation of GMO regulation. Our expectations for it should be tempered accordingly".
3) "Multilateral regimes can help states cooperate, but they are hampered by the dual challenges of distributive conflicts and regime complexes."

After analyzing how countries have responded to regulatory commitments and concerns, they argue that a monolithic developing country position is not likely to emerge and LDCs adopt different positions on regulation and the scope of global harmonization of regulation in GM foods and crops is limited. In other words, the LDCs should use creatively the policy space available to them without imitating the USA or the EU and craft policies that are suited to their national contexts and needs.

Translating this into practice is not likely to be easy, particularly when countries face dilemmas over GM foods and crops. Elsewhere in this report we address the issue of organics, standards and biotechnology policy where a similar dilemma is in the offing.

countries should decide upon the level of compliance with Protocol and to what extent they want to regulate GM foods. For example, a provision for labelling if the GM food is more than 1per cent of the quantity is more expensive for producers and processors than a provision that is more liberal. So cost-benefit analysis of regulation and its implications for trade should be taken into account in developing regulatory regime. One approach is to opt for enforcing regulating regime for some products first and then based upon the experience extend it or fine tune it for other products. Another option is to strictly regulate GM food for human consumption and not so restrict regulation for use of GM food for purposes other than human consumption, provided the processed food is not used for human consumption directly/indirectly. For example, use of GM soya for industrial purposes may be de-regulated while use of GM soya to derive products like Tofu may be strictly regulated. It is suggested that in capacity building programmes in biosafety these factors are taken into account and countries should not opt for stronger versions of precautionary principle for regulating GM foods and crops, if they find that such options entails more costs and little benefits.

As both the USA and the EU are promoting Free Trade Agreements with many countries/regional trading blocs, countries in AP, particularly LDCs should know how best to deal with this issue. If a country that is largely dependent on the EU market for its agricultural markets decides to adopt GM agriculture rapidly, that may affect the export potential. On the other hand, if a country has no clear cut policy on GM foods and import of GM and non-GM food from other countries, it has to be careful when it exports food products that have both GM food and non-GM food as even adventitious presence of GM food beyond the acceptable level can create problems in some export markets.

Table 2.7: National Initiatives in Asia-Pacific on Bio-safety

Country	Details
Australia	Gene Technology Act 2000, Labeling for GM food
Bangladesh	No stand alone policy, Framework developed under UNEP-GEF project
Cambodia	National law and regulation in progress
China	National regulation in place
India	No GM labeling, regulatory regime is in place and under revision
Indonesia	Regulation in place
Japan	Regime in place for import and export of LMOs
Korea	Bioethics and Biosafety Act 2004, regulation of LMOs
Laos PDR	Draft law yet to be approved
Malaysia	Biosafety Act of 2007
Nepal	National Biosafety Framework 2007
New Zealand	Biosafety regulations in place
Pakistan	National Biosafety Guidelines 2005
Philippines	No holistic framework
Singapore	Regulatory regime for research on GMOs and biosafety
Sri Lanka	Biosafety framework evolved , GM labeling regulation 2007, national policy in progress
Thailand	No comprehensive Act, only rules are in place
Vietnam	Initial stages of development

Countries in AP are in different stages when it comes to biosafety and regulation. Table 2.7 indicates, some have well developed regulatory system while some are in the initial stages of developing appropriate regulatory regimes.

Organic agriculture is becoming more popular and organic food is becoming more a mainstream food than a food for a niche. Although terms like organic agriculture, agrocecological farming, permaculture, natural farming, Low External Input Sustainable Agriculture, are often used to denote agricultural practices that do not involve use of synthetic chemicals including chemical fertilisers, pesticides from a trade and regulatory perspectives, issues like labelling, standards matter most than processes of production. Thus while organic agriculture covers a broad rubric of agricultural production methods for the purposes of standards what matters is whether the output meets the standards set. Similarly, labelling a food as organic is linked with both production methods and permissible levels and standards set. While international regulation and standardization of organic food is evolving using organic agriculture provides both opportunities and threats to countries in AP which are promoting biotech, particulatly agri-biotech in food crops.

Regarding the relationship between organic agriculture and agricultural biotechnology there are three different perspectives that inform the debate. The first perspective, the most well known, one is that they are antagonistic to each other and are incompatible. Most of the civil society groups and NGOs opposed to agri-biotech take this position this is well known. According to this perspective, while agri-biotech is a threat to organic/natural agriculture agri-biotech particularly GM food is not a sustainable solution in agriculture. Hence these groups and NGOs call for stricter regulation of agri-biotech, enforcement of liability for polluting fields in which non-GM crops are planted and labeling of GM foods.

The second position is that both have a role to play and need not be considered as antagonistic to each other. Instead we should use both of them appropriately and learn from both than to pit one against another. For example, according to David Baulcombe who suggests a third way instead of choosing either organic farming or GM crops,

"However there is a third way that takes the best of both approaches. It would use GM crops, for example, that are consistent with no-till agriculture, do not require toxic insecticides, resist late blight and viruses or that that have enhanced nutritional content. From a trait perspective I find it difficult to see how there can be an objection to these developments."[46]

This position is reasonable but it is not heard often and is not advocated by most of the supporters of GM crops who see agri-biotechnology only as a viable technology.

The third position, informed by field work, argues that often what matters is not what people profess to believe but what they do and hence only by studying how people who are supporting organic agriculture by practicing, respond to biotechnology we will come to know the preferences and choices before farmers . This position does not see such farmers using Bt crops/GM crops as an aberration but as farmers making informed choice. For example, the field work by Devparna Roy in Gujarat shows a section of the agriculturalists who consider themselves as organic agriculturalists are not averse to using Bt cotton in some circumstances if they consider that as a sustainable solution.[47]

However, for countries in AP the issue is more than a rhetorical debate, it is about making right and informed choices as indicated in Box 2.2.

Box: 2.2 Organic Agriculture, Standards and Biotechnology Regulation

The global organic market is growing and in the organic market there are different players with different capacities to exert influence. Supportive policies and the premium price for organic products is likely to encourage more farmers to switch over to organic farming, particularly for market. The increasing importance of standards in global organic production, distribution and consumption provides an opportunity for countries although it is also a threat as complying with that standards can increase the cost of production and fewer acceptances for organic produce that does not meet these standards. Under the norms in the USA, foods labelled " organic " should not contain bio - engineered ingredients or be irradiated to kill bacteria and lengthen shelf life. Similarly meats labeled and sold as organic cannot be produced from animals that have received antibiotics.[48]

But what is proving to be more relevant and challenging for countries in AP is the emergence of MNCs as major buyers of organics and their attempts to bring in standards for organic products. The standards are no longer informal or set by farmers associations but are outcomes of standard setting processes at global level. According to a one study, as the export of organic food from three South-East Asian countries (Thailand, Vietnam and Indonesia) grows, the state is increasingly getting involved in standard setting and in this exercise the structural power of the corporate agri-food industry is very much evident.[49]

The challenge before governments that want to encourage such exports is how to reconcile this with the policies for promotion of agricultural biotechnology. Opting for one or another is not possible. Organic agriculture is well suited as an option in crops where there are no transgenics and where the scope for contamination from GM crops does not exist. For many small and marginal farmers organic agriculture is also a cost effective solution if they can get a premium price for their produce. Implementing standards may be expensive but becomes inevitable when it comes to catering to global markets. Here governments and other stakeholders should work together to ensure that standards are not unilaterally set or are unduly difficult to implement.

If there is a global demand for organic rice and if the government is keen on promoting transgenic rice, reconciling between both is necessary and possible. For this the government can enforce norms on cultivating organic rice in some areas while in some areas transgenics can be encouraged. Another option would be to designate some zones as GM free zones where production, i.e. cultivation and processing of organic food, is encouraged. Some areas can be classified as mixed zones or zones where both GM and non GM crops can be grown. When it comes to conducting field trials, also such classifications can be made and it could be ensured that for varieties/crops that are grown organically in areas where conservation of germplasm is encouraged, there are no field trials or experiments. One of the recommendations of the Taskforce headed by Dr. Swaminathan on Biosafety Regulation in India was that the transgenic research should not be done on crops which earn substantial foreign exchange, e.g. basmati rice, Darjeeling Tea.

2.7 Capacity Building and Regional Cooperation in Biotechnology

Most of the multilateral and regional institutions have played an important role in developing a pan-Asia-Pacific approach for promoting agriculture innovation and for strengthening R&D endeavors. Regional institutions like South Asian Association for Regional Cooperation (SAARC), Association of South-East Nations (ASEAN) and Asia-Pacific Economic Cooperation (APEC) have launched several R&D collaboration programmes along with manpower training and skill upgradation initiatives.[50]

There are regional institutions like IRRI, ICRISAT and ICGEB which have also played an important role. Rockefeller Foundation has been one of the major funding agencies for rice biotechnology research. It had supported (till 2000) research in both basic science and applied research on rice including research on rice genome mapping.[51] It has been one of the supporters of the Golden Rice research project right from the beginning.

In 2008 it reaffirmed its commitment to the project by indicating that it would fund IRRI for working on regulatory measures relating Golden Rice in Bangladesh, India, Indonesia, and the Philippines. The continued support is part of the Rockefeller Foundations overall support for biotechnology which extends to a similar support to initiatives in Africa. ICRISAT is one of the CGIAR centers and is located at India. Its focus is on crops for semi-arid regions and developing appropriate varieties and technologies. In biotechnology ICRISAT is working closely with the Government of India and other national governments. It has established The Centre of Excellence in Genomics to provide high-throughput, low-cost genotyping services for research and breeding and this will enable National Agricultural Research Systems (NARS) to do genotyping. Another initiative that has been started with the support of the Deprtment of Biotechnology (DBT) , India is Platform for Translational Research on Transgenic Crops (PTTC) for evaluating new options in agricultural biotechnology.[52]

Another CGIAR institution, International Rice Research Institute (IRRI) has been involved in rice research for almost half a century. Its approach includes biotechnology and it supports both basic and applied research in this. Its involvement with biotechnology started in 1978 with tissue culture. IRRI's biotechnology programme is also engaged in human resources development and has imparted training to plant breeders and other scientists from developing countries.

ICGEB is an initiative sponsored by UNIDO for application of biotechnology in developing countries to solve their problems. Its head quarters are in Trieste and the Centre in India (New Delhi) is the centre in Asia. ICGEB works on biomedicine, crop improvement, environmental protection/remediation, and biopharmaceuticals and biopesticides production. It is involved in human resources development through PhD and Post-Doctoral fellowships. It is working on enzyme to develop a new and improved treatment for Malaria.

UNESCO and the Ministry of Agriculture, Government of Bhutan, organised a training workshop in molecular propagation of medicinal plants in Bhutan. Laboratory experiments covering basic biotech techniques in micro-propagation were also undertaken during the training course. UNESCO supported the government of Maldives in their efforts of taking protective measures against the threats to the country from global ecological degradation, and pursuing environmentally-friendly lifestyles with the aid of modern technology as has been faithfully outlined in the Government's 7th National Development Plan. UNESCO organised training course on conventional and molecular fish disease diagnosis. Researchers from Marine Research Centre, Maldives spend 17 days at the UNESCO MIRCEN (Microbial Research Centre) at the Karnataka Veterinary, Animal and Fisheries Sciences University College of Fisheries, Mangalore, India receiving training on use of equipment for health management of captive aquatic animals, and use of biotechnology techniques in Fish disease diagnosis. UNESCO and the National Science Foundation, Sri Lanka organized symposium on Science Journalism. UNESCO supported the fourth Conference on Biotechnology and Development in Nepal, in collaboration with RIS and Nepal Government.

There are also regional initiatives in improving infrastructure for betterment of agricultural production. The Greater Mekong Subregion (GMS), initiated by the Asian Development Bank, is an innovation in international cooperation especially in infrastructure development and benefit sharing. The unique features of the GMS are its geography (with each country sharing atleast three border areas), economics (bordered by China and Thailand) and sponsorship (ADB from national allocations).[53]

In Asia, the regional cooperation in science and technology has also been catalysed by countries like Japan, which are keenly supporting active networks within the region. The Official Development Assistance (ODA) being extended by Japan is aptly analyzed.[54] The findings have shown that till now the focus of Japanese assistance is on ethical issues within biotechnology. However, it is being argued that Japan should consider redesigning the ODA as an instrument for meeting the larger economic needs in the AP region with the help of biotechnology. The response to these global developments from the AP countries is at different levels. Largely it has remained confined to joint technology development programmes, in case of ASEAN, and issuing statements of intentions in case of SAARC. These groupings have yet to reach at the stage of commercialization of frontier technologies. One basic difference, which stands very clear, among these groupings is the very raison d'être for cooperation. Where the EC wants to retain its comparative advantage in the higher band of technologies, groupings like SAARC are looking for complementarities to overcome the high cost R&D for ensuring success of policy programmes such as food security. The urge to establish SAARC gene bank probably emphasises that point only. The example about island communities and UNESCO's efforts behind MIRCEN network signifies the same spirit. The central issue, however, is that after creation of infrastructure services and policy framework for promotion of biotechnology. AP countries have to focus on strengthening the implementation of biosafety guidelines affiliated with the commercialization of biotechnology products. The challenge is to ensure the working of the regulatory regime not only at the level of research laboratories but also at the operational levels such as trade, quarantine and embarking points. This again requires specialized training of personnel who are manning these entry points. In case of AP countries, regional cooperation at the level of trade groupings like SAARC and ASEAN may play a vital role in evolving and implementing the biosafety guidelines. Since geographical conditions and biological vegetation are almost same, regional cooperation may facilitate emergence of harmonised approach towards biotechnology.

The importance of cooperation for technology development is well acknowledged in the literature. The Green Revolution would not have been possible had there been no cooperation. In case of biotechnology it is clear from our surveys that there had been many cooperative initiatives in the countries in the AP region. Bilateral and multi-lateral efforts have played an important role in development of technology in this region.

But a closer look reveals that though they are necessary, they themselves are not sufficient enough to spur a biotechnological revolution or sustain it. They can succeed well if they are integrated into a broader policy framework or national biotechnology strategy. Otherwise they remain confined to one institution or one technology and the linkage between them and the overall policy framework is missing. For example, Pakistan and Indonesia had benefited from bilateral and multilateral initiatives in cooperation but these initiatives have had very limited impact on the overall development of biotechnology in these countries. The absence of a strategic framework, lack of funding for biotechnology, and the limited scope of most of the initiatives are some of the factors that constrain the country from deriving the best from such initiatives. In case of Sri Lanka, FAO had played an important role in formulating the National Strategy and in capacity building. Similarly, UNEP has played an important role in bio-safety issues. Rockefeller Foundation, US AID, ADB are some of the other institutions that have helped growth of biotechnology in the region. But it is up to the national governments to come out with a policy and regulatory framework and make the best use of these initiatives.

Strangely the cooperation between or among the countries in this field are limited and perhaps there are more multilateral initiatives than bi-lateral initiatives. As countries are at different levels of economic development and application of biotechnology, it can be argued that the scope for such a co-operation is limited. It is also true that countries often lack the financial and other resources to engage in such a co-operation in a big way. But the question is, if there can be regional trade agreements and trade blocks why there cannot be a regional co-operative effort in biotechnology too. In case of South East Asian countries like Vietnam, Laos, and Cambodia many lessons can be learned from the experiences of Thailand and South Korea. Similarly, Indonesia can benefit immensely from the technological leadership and dynamism of the biotechnology sector in those two countries if there is a long-term coperation programme with well though out plans and programmes. In case of SAARC there is little that has been done in this. The India's stride in biotechnology offers many a lesson to Bangladesh, Sri Lanka and Nepal. Yet under SAARC there are no significant initiatives in this.

Regional co-operation does not necessarily mean that it is one-way traffic in the sense, that one country helps the other(s) and there are only donor(s) and recipient(s). The scope for regional co-operation in joint research, development of technology and transfer of technology should be envisaged and some common themes for such a research can be identified. For example, in SAARC rice biotechnology is one theme that is of importance to India, Pakistan, Sri Lanka and Bangladesh. Biotechnology for plantation crops is a theme that can be jointly explored by India and Sri Lanka. Besides these specific crop/theme focused regional co-operation, there should be co-operative efforts at the Pan AP level in sectors like health, industrial application of biotechnology, second/third generation bio-fuels using biotechnology.

2.8 Human Resources

The importance of human resources in biotechnology is too obvious to be dwelt at length. Development and utilization of human resources in biotechnology has been highly uneven in Asia. A country like Singapore is trying to attract globally best talent in biotechnology by offering incentives but for many counties decline in national agricultural systems in terms of human resources, brain drain and lack of human resources to undertake biotechnology R&D is a harsh reality. These factors pose a major challenge in translating the biotechnology policies in to strategies and in achieving the targets set under the national plans. But as biotechnology is a field that needs skills and expertise in a range of disciplines it is essential that human resource development plans should cover all the relevant disciplines instead of a narrow focus on applied biotechnology or industrial biotechnology. While China, South Korea and India have invested heavily in human resources capacity building in biotechnology such an option is not available to many counties which lack resources to invest heavily over a decade or so in biotechnology. In fact if a small country tries to do anything and everything in biotechnology by spreading its resources in capacity building in all areas in biotechnology it may end up in spreading resources too thin to make any significant impact in any area. Even if there are sufficient financial resources, human resources could turn out to be a major constraint.

Even at the downstream end of advanced biotechnologies (e.g. using validated molecular markers, diagnostics, tissue culture and micropropagation), biotechnology research and development (R&D) comes at additional cost. Working further upstream (e.g. in structural and functional genomics, basic immunology and genetic modification) increases both start-up and maintenance costs considerably.[55]

Instead a better option would be to dovetail the human resource development strategy with S&T policy and biotechnology policy and assess whether the current National Agriculture Research System is adequate for the envisaged tasks. Similarly, countries can give more importance to development of human resources in applied R&D, in the beginning stage, and dove tail with appropriate technologies that are relevant.

In our view, the challenges in human resources development cannot be addressed sufficiently by many countries on account of various reasons ranging from decline in NARS to budgetary constraints. Hence we urge that agencies of the UN like UNESCO, donor agencies, philanthropic foundations and developed countries should give more importance and support to capacity building in human resources in biotechnology. In this regard the suggestion from a veteran who has worked with NARS and other foundations is important although it is made largely in the context of Africa.[56] Local capacity development in NARS is crucial and in the absence of such a capacity no amount of resources transferred from outside will be effective in enhancing the productivity. Thus human resources lies at the heart of the problem.

The uneven development of human resources in biotechnology is a case for concern. As biotechnology is knowledge intensive industry the availability of trained and qualified personnel is essential for growth and development of industry and capability to use biotechnology. Development of human resources in basic science and applied research is a necessary condition for sustaining biotechnology development in any country. Table 2.8 provides an overview of the situation in different countries and further analysis is provided in the subsequent chapters.

The biotechnology revolution is expanding as well as deepening. Technological convergence is giving a new impetus to this. Countries in AP are in different stages of development in harnessing biotechnology. There are many positive developments and some of the trends are disquieting. In our view, the time to assess the direction and trend of the biotechnology revolution in AP has come and relevant measures have to be taken. One important lesson is that in a globalised world where science and technology is also globalised, countries should be aware of both the threats posed by and the opportunities provided by this globalization. By and large, states in AP have been positive supporters of biotechnology and this is likely to continue in future also.

2.9 Regulation, Intellectual Property and Trade Issues

While many developing countries have taken steps to frame regulatory rules for biotechnology, partially as a part of their national policy and partially as parties to the Protocol on Biosafety, regulation of biotechnology remains as a contentious issue. Countries often face the Hobson's choice in this. They cannot setoff economic interest against potential environmental and health risks or vice-versa. Globally, risk assessment, application of the relevant principles in risk assessment (precautionary principle, substantial equivalence) and issues relating to labelling have been controversial issues globally. The dispute before WTO on import of GM food into Europe is an indication of the trans-Atlantic divide in these issues.[57]

But for developing countries for whom both Europe and the USA are important trading partners and export-import markets for food products the divide has other implications. They cannot afford to support one side and oppose another in this, nor can act as mediators in this. In our view, developing countries in Asia should take a pragmatic view on this and develop appropriate regulatory regimes taking into account their needs, costs and benefits of enforcement and regulation and their commitments under WTO Agreements (SPS and TBT).[58] Similarly, on labelling they should take a realistic assessment of the needs of consumers, trade concerns and formulate rules accordingly rather than to imitate Europe or the USA. These are not easy tasks and these are issues that cannot be solved through a one-go one-shot approach. Thus, regulatory regimes should be capable of evolving with in-built flexibilities and should focus most on where regulation is needed most in terms of environmental and human health impacts. The regulatory policy thus should move towards governance from regulation by command and control.

We know that this is a challenge but that cannot be avoided as the global scenarios for trade in GM products are full of uncertainties while countries have the option to go for standards that are higher than what the CODEX prescribes. Implementation of REACH by Europe is an example of harmonization upwards. In case of biotechnology, such an upward harmonisation results in higher standards in traceability, levels of acceptable GM in food where GM and non-GM are found and liability for GM contamination. Although Europe is moving forward in these, as Europe is a significant market for Asian countries in food, fiber and processed sea-food these cannot ignored by Asian countries. Countries, which want to promote agricultural biotechnology and at the same time also want to exploit the booming market for organic products face many a dilemma.[59]

Countries in Asia would need assistance in capacity building in regulatory regimes and in matters like Standard Setting, meeting the needs of SPS/TBT Agreements. Studies have shown that SPS/TBT Agreements could be used as indirect trade barriers. UNEP and FAO have helped developing countries in designing regulatory regimes in terms of risk assessments, framing rules and enacting laws. But today the complexity in regulation goes beyond matters of science and standards as trade issues are getting entangled with regulation. Hence developing countries will need assistance from UN agencies like UNCTAD in crafting a coherent regulatory regime that when combined with national standards and rules can meet the requirements under SPS/TBT and can be used as an effective bulwark against protectionist measures disguised in terms of standards or environmental-health safety requirements.

Different countries are in different stages of using biotechnology, developing regulatory framework and National Biosafety Frameworks. A study on the biotechnology regulatory capacity in Southeast Asia points out that each country has unique features and, therefore, greater co-ordination among various institutions in the countries is needed. It also points out that policies on use and regulation of GM crops is not uniform and biosafety regulations have not been given the importance they deserve in some cases.[60]

Issues become more complex when countries in an economic/trade group adopt different principles to regulate risk in biotechnology and are in different stages in biotechnology utilisation, biosafety capacity and have different capacities to regulate. For example, within APEC countries trade in GM products in agriculture is significant yet regulatory system is not fully geared to meet the challenges posed by agricultural biotechnology and harmonisation seems to be years away.[61]

The differences in regulation with APEC can be illustrated by regulation of stacked events. Right now there is no consensus on regulating such stacked events. Within the APEC region Australia, the USA, Canada and New Zealand don't require submission of additional data if the individual traits are already approved and if the combination is not to result in concerns about safety. However,Japan treats them as individual or new events and thus separate approvals are needed. While the Philippines and Korea have devised regulation that eschews both the above approaches, Malaysia is yet to develop a policy on this.[62]

In this context, the social audit of Water Efficient Maize for Africa (WEMA) project, which is a public-private partnership (PPP) and is working to develop drought-tolerant, royalty-free African maize varieties for small-scale farmers in sub-Saharan Africa underscored the need to anticipate the concerns of stakeholders on trait stacking in advance so that their adoption is facilitated and trust of the community of users is gained.[63]

IP issues have implications for development and diffusion of biotechnology. While interpreting Article 27.3(b) has resulted in diverse solutions,

Table 2.8: Human Resources in Biotechnology Sector

Country	Details
Australia	8820 in industry & academic institutions
Bangladesh	Limited
Cambodia	No industry – very few in academic institutions
China	Well developed in both basic & applied research
India	61 universities offer PG/PH.D courses
Indonesia	5 public sector organizations, 3 private sector
Japan	Well developed – strong base in basic and applied
Korea	approx.20000 persons in industry, strong academic research
Laos PDR	Limited human resources`
Malaysia	Fast growing industry and emphasis on education & research
Nepal	Limited human resources
New Zealand	Demand more than supply, relaxed norms for foreigners
Pakistan	29 centers/departments, industry nascent stage
Philippines	<1000 in biotech R&D firms,
Singapore	about 12000 employees, strong research base
Sri Lanka	<300 researchers mostly in govt. sector
Thailand	plans to develop human resources in a big way
Vietnam	Limited human resources

Source: Authors' compilation based on various sources including OECD (2012).

including, the sui generis system in India, issues like Freedom to Operate, scope and criteria for patentability of micro-organisms, patenting of methods of treatment and diagnostic tests cannot be ignored. Countries should use the flexibilities under TRIPS to the maximum and should be careful in grant of very broad patents on genes and gene sequences. The patent law and policy should strike a balance between the need for incentives and the need for access to technologies and public goods. In this regard, we suggest that Asian countries which have worked together in WIPO, WTO and CBD should come together and formulate IP policies that are coherent and that are compatible with the positions they have taken in WTO and CBD. For example, countries can formulate policies that use competition law and provisions in TRIPS to minimise the undesirable effects of monopoly over key technologies. Use of competition law and compulsory licensing can result in availability of GM seeds at affordable prices.

IP rights create incentives for innovation but at the same in the hands of monopolist and cartels they can be used to charge exorbitant prices for inputs like seeds. Strong public sector with focus on developing appropriate varieties and farmer oriented seed distribution system can play an important role in ensuring that competition in the market helps farmers and prevents seed companies from making huge profits on account of IPRs.

If agricultural inputs are considered as toll goods then it is important that policy makers are sensitive to IP issues and take steps for remedying negative impacts. Although the options before policy makers in terms of compulsory licensing are limited by TRIPS Agreement, they can still use competition law and policy. But when the need is to promote innovation and ensure access, policymakers have to think in terms of solutions that meet multiple objectives so that the overall outcome of the policy interventions is positive. In case of agricultural biotechnology, as indicated elsewhere in this report the policymakers have to think about non-GM options. They have to consider options like open source biotechnology, open innovation oriented biotechnology research. On the other hand there are options like levy funded research, public-private partnerships and government funding for creating a non-profit organisation to produce the toll good.

In a recent article Richard Gray examines some of the initiatives in Canada, Australia and France and points out these initiatives can play an important role in creating incentives for innovation and meet the needs of end users effectively by giving them the voice in deciding on the needed innovations The levy based funding is a model that can be tested in developing countries, particularly in countries where the market size is not attractive enough for private sector to develop new varieties or where on account of lack of patent rights on plant varieties and seeds private sector is reluctant to release new varieties as Plant Breeders' Rights with many exemptions will result in lesser royalties.

The Saskatchewan Pulse Development is funded by the mandatory 1 per centcheck-off of value of gross sales of all pulse crops in that province of Canada. The revenue from this is used to fund R&D in new varieties, extension services and variety release programmes. SPG has funded Crop Development Centre Pulse Breeding Programme at University of Saskatchewan and varieties developed there are technically owned by CDC but SPG receives exclusive rights to distribute all new pulse varieties developed by CDC. SPG licenses new varieties to private sector in return for royalties. But it ensures that fair pricing of such varieties is made possible. SPG through its control over germplasm and varieties it has funded is able to leverage this for the benefit of pulse growers and facilitates development and release of new varieties. Similarly, in Australia Grains Research and Development Corporations collect levy of 1 per cent of farm sale in 25 field crops. The levy collected is used to fund variety development programmes. These Corporations and public share holders as co-owners of firms engaged in variety development and distribution provides scope for knowledge sharing and for dealing with issues in over-pricing.

These models combine public interest with private sectors capacity to develop new varieties and distribute even when they engage public sector in research. In developing countries the state can make matching grants to such institution for the levy collected and allow them to decide on investing the levy. Since these institutions have representatives from growers who are also users of varieties, they can address better the needs of the growers in varietals development and extension.[64]

In the recent years the role of Public-Private Partnerships in agriculture has increased and CGIAR system is no exception to this.[65] It has been suggested that push and pull mechanisms can be used to attract and stimulate private sector R&D and in general in agricultural innovation so that market forces are harnessed or supplement the public sector R&D.[66] While such ideas can be examined in the context of biotechnology issues like IPR, Freedom to Operate have to be resolved. While push and pull mechanisms may be necessary they may not be sufficient to attract investment in every case. On the other hand, the relevance of push and pull mechanisms in health policy indicates that while they are useful, often it is difficult to decide ex-ante which one is better or how effective they will be. Hence there is a case for taking a cautiously optimistic perspective on them. On the other hand, the mere availability of push and pull mechanisms has not resolved issues in finding drugs for tropical and neglected diseases and hence the call for global R&D Treaty has been made by developing countries. The important lesson here is while these push and pull mechanisms are necessary their utility varies in different contexts and often these mechanisms need support from the state in different forms. Globally during the past two decades public sector R&D has not increased significantly while private sector R&D has increased, particularly in agricultural biotechnology.[67] Thus today private sector's contribution to agricultural biotechnology is too important to be ignored. The challenge lies in creating a synergy between public sector R&D and private sector R&D and mechanisms like push and pull and PPPs can play an important role in this.

Of late, there has been a controversy over patenting of 'climate ready' genes as ETC Group in its reports alleged that multinationals are patenting genes and processes that are important to develop varieties that are adopted to climate change.[68] While it has been pointed out that such claims are exaggerated, patenting of biological processes, plant breeding methods, which can restrict/block access to research tools, genetic materials, etc., have impacts for R&D and development of varieties.[69] For plant breeders assessing the Freedom To Operate (FTO) is important as broad patents do limit the options available to plant breeders in developing varieties.[70] Irrespective of the controversy over climate ready genes it is important that patent landscaping analysis of patents related to climate change is done to understand how they will impact public sector R&D and FOT as a recent study for OECD indicates that OECD countries and private sector are the dominant players in patents on/patent applications for varieties with traits relevant in adaptation/mitigation.[71] Neglected and underutilised crops are potential sources of genes that could enhance traits like salinity tolerance in plants. For example, it has been pointed out that genes isolated from mangroves can be useful in genetic enginerring of plants to salinity tolerance.[72]

Thus what we are seeing is the continuation of older debates on access to seeds, germplasm and role of IPR in public sector R&D and role of private sector in agricultural biotechnology, in a new context, i.e. climate change. While the old issues are not fully resolved there are new challenges and new issues to be addressed. This is an important challenge that cannot be wished away.

2.10 Climate Change, Agricultural Research and Role of Biotechnology

Climate change is emerging as a major issue in agriculture on account of its impact on food production and food security. Integrating biotechnology in the agricultural research and development agenda is hence very important for developing countries which are expected to be affected by global climate change.[73] CGIAR centers and National Agricultural Research Systems are involved in meeting these challenges. Underscoring the need for more support to agricultural R&D in Asia-Pacific Region the Tsukuba Declaration 'On Adapting Agriculture to Climate Change' (2008) pointed out that CGIAR Centers, and National Agricultural Research Systems have a major role in developing new genotypes and applying plant breeding and biotechnology to develop them.

While the technological potential of biotechnology for crop improvement in the context of climate change is well acknowledged, the gap between the potential and performance remains.[74] To reduce this gap many measures need to be taken and it is important that the potential is translated into varieties and seeds that are needed most by the farmers.[75] But it should be remembered that part of the problem is in the capacity of agricultural innovation systems to effectively use the technology and respond to climate change. In this, the case studies on agricultural innovation systems and application of biotechnology can give important insights into the functioning of agricultural innovation systems and agricultural biotechnological policies in meeting the needs of diverse stakeholders including poor and marginal farmers.[76] Thus, while climate change poses new issues and challenges in using biotechnology, it should be stressed that realising the potential is not possible if the agricultural innovation system is weak or is not capable of translating research in to products and services that are needed. In our view, this calls for more efforts in improving the capability of NARS, capacity building and sharing of resources and skills. Biotechnology should be used a major weapon in the fight against climate change, particularly to mitigate the effects in agriculture. But this calls for a change in the current approach to both biotechnology and climate change. Instead of viewing both as unrelated, there should be frameworks that could integrate biotechnology in both adaptation and mitigation plans in agriculture and in finding technological solutions for climate change. The National Action Plans or National Strategies should indicate how biotechnology would be used in the plans with its role delineated in specific sectors. Further, Asian countries should take advantage of their achievements in application of biotechnology and formulate policies that build upon their strengths in both traditional agricultural research and biotechnology research. For example, countries which have limited land resources and need biofuels can examine the possibility of using biotechnology in forestry as a complementary option for biofuels.

Plant biotechnology will have a major role in meeting future energy needs. Energy crops will be important in the future as they will be key sources in biofuels. Exploitation of plant based resources will be all the more important in future. For example, Modification of lignin biosynthesis, increased biomass production and yield, resistance to abiotic stress and metabolic engineering to improve oil content and composition for biodiesel as well as sugar and starch for ethanol, are examples of biotechnology solutions for bioenergy.[77]

Biotechnology can play a vital role in meeting the needs for three Fs: Food, Fuel and Fibre. For example, the plant based resources are important sources for bio-fuel. While much of the controversy over biofuels arises of out the dilemma of allocating land resources for fuel vs. food needs biotechnology can be used to find a solution by focusing on process improvement, genetic modification to bring in or enhance required traits and by developing processes that could use agri-waste and other waste as feedstock for biofuels.

2.11 South-South Cooperation

The application of biotechnology to solve the problems of low agricultural productivity, enhancing food security and meeting health needs of a growing population demands policy intervention and crafting appropriate strategies that enhance the innovative capacity and integrating biotechnology policy in the overall development strategy. Biotechnology offers immense scope for South-South Cooperation and learning from other countries as well using the facilities available in other countries. Some of the successful collaborations are:

- Developing diagnostic for Chagas disease-Brazil-Argentina collaboration;
- Developing Cholera vaccine in India -Bangladesh collaboration;
- China-India collaboration on mitochondrial DNA; and
- Brazil and Cuba cooperation to solve health problem of meningitis in Africa

While the opportunities for biotechnology are many, there are numerous challenges that have to be faced. There is a strong case for focused approach to utilisation of biotechnology in development strategy and suggests that UN agencies, national governments and other stakeholders should collaborate in this.[78]

In this context India' Open Source Drug Discovery Project (OSDD) is an example of applying Open Source principles to drug discovery and development. Open Innovation and Open source offer enormous scope in health biotechnology and agricultural biotechnology.[79]

But this potential can be realised well only if concrete efforts are made to promote South-South collaboration in biotechnology. Right now there are no regional initiatives in this, nor is there any effort to develop projects that are disease specific which have a significant South-South collaboration. In our view, South-South collaboration should be promoted by inter-governmental organizations which should identify potential projects and partners and bring them together.

2.12 Summing Up

The contours and direction of biotechnology in AP are clear. In terms of growth and innovation agricultural biotechnology is the most well developed biotechnology in AP. Medical biotechnology is taking roots in some countries and in some countries like Singapore it is emerging as the significant application of biotechnology. There are enough indications that biotechnology industry is growing in all countries, albeit in different paces. While the continued support of the state for biotechnology is necessary, the importance of strengthening national innovation systems need not be over-emphasised. For countries that have a weak and under-funded innovation system in agricultural research, optimum utilisation and benefiting from agricultural biotechnology will be difficult. In medical biotechnology, many states have realised the importance of supporting research in basic life sciences and have invested heavily in supporting it or in developing the right infrastructure. Development of biotechnology clusters is becoming an important phenomenon in some countries. The biotechnology clusters and regional initiatives in some countries (e.g. New Zealand) are expected to add momentum to development of biotechnology in AP. Thus, biotechnology in AP is entering a crucial phase and the path ahead is full of many opportunities and challenges.

Regulation of biotechnology has emerged as an important issue. Most of the nations in AP are either signatories to Cartagena Protocol or have taken steps to implement it in the national regulatory framework. Some countries like Sri Lanka are moving closer to implementing a national biosafety framework. In this area, i.e. regulation and biosafety, capacity building is vital and there is ample scope for regional and multilateral collaboration. A well-developed and coherent regulatory framework is essential for development of biotechnology industry in any country. Countries should realise this and ensure that appropriate framework is in place as early as possible. Although collaboration in developing regulatory framework and capacity is welcome, ultimately the framework should be credible and relevant to the needs of the country implementing it.

Although there are many multilateral initiatives in biotechnology in the AP, these are not sufficient, considering the needs of the countries and for the growth of biotechnology. The scope for more initiatives, particularly in human resources development and collaborative regional research has been highlighted in this report. Here too, such efforts have paid a rich dividend and have been part of the initial initiatives in establishing biotechnology. Issues like technology convergence and the challenges posed by globalised science and technology need to be understood and appropriate policies have to be developed by countries in AP.

Due to lack of reliable data and problems in accessing and analysing the data and information it is difficult to make a comprehensive analysis and comparative study of the information and data available from different sources. The issues relating to data collection and methodology have been highlighted elsewhere. Still from the data and information available it is possible to make some preliminary inferences.

The biotechnology industry is growing but it is nowhere near the size and diversified nature of the industry in the USA or Europe. The number of firms involved in R&D is increasing but it is still small. The number of firms dedicated to R&D is very less. Most of the biotechnology firms are small and medium enterprises in terms of employment although the value addition per employee is likely to be higher than that of other industries. As the country chapters indicate, the industry has grown through different stages and in some countries like Vietnam and Sri Lanka it is in nascent stages. In countries like Japan, Korea and Australia the industry is trying to catch up globally and has strong roots. Venture capital is an important source in Japan and New Zealand but in many countries there is no venture capital investment in biotechnology. International collaboration and technology partnerships are becoming important in countries like Korea, Malaysia, Japan and Singapore. The strong support from the state through various schemes, incentives and investment in infrastructure is giving the biotechnology industry, the much needed impetus. But this alone cannot sustain the industry in the long run, particularly in sectors where innovation is the important source for growth. Hence the strengthening of national innovation systems, more collaboration with academic institutions/universities, improving the capacity to develop novel products and capitalising upon/ building on research and development in basic sciences are necessary for the industry to grow and sustain. Focusing in niche areas/technologies like stem cell technology, and use of medical tourism, attracting foreign talent are some of the strategies that are put to use by the industry and government.

The biosafety regulation in AP is a cause of concern as many countries have not implemented national regulatory frameworks. Some countries have them in place for many years and are in the process of revising them (e.g. India) or have revised them (e.g. Japan). But in some countries there is lack of clarity on issues like labelling of GM foods, regulating agricultural biotechnology and this will affect the growth of biotechnology. Most countries in AP are signatories to the Cartagena Protocol and have taken steps to adhere to it.

In terms of human resources the countries in AP are in different stages of development. Countries need to do more in this and strengthen the national innovation systems. Countries like Thailand, China, and India have invested in their tertiary educational system to develop appropriate human resources in biotechnology. But for many countries the dependence on public sector research institutions in agriculture/agricultural biotechnology is heavy as there is no significant activity by private sector in this. The lessons from Green Revolution are relevant here. Without sustained efforts including bilateral/multilateral support and collaboration in capacity building these countries will not be able to build up a critical mass in human resources and other capacities to benefit from biotechnology.

Many countries have developed biotechnology strategies or policies on promoting biotechnology. Some countries have no specific policy but indicate the importance of biotechnology in their development/Science and Technology policy. The biotechnology strategies with specific objectives and focusing on particular areas bring in needed clarity and induce the private sector to identify sectors for investment. The absence of a policy or strategy may indicate that while the government is not averse to biotechnology, it has no special plan to promote it. Hence it is essential that countries develop coherent and appropriate policy frameworks/strategies to promote biotechnology.

Technology convergence, declining investment in public sector R&D for agriculture, intellectual property rights, public acceptability and attitude towards biotechnology are some of the issues that deserve attention from governments and policy makers. Moreover, recent developments in India and China indicate that resistance to biotechnology is a matter of concern and support from policy makers cannot always be taken granted.[80] Such developments should be handled with care by scientists and others who promote biotechnology as a solution have to engage more with public and policy makers than to merely believe that anti-GM rhetoric is just anti-science and hence can be ignored.

To sum up, while it is necessary to learn from the past, it is equally important to think about new approaches and initiatives in the future to sustain the biotechnology revolution in AP.

Endnotes

1. Halford, Nigel G. (2006).
2. Bainbridge, William Sims and Mihail C. Roco (2006) and Silberglitt, Richard, Philip S. Antón, David R. Howell, Anny Wong *et al.* (2006).
3. *ibid.*
4. See Niosi, Jorge , Petr Hanel , Susan Reid (2012). "The International Diffusion of Biotechnology: The Arrival of Developing Countries". *Journal of Evolutionary Economics,* 22: 767-783.
5. UNESCO (2010). *World Science Report (WSR).* Paris: UNESCO.
6. WSR (2010), and Royal Society (2011). *Knowledge, Networks and Nations: Global Scientific Collaboration in the 21st Century.* London: Royal Society.
7. OECD (2011). *S&T Outlook*. Paris: OECD.
8. *Nature Biotechnology (2012).* February Editorial.

9 6th ABDC Presentation and Country Chapter in this volume.
10 Country Chapter in this volume.
11 Country Chapter in this volume.
12 Country chapter in this volume.
13 Presentation on Biotechnology in Malaysia by Dr. Kodieswaran at the 6th ABDC.
14 Banji Oyelaran-Oyeyinka, Padmashree Gehl Sampath (2009). *The Gene Revolution and Global Food Security : Biotechnology Innovation in Latecomers.* New York: Palgrave Macmillan.
15 *ibid.*
16 Nataporn Chanvarasuth (2008). "Thailand Biotech Business: Product of the National Policy", *Journal of Commercial Biotechnology*, Vol. 15, 1, 66-72.
17 Country Chapter in this volume and references there in.
18 Jawahir L. Karihaloo and Oswin Perera 2010. "Harnessing Biotechnologies for Food Security in the Asia-Pacific Region". A*PAARI Issue Paper.*
19 Wong, J. (2005). "Re-making the Developmental State in Taiwan: the Challenges of Biotechnology". *International Political Science Review*, 26: 169-191. See also Joseph Wong (2011) *Betting on Biotech: Innovation and Limits of Asia's Developmental State.* Itahac: Cornell University Press, for a review of such efforts in Taiwan, South Korea and Singapore.
20 Brian Salter, Alex Faulkner (2011). "State Strategies of Governance in Biomedical Innovation: Aligning Conceptual Approaches for Understanding 'Rising Powers' in the Gobal Context". *Globalization and Health*, 7:3.
21 See Wong (2011) for a discussion on limitations of state interventions in biotechnology in Asia.
22 RIS UNESCO Report.
23 Calestous Juma (2011). *The New Harvest: Agricultural Innovation in Africa.* New York: Oxford University Press.
24 Grossman (1991).
25 Pack and Westphal (1986).
26 Vittorio Chiesa and Davide Chiaroni (2004).
27 D'Costa, A.P. and G. Parayil (eds.) (2007).
28 Pack and Westphal (1996) and Ernst, Ganiatsos and Mytelka (eds.) (1998).
29 Gary P. Pisano (2006).
30 Cooke, Philip, Carla De Laurentis, Franz Tödtling, and Michaela Trippl (2007).
31 Zika, E. *et al.* (2007) and EC (2007). In both the references to the USA indicated that the EU considers the USA as a benchmark to measure the state of biotechnology in Europe. In 2007 a mid-term review was made. Mid-term review http://ec.europa.eu/biotechnology/docs/com_2007_175_en.pdf
32 Richard Mahoney, Keun Lee and Mikyung Yun (2005).
33 UNCTAD (2007).
34 Meric, S., Gertler and Tara Vinodrai (2009).
35 Pardey *et al.* (2006).
36 IAASTD (2009).
37 *ibid.*
38 Sasson (1988).
39 Jennifer S. James, Philip G. Pardey and Julian M. Alston (2001).
40 Parayil, Govindan (2002).
41 Philipp, Aerni (2007).
42 IRRI (1984).
43 Bharadwaj, Aditya and Peter Glasner (2009).
44 Jasanoff, Sheila (2005).
45 Daniel Lee Klienman, Abby J. Kinchy, and Robyn Autry (2009).
46 http://www.plantsci.cam.ac.uk/research/baulcombe/pdfs/reconciling.pdf
47 Roy, Devparna (2012). "Cultivating Bt Cotton in Gujarat (India): Self-Identified Organic Cotton Farmers Revisited". *Asian Biotechnology and Development Review,* Vol.14, No.2.
48 Neal D. Fortin (2009). *Food Regulation: Law, Science, Policy and Practice.* John Wiley & Sons, Inc.
49 Steffanie Scott, Peter Vandergeest, and Mary Young (2009). "Certification Standards and the Governance of Green Foods in Southeast Asia" in Jennifer Clapp and Doris Fuchs (eds) *Corporate Power in Global Agrifood Governance.* The MIT Press.
50 For details see Chaturvedi (2007).
51 http://www.rockfound.org/library/01rice_bio.pdf
52 http://www.icrisat.org/gt-bt/gt-bt.htm
53 IAASTD (2009).
54 Macer and Bhardwaj (2005).
55 FAO (2011). *Synthesis: Policy Options for Agricultural Biotechnologies in Developing Countries.*
56 Robert W. Herdt (2012). "People, Institutions, and Technology: A personal View of the Role of Foundations in International Agricultural Research and Development 1960-2010". *Food Policy,* 37, 179-190.
57 Mark A. Pollack and Gregory C. Shaffer (2009). *When Cooperation Fails: The International Law and Politics of Genetically Modified Foods.* New York: Oxford University Press.
58 RIS UNESCO Report.
59 *ibid.*
60 Linda M.Penabla, Dulce D. Elazegui, Ker Monthivuthu (2011). Building Biotechnology Regulatory Capability in Southeast Asia (Summary).
61 Margarita Escaler, Paul P.S. Teng, and Andre D. Powell (2012). "Challenges of Harmonization of Agricultural Biotechnology Regulatory Systems across APEC Economies." *Biosafety,* Vol. 1, No. 3, pp 1-7.
62 *ibid.*
63 Obidimma C Ezezika, Nadira Saleh, and Abdallah S Daar (2012). "Trait Stacking for Biotech Crops: An Essential Consideration for Agbiotech Development Projects for Building Trust". *Agriculture and Food Security,* 1:5. http://www.agricultureandfoodsecurity.com/content/1/1/5

64 Richard Gary (2012). "Intellectual Property Rights and the Role of Public and Levy Funded Research: Some Lessons From International Experience". OECD *Improving Agricultural Knowledge and Innovation Systems.* Paris: OECD. Pp 183-203

65 Spielman, D.J., Hartwich, F., and von Grebmer, K. (2007). "Sharing Science, Building Bridges, and Rnhancing Impact: Public-Private Partnerships in the CGIAR". *International Food Policy Research Institute Discussion Paper No. 708.* Washington, DC: International Food Policy Research Institute.

66 Anwar Naseem, David J. Spielman and Steven Were Omamo Agribusiness (2010). "Private-Sector Investment in R&D: A Review of Policy Options to Promote its Growth in Developing-Country Agriculture". *Agribusiness,* Vol. 26 (1): 143-173 and Kimberly Ann Elliott (2010) "Pulling Agricultural Innovation and the Market Together." CGD Working Paper 215. Washington, D.C.: Center for Global Development.

67 J. Piesse and C. Thirtle (2010). "Agricultural R&D, Technology and Productivity". *Philosophical Transactions of the Royal Society of Biological Sciences,* 365, 3035-3047.

68 Elisabeth A. Aberge l (2010). "Climate-ready Crops and Bio-capitalism: Towards a New Food Regime?" *International Journal of Society of Agriculture and Food,* Vol. 18, No. 3, pp. 260-274.

69 Michael Blakeney (2011). "Trends in Intellectual Property Rights Relating To Genetic Resources For Food And Agriculture". Background Study Paper No. 58. Commission On Genetic Resources For Food And Agriculture. Rome: FAO analyses the controversy over 'climate ready genes' while Christoph Then & Ruth Tippe (2012) European Patent Office at Crossroads Report – Patents on Plants and Animals Granted in 2011 http://www.evb.ch/cm_data/npos_patente_report_march_2012_en.pdf caution against the broad claims in recent patent applications and patents granted See also Andreas Hübel, Thilo Schmelcher, and Ulrich Storz (2012). Biopatent Law: Patent Strategies and Patent Management Heidelberg: Springer, pp 1-13.

70 Arvind kapur (2011). "IPR Laws to Protect Innovation, Not to Restrict Crop Breeding". *Journal of Intellectual Property Rights,* Vol. 16, March, 117-123.

71 Agrawala, S. C. Bordier, V. Schreitter and V. Karplus (2012). *Adaption and Innovation: An analysis of Crop Biotechnology Patent Data.* ENV/WKP. Paris: OECD .

72 Anath Bandhu Das (2013). "Bioprospecting and Genetic Engineering of Mangrove Genes to Enhance Salinity Tolerance in Crop Plants" in S.M.Jain and S. Dutta Gupta (eds) Biotechnology of Neglected and Underutilized Crops, Heidelberg: Springer.

73 Rattan Lal, Mannava V.K. Sivakumar, S.M.A. Faiz, A.H.M. Mustafizur Rahman, Khandakar R. Islam (eds) (2010). *Climate Change and Food Security in South Asia.* Heilderberg: Springer. Also see Bipul Chatterjee and Manbar Khadka (Eds) (2011) *Climate Change and Food Security in South Asia*, Jaipur: CUTS; and Asian Development Bank and International Food Policy Research Institute (2009) *Building Climate Resilience in the Agriculture Sector in Asia and the Pacific.* Mandaluyong City, Philippines: Asian Development Bank.

74 See Chikelu Mba, Elcio P Guimaraes, Kakoli Ghosh (2012). "Re-orienting Crop Improvement for the Changing Climatic Conditions of the 21st Century". *Agriculture and Food Security*, 1:7. Available at: http://www.agricultureandfoodsecurity.com/content/1/1/7. Also see Rajeev K. Varshney et.al (2011) "Agricultural Biotechnology for Crop Improvement in a Variable Climate: Hope or Hype" T*rends in Plant Science,* Vol 16. No. 7, July, pp. 363-371. Both articles discuss the potential of biotechnology and the various factors that can constrain the application and fuller of biotechnology and some of the constraints are institutional and regulatory in nature. The institutional and regulatory constraints cannot be wished away and need careful approaches to ensure that the developed varieties and seeds are perceived as useful, safe and are available to farmers who need them most.

75 *ibid.*

76 See for examples in Sally Brooks, Michael Loevinsohn (2011). "Shaping Agricultural Innovation Systems Responsive to Food Insecurity and Climate Change". *Natural Resources Forum,* 35: 185-200. Also see Norman Clark *et al.* (2012) "Biotechnology and Agricultural Development in Low Income Countries: Case Materials from the Research into Use Program", *Innogen Working Paper 101* ESCRC Genomics Network.

77 Dulce E. de Oliveira and Marc Van Montagu (2011). "Plants for the Future" in *Challenges for Agricultural Research,* OECD.

78 See Thorsteinsdóttir H. (ed) (2011). *Building Bridges: A Study on South-South Collaboration in Health Biotechnology.* New Delhi: Academic Foundation.

79 Ademola A. Adenle, Sulayman K. Sowe, Govindan Parayil, and Obijiofor Aginam (2012). "Analysis of Open Source Biotechnology in Developing Countries: An Emerging Framework for Sustainable Agriculture," *Technology in Society*, Volume 34, Issue 3, Pages 256-269. Also see Minna Allarakhia, D. Marc Kilgour, David Fuller (2010) "Modelling the incentive to participate in open source biopharmaceutical innovation", *R&D Management*, Vol. 40, No. 1, pp. 50-66.

80 Kilugudi Jayaraman (2012). "GM phobia spreads in south asia" *Nature Biotechnology,* Vol.10, No. 11, pp. 1017-1019.

Chapter 3:
Australia

3.1 General Introduction

Australia is a high income level country[1] and a member of OECD [GDP, Current Prices (USD in Trillions): 1.5[2]; GDP, Purchasing Power Parity (USD in Billions): 970.7[3]; GDP (PPP) Share of World Total (%): 1.2[4]]. Its economy is basically Services sector driven [GDP Composition by Sector (%)[5]: Agriculture: 4, Industry: 26.6, Services: 69.4 (2012 estimate)] and Services sector also is the major sector of employment [Employment (% of total employment)[6] 2009: Agriculture: 3.3, Industry: 21.1, Services: 75.5].

The role of Research and Development in fostering growth of a nation's economy as well as in addressing its needs and aspirations is very important. In technology-intensive sectors, R&D strength and capability have to be very robust and innovative. In this respect, Australia has one of the highest expenditure on R&D among leading nations across the world. Its Gross Expenditure on R&D in 2012 [GERD] (USD in Billions, PPP)[7] was 21.8 and its expenditure on R&D in 2012 (per cent of GDP, PPP)[8] was 2.28. This very clearly suggests that Australia is very much keen in taking the lead in innovation. This is also evident from its high ranking in both Knowledge Economy Index and Global Innovation Index. [Australia was ninth in Knowledge Economy Index (KEI) in 2012[9] and its ranking on Global Innovation Index in 2012 was 23.[10]]

As far as Human resource in R&D is concerned, Australia has an impressive number of researchers per million people, which is well above many countries of the region and of the world [Researchers in R&D (per million people)[11] in Australia were 4293 in 2008.

3.2 Biotechnology in Australia

Australia has developed a reputation for itself in the field of biotechnology and now is one of the major centres for biotechnology in the world after United States, Canada, Germany and the United Kingdom. Realizing the importance of biotechnology well ahead of many others the Australian government attempted to plan and promote biotechnology development through the setting up of the Biotechnology Australia in 1999. Subsequently, it came out with National Biotechnology Strategy in July 2000. The key objective of the National Biotechnology Strategy is to provide a framework for the Government and key stakeholders to work together to ensure that developments in biotechnology are captured for the benefit of the Australian community, industry and the environment, while safeguarding human health and ensuring environmental protection.

This agency was supported with $30.5 million for a period of three years (2001-04). The Strategy received a further $66.5 million in 2001, with funding for the Biotechnology Centre of Excellence, the Australian Stem Cell Centre, and additional funding for the Biotechnology Innovation Fund (BIF). The Strategy and Biotechnology Australia were again funded $20 million in July 2004 to continue the National Biotechnology Strategy and Biotechnology Australia until 2008. Further funding was also provided to extend support for the Australian Stem Cell Centre until 2010-11.[12] The Australian Government is considering an independent review of both these initiatives. In addition to the Australian Government's contribution to biotechnology, State and Territory governments also commit substantial resources to the development of biotechnology. In addition to all this are the benefits that biotechnology developments receive from government's other programmes in health, agriculture, environment, industry and education portfolios.

Biotechnology R&D expenditures by the public sector (Millions USD PPP) was 89.5 in 2008.[13] Australia's biotechnology R&D expenditures by the public sector as a percentage of total public-sector R&D was 1.31 in 2008.[14]

Percentage of biotechnology R&D investments by application in Australia in 2010 was as follows:[15]

- Health: 72.2 per cent
- Agriculture: 11.9 per cent
- Food and Beverages: 0.0 per cent
- Natural Resources: 0.0 per cent
- Environment: 9.3 per cent
- Industrial Processing: 6.6 per cent
- Bioinformatics: 0.0 per cent
- Other: 0.0 per cent

3.3 Programme Framework and Funding

3.3.1 National Biotechnology Strategy

National Biotechnology Strategy (NBS) of Australia was launched in July 2000 with the objective of providing a framework for the Government and key stakeholders to work together to ensure that developments in biotechnology are captured for the benefit of the Australian community, industry and the environment, while safeguarding human health and ensuring environmental protection. The strategy addresses six key themes with specific objectives and activities to achieve them. They include biotechnology in the community which had to focus on establishing and providing channels for credible sources of information on biotechnology; ensuring effective regulation which comprised setting up of Office of the Gene Technology Regulator (OGTR) in collaboration with the Department of Health and Ageing (DoHA) apart from Ecological Risk Programmes for providing information on risks associated with GMOs; biotechnology in the economy provided support for industry development through NBS funding and for establishing a peak industry body called AusBiotech and National Stem Cell Centre (NSCC); Australian biotechnology in the global market was the another theme which received funding from the NBS, which led to funding for supply chain management of GM and non-GM products in partnership with industry; resources for biotechnology programme of NBS worked towards improving access to Australian biological resources across States and Territories; for maintaining momentum and coordination, NBS attempted to establish resource coordination among Commonwealth Biotechnology Ministerial Council

(MinCo), Australian government, State and Territory Biotechnology Liaison Committee (BLC) and an independent advisory body on biotechnology – the Australian Biotechnology Advisory Council (ABAC). Following the 2004 US Bio conference, a National Approach Work Programme was agreed to by the Australian Government to build on national strengths in biotechnology collaboratively to avoid duplication and dilution of effort.

3.3.2 National Bioinformatics Strategy

Bioinformatics has been identified as a Priority Goal within the National Research Priorities. For the period 1999 to 2006, the Australian Government provided or committed around USD 60 million to specific bioinformatics activities, and around USD 80 million overall to more generic types of infrastructure and project support.[16]

Table 3.1 lists the top 10 Australian universities/research centers in the field of biotechnology based on their publication activities in the period 2001-2012.

3.4 Biotechnology Industry

Australia biotech industry saw 14 per cent rise in annual capital raising in 2011 to $ 630 million. The biotechnology industry in Australia has shown good recovery since 2008 by attracting significant new investments of $554 million in 2010 against $672 million in 2009 and $183 million in 2008. Australia has more than 400 biotechnology and 600 medical technology companies.[17] Out of these most of the companies are into therapeutics, diagnostics and medical technology. The Australian biotechnology sector covers human therapeutics, industrial applications, the agriculture sector, food technology, medical devices and diagnostics, and cleantech.[18] There are currently 100 Australian Stock Exchange (ASX) listed life sciences companies, with a market capitalization of $31.4 billion.[19] In the private sector there is steady expansion in Australia. In 1999 there were 170 private firms and this number increased further. In 2009, there were more than 510 firms[20] providing employment to nearly 7000 people.[21] The performance of Australian publicly traded biotechnology companies showed robust improvement in 2011. Revenues grew by 6 per cent, R&D expenses by 13 per cent and the collective bottom line improved by 15 per cent relative to 2010.[22]

Total biotechnology R&D expenditures in the business sector in Australia increased to USD 122.1 Million (PPP) in 2010.[23]

The Industry comprises a range of companies, from start ups to more

Table 3.1: Top Ranking Australian Universities

Top Ranking Institutions based on Publications in 'Biotechnology and Applied Microbiology' in the period 2001-2012
University of Queensland
University of Melbourne
Monash University
University of Sydney
University of New South Wales
University of Adelaide
University of Western Australia
Queensland University Of Technology
Australian National University
Macquarie University

Source: Thomson Reuters' Web of Science Database, 2013.

Table 3.2: Break up of Firms dealing in Biotechnology Applications

Biotech Application	No. of Firms
Health	353
Agriculture	185
Natural Resources	22
Environment	85
Industrial Processing	90
Bio-Informatics	84
Others	48

Note: A given firm can deal in more than one application.

Source: OECD (2009).

developed companies selling products in Australia and overseas, operating in applications of biotechnology including health, industrial processing, agriculture and environment. Total number of firms operating in application of biotechnology in 2006 was 527 out of which 353 were dealing in Health Biotechnology (Table 3.2). A total of 384 firms were dedicated only to biotechnology which is about 73 per cent. In 2006, the number of people employed in Biotech R&D firms was about 18,700.[24]

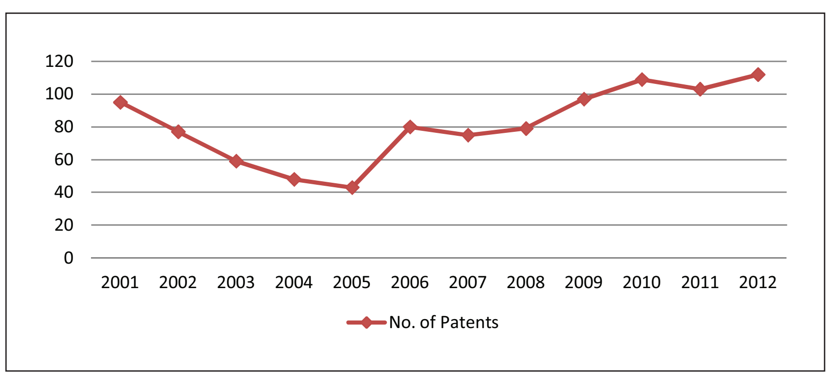
An estimated 8,820 persons were employed in 72 publicly listed biotech companies in 2006-07 whose turnover in the same year was about USD 2300 million. Six companies had a market capitalization of over USD 100 million at the end of 2008.[25]

As far as biotechnology employment in biotechnology firms is concerned, there were 28573 employees in 2006.[26]

3.5 Patents and Publications

In Australia for boosting innovations, one of the most significant changes in terms of policy reforms has been the introduction of the research and development (R&D) tax incentive policy to boost innovation and research in the industry.[27] Australian Government has also established Innovation Investment Fund (IIF). It is a venture capital programme that supports new innovation funds and fund managers with expertise in early-stage venture

Figure 3.1: Patents Granted in Biotechnology at USPTO in the period 2001-2012



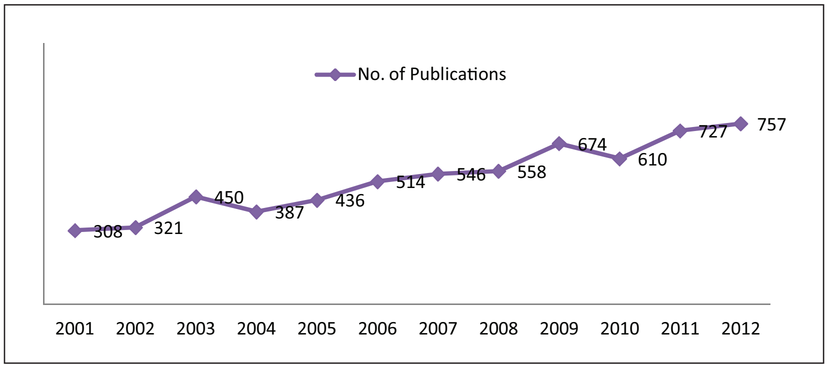
Notes: Australia's share in biotechnology patents filed under PCT in the period 2008-10 was 1.68.[29]

Patents Granted in 'Biotechnology' in USPTO in the Period 2001-2012: 977.

Patents Granted in 'Biotechnology' in EPO in the Period 2001-2012: 511.

Source: Thomson Innovation Database, 2013.

Figure 3.2: Publications in Biotechnology in the period 2001-2012



Source: Thomson Reuters' Web of Science Database, 2013.

capital investing. It co-invests with private sector investors in venture capital funds to grow early-stage companies to commercialize the outcomes of Australia's strong research capability.[28]

Figure 3.1 gives the increasing trend of patents granted to Australia in Biotechnology at USPTO in the period 2001-2012.

A total of 556 biotech PCT patent applications were filed by Australia in the period 2004-2006.[30]

As far as publication is concerned, Australia has published more than 6000 papers in the research area 'Biotechnology and Applied Microbiology' in the period 2001-2012 (Figure 3.2).

3.6 Regulation of Biotechnology

3.6.1 Office of the Gene Technology Regulator

Office of the Gene Technology Regulator is an Australian Government agency, located within the Government Department of Health and Ageing. The Gene Technology Act 2000 established a statutory officer, the Gene Technology Regulator, to make decisions regarding 'dealings' with GMOs, including research, manufacture, production, experiment trails, commercial release and importation. The Regulator has the responsibility for identifying, assessing and managing potential risks to human health and the environment that may be posed by gene technology. Therefore, the regulator will not issue a license for a GM dealing without being satisfied that the health and safety of the people and environment are protected. The Act also establishes a public record of GMOs and GM products approved in Australia (the GMO record). The GMO record is available on the OGTR website and lists of all GMOs is approved by the Regulator and all GM products are approved by other product regulators. The Regulator has extensive powers to monitor and enforce the law. Anyone who does not adhere to license conditions, or follow directions from the Regulator to take measures to protect human health and safety and the environment from risks posed by gene technology, could face criminal penalties, including fines and imprisonment. Marketability and agriculture trade issues that may be posed by gene technology are excluded from the scope of the assessment of the Regulator.

3.6.2 Food Standards Australia-New Zealand (FSANZ)

Food Standards Australia New-Zealand (FSANZ) is a binational government agency, which ensures the safety of all consumable foods, including imports, by developing effective food standards for Australia and New Zealand. For Australia, FSANZ develops food standards for the entire food supply chain, from primary production through to manufactured food and food retail outlets. Australian Government, through Office of the Gene Technology Regulator and Food Standards Australia-New Zealand ensures that all food products that reach consumers (including imports) are biologically safe to consume.

3.6.3 GM food Labeling

The Standard for labeling GM food came into force in December 2001. It requires any food, food ingredient or processing aid produced using gene technology and containing novel DNA of novel protein to be labeled as 'genetically modified'. The standard also allows 1 per cent unintentional presence of GM food or ingredient in a final food.

3.7 Summing Up

Australia has a vibrant biotechnology industry and a supporting policy milieu including financial support from the federal government and state and territory governments. The presence of a developed regulatory regime is another feature that will help growth of biotechnology in Australia. Agricultural biotechnology and health biotechnology are the two most important sectors. In terms of human resources Australia can draw on the well developed tertiary education sector including the universities that attract students and faculties from other countries in AP. Hence biotechnology in Australia can be expected to grow further and deepen in the years to come.

Endnotes

1 WDI, World Bank Data 2013.

2 International Monetary Fund, World Economic Outlook Database, April 2013.

3 International Monetary Fund, World Economic Outlook Database, April 2013.

4 International Monetary Fund, World Economic Outlook Database, April 2013.

5 CIA, The World Factbook, May 2013.

6 WDI, World Bank Data, 2013.

7 Global R&D Funding Forecast 2013, Battelle and RDMag.com, 2012.

8 Global R&D Funding Forecast 2013, Battelle and RDMag.com, 2012.

9 World Bank, Knowledge for Development, 2013.

10 WIPO and INSEAD, The Global Innovation Index 2012.

11 WDI, World Bank Data, 2013.

12 Biotechnology Australia (2007).

13 OECD, Biotechnology Statistics Database, December 2012.

14 OECD, Biotechnology Statistics Database, December 2012.

15 OECD, Biotechnology Statistics Database, December 2012.

16 Biotechnology Australia (2007).

17 "Australia Records Muted Growth", *Biospectrum Asia*, Vol 7, Issue 10, 2012. Available at http://www.bsadm.cybermediaservicesdigitalmag.com/vol7_issue10/BSA_pages/vol7_issue10.pdf

18 Aus Biotech (2012). "Australia Biotechnology Industry Overview" Australia's Biotechnology Organization. Available at: http://www.ausbiotech.org/content.asp?pageid=25

19 "Is 2012 the year for Australian Biotechs to Shine?" *Bioforum Edition,* 38, 2012. http://www.pwc.com.au/industry/technology/assets/bioForum/BioForum-Ed38-Feb12.pdf

20 "Biotechnology Market In Australia", Market profile September 2010.

21 IBIS (2009).

22 "Beyond Borders", *Global Biotechnology Report,* 2012, E&Y. http://www.ey.com/Publication/vwLUAssets/Beyond_borders_2012./$FILE/Beyond%20borders_2012.pdf

23 OECD, Biotechnology Statistics Database December 2012.

24 OECD, Biotechnology Statistics Database, 2009.

25 AG (2009).

26 OECD, Biotechnology Statistics Database, 2009.

27 Australia Records Muted Growth", *Biospectrum Asia,* Vol 7, Issue 10, 2012. Available at http://www.bsadm.cybermediaservicesdigitalmag.com/vol7_issue10/BSA_pages/vol7_issue10.pdf

28 AusIndustry, An Australian Governemnt Initiative, http://www.ausindustry.gov.au/programs/venture-capital/iif/Pages/default.aspx. Last accessed on August 9, 2012.

29 OECD, Biotechnology Statistics Database, December 2012.

30 OECD, Biotechnology Statistics Database, 2009.

Chapter 4:
Bangladesh

4.1 General Introduction

Bangladesh is a low income level[1] developing country in South Asia region [GDP, Current Prices (USD in Billions): 122.7[2]; GDP, Purchasing Power Parity (USD in Billions): 306[3]; GDP (PPP) Share of World Total (%): 0.3[4]]. Agriculture sector has a substantial contribution into its GDP [GDP Composition by Sector (%)[5]: Agriculture: 17.3, Industry: 28.6, Services: 54.1 (2012 estimate)] and it serves as a major sector of employment for around half of the total employed people in Bangladesh. [Employment (% of total employment)[6] 2005: Agriculture: 48.1, Industry: 14.5, Services: 37.4]. These statistics indicate that Bangladesh economy is pre-dominantly driven by Agriculture.

As far as Bangladesh's Knowledge Economy Index is concerned, it stands at a very low position of 137 out of 146 [Knowledge Economy Index (KEI) 2012 Ranking[7]]. This depicts a picture of poor economic and incentive regime, innovation system, education system and ICT infrastructure. This is further corroborated by its poor ranking in Global Innovation Index, where it stands at 112. [Global Innovation Index 2012 Ranking.[8]]

4.2 Biotechnology in Bangladesh

As mentioned above Bangladesh's economy is pre-dominantly driven by agriculture, it has launched major efforts for promoting commercialization of biotechnology in the agriculture sector. The National Technical Committee on Crop Biotechnology in the Ministry of Agriculture has approved import of some biotech products for contained trials; these include: golden rice, fruit and shoot-borer resistant Bt egg plant, late blight resistant potato, insect resistant Bt chickpea, and ring spot virus resistant Papaya. After successful completion of the contained trials, Bangladesh Agricultural Research Institute (BARI) has performed two cycles of confined field trails of fruit and shoot borer resistant Bt-brinjal and late blight resistant (LBR) potato at multiple locations. BARI is now conducting greenhouse trails of imported golden rice.[9] There are interesting research projects initiated at the Dhaka University for developing saline resistant rice varieties, which are being field tested at Satkhira. Similarly, a large number of jute varieties from Gene Bank of Bangladesh Jute Research Institute have been screened for cold tolerance. The next phase for these biotech trials will be the approval for multi-location trials in farmers' fields. Bangladesh has also taken initiatives to tap international institutions. It became member of ICGEB in the 1990s. It has established a National Institute of Biotechnology with a view to create a Centre of Excellence in modern biotechnology. Recently, one of the leading pharmaceutical firms INCEPTA signed an MoU with ICGEB, Delhi to access recombinant DNA technology for vaccine production to manufacture Hepatitis B vaccine in Bangladesh.[10] The largest pharmaceutical company, the SQUARE Ltd., has also taken up ambitious programme in modern biotech products.

4.3 Policy Initiatives

Bangladesh had undertaken efforts to consolidate R&D policies in the biotechnology sector through the National Biotechnology Policy, which was a follow up of the work identified at National Committee on Biotechnology Product Development, 1993. It was in May 2004 that the Government of Bangladesh constituted a National Committee for the formulation of a National Biotechnology Policy. The Committee came out with a draft policy in August of the same year itself, which was circulated widely for comments and discussion. Finally, the National Biotechnology Policy, prepared by the Ministry of Science, Information and Communications Technology, Government of the People's Republic of Bangladesh and approved by the National Task Force on Biotechnology, was released in July 2006. The released document was the fifth draft of the policy and covers almost all aspects of biotechnology and its utilization for national development. Again in 2011, a Strategic Road Map to implement Biotechnology Policy in Bangladesh was prepared to provide a framework for the government to work with and coordinate all the stakeholders, to obtain the benefits of biotechnology for the development of Bangladesh.[11]

Research work in Bangladesh till recently was mostly carried out by individual scientists in a fragmented manner. Previously, there was no separate research budget for the purpose. Presently, separate R&D budget is given by the government for carrying out research work. In addition, a special grant of 180 million taka is provided by the Ministry of Science and ICT every year for R&D in physical, biological and engineering sciences. However, the annual expenditure per scientist in a year will not exceed $500.

The National Policy (2006) envisaged setting up of an autonomous National Commission for Biotechnology (NCBT) with its own Secretariat and independent funding.[12] This is expected to be national with the following responsibilities:

i. Be the GoB's focal point for promoting and supporting all biotechnology-related activities in Bangladesh through interaction and coordination with relevant government departments, academic and research institutions, and local biotechnology and pharmaceutical industries;

ii. Formulate and implement biotechnology-related policies;

iii. Coordinate and fund biotechnology research in Bangladesh;

iv. Support biotechnology education and training;

v. Help raise funds from government and private sectors in Bangladesh and from international funding agencies and development partners; and

vi. Be the reference centre for biotechnology-related regulatory and intellectual property issues.

However, it was also envisioned that the flag-ship for research would remain with the National Institute of Biotechnology (NIB). Both NCBT and NIB are expected to work closely for optimum economic returns. It is also proposed that the NCBT and NIB share the same International Scientific Advisory Committee (ISAC) for the first five years.

The policy was revised in 2010. Biosafety regulations were adopted in 2011. Medical biotechnology is now given importance with a cell established at the Ministry of Health for medical biotechnology and guidelines have been released. The Institute for Biotechnology has also been established.

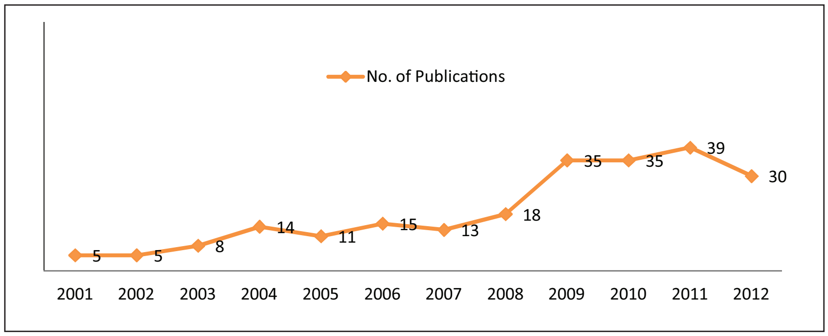
4.4 Institutional Framework

Since independence, Bangladesh has launched several initiatives for strengthening institutional framework for academics and education sector. Universities in Bangladesh represent about 75 academic bodies out of a total 105 institutions, representing the conventional higher education institutions (HEI) in Bangladesh. Segmented by management and financial structure, these include 30 public universities, 54 private universities, one international university, 31 specialized collages, and two special universities. There are specialized universities in both categories, offering courses principally in technological studies, medical studies, business studies and Islamic studies. There are two private universities dedicated solely to female students. The number of universities is growing mostly in and around the capital city of Dhaka.[13] However, this is not sufficient as number of applicants for various posts is huge and it does not cope up with the overall requirements. As a result, more than 50 candidates appear for one seat in a government university. The total capacity of all the government universities will be less than 50,000.

There are several institutions of national importance established in Bangladesh which cover various areas of research. Most of these institutes are functioning for more than 30 years and the total number of scientists working in different institutes will be nearly 3000. The most important of them are: Bangladesh Atomic Energy Commission (BAEC); Bangladesh Council of Scientific and Industrial Research (BCSIR); Bangladesh Rice Research Institute (BRRI); Bangladesh Agricultural Research Institute (BARI); and Bangladesh Institute of Nuclear Agriculture (BINA). The Sericulture Research Institute (SRI) at Rajshahi has been working on improvement of sericulture production in Bangladesh. Another important institution is Bangladesh Livestock Research Institute (BLRI) which has launched modern biotechnology research programme in collaboration with Bangladesh Agriculture University (BAU). They include embryo transfer technology and multiple ovulation embryo transfer technology. There are two major NGOs also working in the realm of biotechnology, especially tissue culture technology for micro-propagation, they are DEBTECH and PROSHIKA.

The National Institute of Biotechnology (NIB) under the Ministry of Science and Technology, Government of Bangladesh, was launched in 1999 for carrying out far more focused work in biotechnology research. It is proposed that the NIB would be a national network for contemporary Biotechnology R&D with an intramural research and administrative centre at Savar and extramural research units (within university and research institutes) spread across the country. This institute has six laboratories working in various areas such as DNA laboratory, plant biotechnology, animal biotechnology, fish biotechnology, fermentation and bioprocessing, and bioenergy and fertilization. The concept of the institute was conceived in 1984 but due to several administrative delays the proposal was finally approved in 1995. At this stage a project proposal was prepared with an estimated cost of 2021.20 lakh taka. The NIB could only be launched in

Figure 4.1: Publications in Research Area 'Biotechnology and Applied Microbiology'



Notes: Patents Granted in 'Biotechnology' in USPTO in the Period 2001-2012: 1.
Patents Granted in 'Biotechnology' in EPO in the Period 2001-2012: 0

Source: Thomson Reuters' Web of Science Database, 2013.

1999.[14] The NIB is expected to have more than 100 scientists on board working at above mentioned six laboratories. It has launched various projects in various areas of national requirement. A project launched in 2006 which is expected to be over soon developing technology for production of valuable materials including foodstuffs using microbes and preservation microbial diversities, would be of immense economic significance, given continuous economic environmental challenges across Bangladesh.

In terms of capacity the universities and public sector research institutions are the leading players while private sector is yet to emerge as a major player. Over the last few years important advances have been made in biotechnology, particularly in agricultural biotechnology (Table 4.1).

Jute genome has been mapped and Dhaka University and Bangladesh Jute Research Institute played key role in this. Bioinformatics is now gaining ground in some universities. Marker assisted selection is being done in Jute. Many of the projects indicate that like other developing countries Bangladesh is also using various technologies ranging from micro-propagation to mapping genome. Some of the important projects like developing stress tolerant varieties in rice, drought tolerant rice, submergence tolerance and multiple stress tolerance are oriented towards developing varieties that could meet the change in climate including

Table 4.1: Top Ranking Institutions in Bangladesh

Top ranking Institutions based on publications In 'Biotechnology and Applied Microbiology' in the period 2001-2012
Bangladesh Agricultural University
University of Dhaka
Rajshahi University
International Centre for Diarrhoeal Disease Research
University of Chittagong
Jahangirnagar University
Shahjalal University of Science and Technology
Bangabandhu Sheikh Mujibur Rahman Agricultural University
Bangladesh Rice Research Institute

Source: Thomson Reuters' Web of Science Database, 2013.

flooding while marker assisted selection is being tried in other crops also. Rice and Jute thus have been given the importance they deserve in agricultural biotechnology research.

Another important development is in area of vaccines and three private sector firms are/have developed vaccines.

4.6 Publications and Patents

The status of both publications and patents in Biotechnology is not encouraging at the moment.

Publications in Research Area 'Biotechnology and Applied Microbiology' in the Period 2001-2012 were 228 (Figure 4.1).

4.7 Biosafety

The Ministry of Science and Technology of Bangladesh formulated Biosafety Guidelines for the first time in 1999. Bangladesh ratified the Cartagena Protocol on Biosafety (CPB) to the Convention on Biological Diversity on February 5, 2004, which came into force in May 5, 2004. Being the National Focal Point (NFP) of the CPB, the Ministry of Environment and Forest took the lead of establishing biosafety regulatory regime. On May 10, 2008, the Bangladesh Department of Environment issued the Biosafety Guidelines of Bangladesh, and the National Biosafety Framework. In this regard, the Ministry of Environment and Forest also issued Bangladesh Biosafety Rules in 2010 with respect to production, storage, export, import and safe transfer of GMOs.[15] However, the regulatory structures as per the policy are yet to be installed as a result, no biotechnology crop is approved for commercial cultivation.

Bangladesh officially prohibits import (for commercial use) of agricultural products containing bioengineered products. On July 19, 2006, the National Task Force on Biotechnology Development (NTFBD) approved a policy framework and guidelines for biotechnology. The Biosafety Guidelines of Bangladesh have subsequently been updated by the Ministry of Environment and Forests in conformity with the CPB and were published in the National Gazette in January 2008.[16] In order to implement the biosafety guidelines following committees were formed which provided administrative support mechanisms at various levels viz. National Committee on Biosafety (NCB), the Biosafety Core Committee (BCC) and the Field Level Biosafety Committee for monitoring confined field trials. In 2007, Bangladesh developed the National Biosafety Framework (NBF). The Biosafety Framework has been finalized through the process of multi-stakeholder consultation and it lays the foundation for establishing a regulatory regime to ensure safe transfer, handling, transit, trans-boundary movement, development, field trial and commercial release of GMOs. The NBF is complimentary to the national commitments towards implementation of a multilateral environmental agreement like the Cartagena Protocol on Biosafety. The Biosafety regulations have been put in place in 2011.

4.8 Summing Up

Bangladesh has made a good beginning in terms of policy and capacity building. It should maintain the tempo and go further in biotechnology development. Bilateral and multilateral support in human resources development will go a long way in realizing the potential of biotechnology. The need for a dynamic biotechnology industry in private sector is obvious as the government and public sector institutions alone will not be able to sustain the biotechnology development in Bangladesh.

Endnotes

[1] WDI, World Bank Data, 2013.

[2] International Monetary Fund, World Economic Outlook Database, April 2013.

[3] International Monetary Fund, World Economic Outlook Database, April 2013.

[4] International Monetary Fund, World Economic Outlook Database, April 2013.

[5] CIA, The World Factbook, May 2013 .

[6] WDI, World Bank Data, 2013.

[7] World Bank, Knowledge for Development, 2013.

[8] WIPO and INSEAD, The Global Innovation Index, 2012.

[9] Strategic Road Map to Implement Biotechnology Policy in Bangladesh, 2011; http://www.nib.gov.bd/ DraftStrategicActionplanofNational BTPolicy-2011_May15.pdf

[10] Islam A. S. (2007).

[11] http://www.nib.gov.bdDraftStrategicActionplan ofNationalBTPolicy-2011_May15.pdf

[12] GNBB (2007).

[13] Choudhury, Naiyyum and M. Serajul Islam (2005).

[14] For details, please see Choudhary (2005).

[15] http://www.doe-bd.org/BiosafetyRules2010 BangladeshDraft.pdf

[16] Haider (2008).

Chapter 5:
Cambodia

5.1 General Introduction

Cambodia is a low[1] income level country in East Asia and Pacific region [GDP, Current Prices (USD in Billions): 14.2[2]; GDP, Purchasing Power Parity (USD in Billions): 36.6[3]; GDP (PPP) Share of World Total (%): 0.04[4]]. However, since 2010, its real GDP growth rate is rising. UN ESCAP's Economic and Social Survey of Asia and the Pacific 2013 project it to be around 7.3% in its 2012 estimate.[5] Agriculture's share in its GDP is huge [GDP Composition by Sector (%)[6]: Agriculture: 34.7, Industry: 24.3, Services: 41 (2012 estimate) and so is its share in providing employment [Employment (% of total employment)[7] 2011: Agriculture: 55.8, Industry: 16.9, Services: 27.3]. This makes its economy basically agriculture-driven.

Cambodia's status on the parameters of incentive and economic regime, human resource, infrastructure, which are essential factors for knowledge economy and innovation, is dismal. This is reflected in its low ranking in Knowledge Economy Index, where it stands at 132 [Knowledge Economy Index (KEI) 2012 Ranking[8]] as well as in its low ranking in Global Innovation Index [Global Innovation Index 2012 Ranking[9]] where its ranking is 129. It's Expenditure on R&D, 2009 (per cent of GDP, PPP)[10] was mere 0.05, which is very low.

5.2 Specific Initiatives

In order to provide a major fillip to agriculture research the Government of Cambodia approached International Rice Research Institution (IRRI) for research assistance on rice, which later on led to the launching of Cambodia-IRRI-Australia Project (CIAP) in 1989. The efforts through this project laid the foundation stone for the evolution of national agricultural research system in Cambodia. The mini project graduated to a major institutional building block, as CIAP evolved as Cambodian Agricultural Research and Development Institution (CARDI) took off in 1999. This institute hired almost 40 researchers from many domestic agencies including the Ministry of Agriculture's Department of Agronomy and Agricultural Land Improvement and Department of Agricultural Engineering.

CARDI's Training and Information Programme manages all training activities. Annually the CARDI training programme offers 10 to 15 training events, typically attended by over 300 individuals.[11] Resource personnel for training are drawn from CARDI's professional staff, and occasionally are supplemented by individuals from other institutions or organizations external to CARDI. With its links to the international science and agricultural communities, as well as its link to government, CARDI has access to a wide range of expertise and training resources. As a result, Cambodia has relatively strong supply system for distribution of standarised seeds and planting material (see Table 5.1).

CARDI has a team of highly qualified scientists and engineers in agriculture and socio-economic disciplines and is regarded as the leading centre for agricultural research expertise in Cambodia. In 2004, CARDI launched advance research laboratory for conducting biotechnology related research in agriculture. It has been engaged in providing training services for many years and has a well designed and resources training facility located at CARDI. The basic objective of CARDI is "Technology for Prosperity", as a part of which CARDI launched biotechnology research in Cambodia.

According to Channa, CARDI has initiated programme on agriculture biotechnology for achieving greater crop productivity, enhancing resistance to biotic and abiotic stresses and improved agronomic traits. However, due to resource constraints Cambodia relies more on first generation agriculture biotechnology like tissue culture for banana production. In many other areas Cambodia still has to rely on conventional breeding techniques for mass and pure-line selection, conventional crossing, and grafting.[12]

Despite progress made over the years, Cambodia lags behind many countries in the region in health indicators. Dietary diversity in this context is a must, as excessive reliance on cereals for calories results in anemia and micro-nutrient deficiency.[13] In order to strengthen the Cambodian vegetable industry, improve household nutritional levels and replace imports with local produce, ACIAR has supported a three-year project on improvement of vegetable production and post-harvest management systems. Cambodian farmers adopt new agricultural technology very well, especially the use of high-yielding hybrid corn seeds.[14] Charoen Pokphand Group (C.P.) from Thailand has successfully introduced hybrid seeds to Cambodia corn growers. Hybrid seeds dominate about 90-95 per cent of the total corn area. The market share of C.P. hybrid seeds is about 70-80 per cent, while the balance goes to hybrid seeds from Vietnam and other multinational companies.[15]

Table 5.2 gives a list of top performing institutes in Cambodia.

5.3 Patents and Publications

Regarding patent regime in Cambodia, laws in patents, Utility Model Certificate and Industrial Design have been in force since

Table 5.1: Quality Seed and Plant Materials

Category	Classification			
	Foundation seed	**Registered seed**	**Certified seed**	**Graded seed**
A. Seed				
1. Rice	USD 3.13/kg	USD 2.50/kg	USD 1.88/kg	USD 0.50/kg
2. maize	USD 6.25/kg	USD 4.36/kg	USD 3.13/kg	USD 1.50/kg
3. Mungbean	USD 6.25/kg	-	-	USD 1.50/kg
4. Tomato	USD 6.25/g	USD 4.38/g	USD 3.13/g	USD 1.25/g
5. Watermelon	USD 1.25/g	USD 0.94/g	USD 0.63/g	USD 0.31/g
B. Seeding and plant propagation materials (CARDI nursery)				
			Age at 6 months	**Age at 3 months**
6. Mango seedling			USD 3.50/plant	USD 2.5/plant
7. Banana tissue culture plantlet (made available by prior purchase order only)				USD 0.40 plantlet

Source: CARDI (www.cardi.org.kh)

Table 5.2: Top Ranking Institutions in Cambodia

Top Ranking Institutions based on Publications in 'Biotechnology and Applied Microbiology' in the period 2001-2
Institute Pasteur
Institute of Technology of Cambodia
National Institute of Public Health

Source: Thomson Reuters' Web of Science Database, 2013.

January 2003. This Law was supplemented on June 29, 2006 by Prakas (Decree) No. 706 on Procedure granting Patent and Utility Model Certificates.[16] Also, laws concerning Marks, Collective marks, Trade names and Acts of Unfair competition have been in force since February 2002. As for the industrial property statistics, the number of applications filed by residents and non-residents in 2003 is 297 and 1559, respectively while the number of applications granted to the same are 270 and 1548, respectively.

Publications in biotechnology are insignificant while patents in biotechnology were nil.

5.4 Biosafety

The objectives of the government in biotechnology and biosafety are:

- Use of biotechnology to reduce the use of chemicals.
- Use of biotechnology to control pollution and to improve environmental health and other aspects of environment.
- Provide capacity for monitoring and enforcement to concerned ministries, NGOs and universities.
- Build capacity in appropriate labs in Cambodia to be able to identify LMOs.
- Utilize biotechnology to produce protein rich products that could be used as animal feed, organic fertilizers, soil conditioners and soil stabilizers.
- Promote sound genetic manipulation to increase fish and crop production.
- Promote the production of biogas, bio-fertilizers, and energy as a by-product of fermentation processes.
- Establish a national directory of human resources working on subjects concerned with biotechnology and biosafety.
- Develop a biotechnology training programme including risk assessment and risk management of LMOs.
- Increase university resources in biotechnology research and development.
- Develop a National Code of Ethics and Guidelines for the use of biotechnologies, LMOs and GMOs.

Cambodia also developed National Capacity Action Plan to address the objectives of the three UN Conventions (UNCBD, UNFCCC, and UNCCD) and identified 160 priority actions for implementation over a period of 10 years (2007-2016).

5.5 International Agreements

Cambodia singed the Cartagena Protocol on Biosafety in 2003. The progress in relation to the protocol includes adoption of national law on Biosafety (2007), the extension of the mandate of the National Biodiversity Committee to also cover the biosafety issues. Cambodia developed its Guidelines for Risk Assessment and Risk Management of Living Modified Organisms in 2007 and a draft National Action Plan on Biosafety and Biotechnology is developed in 2008. A biosafety clearing house is thus established with the Ministry of Environment for sharing information with the CBD secretariat and other Parties to the Protocol.

5.6 Summing Up

It is clear that Cambodia has a long way to go in biotechnology. The modest beginning needs assistance from other countries and international agencies. Cambodia is rich in biodiversity and its plans for biotechnology can focus on increasing agricultural productivity through biotechnology and conservation and sustainable use of biodiversity.

Endnotes

1 WDI, World Bank Data, 2013.

2 International Monetary Fund, World Economic Outlook Database, April 2013.

3 International Monetary Fund, World Economic Outlook Database, April 2013.

4 International Monetary Fund, World Economic Outlook Database, April 2013.

5 UNESCAP (2013). *Economic and Social Survey of Asia and the Pacific*.

6 CIA, The World Factbook, May 2013.

7 WDI, World Bank Data, 2013.

8 World Bank, Knowledge for Development, 2013.

9 WIPO and INSEAD, The Global Innovation Index 2012.

10 UNESCO Science Report, 2010.

11 Homepage: CARDI (www.cardi.org.kh). Last accessed on July 31, 2009.

12 Channa *et al*. (2004).

13 Integrated Food Security and Humanitarian Phase Classification (IPC) Pilot in Cambodia World Food Programme. http://www.ipcinfo.org/attachments/Fullreport_IPC_Cambodia_WFP_may2007.pdf

14 GAIN (2006).

15 GAIN (2006).

16 Cambodia, Law on Patents, Utility Models and Industrial Designs, WIPO Resources. http://www.wipo.int/wipolex/en/details.jsp?id=5781

Chapter 6:
China

6.1 General Introduction

China is an upper middle income level[1] country in East Asia and Pacific region. It is the second largest economy in the world today after USA [GDP, Current Prices (USD in Trillions): 8.26[2]; GDP, Purchasing Power Parity (USD in Trillions): 12.4[3]; GDP (PPP) Share of World Total (%): 14.9[4]]. Industry's share in its GDP is more than the other two sectors, i.e. agriculture and services [GDP Composition by Sector (%)[5]: Agriculture: 10.1, Industry: 45.3, Services: 44.6 (2012 estimate)]. This highlights the prominent role of industries in the economy of China. However, agriculture is the major employment-giving sector [Employment (% of total employment)[6] 2010: Agriculture: 36.7, Industry: 28.7, Services: 34.6].

As far as, research and development is concerned, China spends enormous capital into it. Its Gross Expenditure on R&D in 2012 [GERD] (USD in Billions, PPP)[7] was 197.3 and its expenditure on R&D in 2012 (per cent of GDP, PPP)[8] was 1.6. Its present status on Global Innovation Index is 34 [Global Innovation Index 2012 Ranking[9]]. However, in Knowledge Economy Index, it is in top 100 countries [China's Knowledge Economy Index (KEI) ranking in 2012 was[10] 84], which is not very much encouraging.

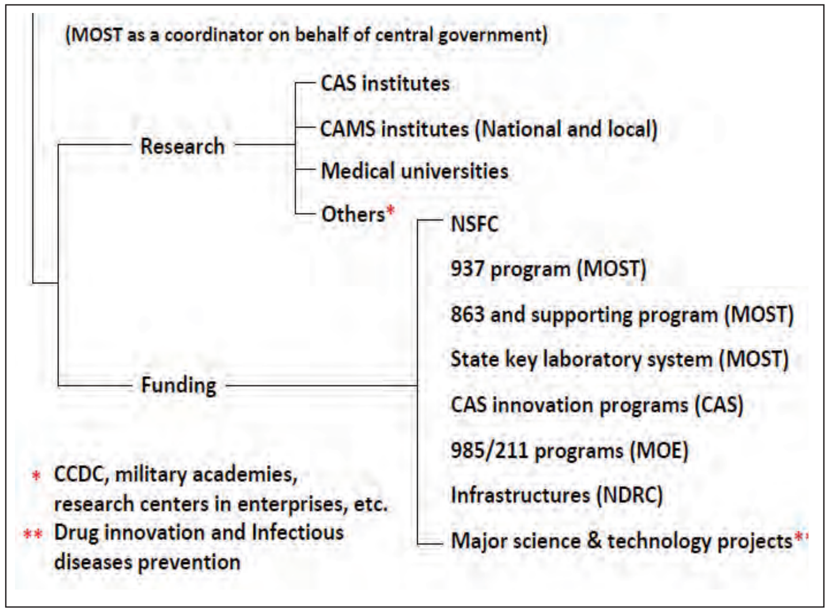
Regarding human resource in research, China had 863 researchers per million of its population in 2009.[11] China is among the top countries in terms of patent applications filed by its residents at PCT. In 2011, 415829 patent applications were filed by Chinese residents.[12]

6.2 Biotechnology in China

Beginning in the early 1980s when China prepared to initiate its national biotechnology programme, its biotechnology developmental goals were multifaceted. The government defined its goals in terms of improving the nation's food security, promoting sustainable agricultural development, increasing farmers' income, improving the environment and human health, and raising its competitive position in international agricultural markets along with other public agricultural development programmes. And from the point of view of the technology itself, the most frequently stated goal was to create a modern, market-responsive, and internationally competitive biotechnology research and development system in China.

The earliest plan to promote biotechnology research was initiated in the beginning of the "Seventh Five-

Figure 6.1: China's Biotechnology Research System



Source: Johnson (2012).[14]

year Plan" (1986-1990) when the first comprehensive National Biotechnology Development Policy Outline was issued. This outline was prepared under the leadership of the Ministry of Science and Technology (MOST), the State Development and Planning Commission (SDPC), and the State Economic Commission in 1985 and further revised in 1986. The outline defined research priorities, the development plan (e.g., the "863 Plan"), and measures to achieve targets or goals. Under this outline, a number of high-profile technology programmes were launched after the middle 1980s.

With the continuous expansion of these programmes, China now has more than 150 laboratories and more than 50 research institutions engaged in frontier areas of biotechnology. China is among the few countries of the world, in which R&D expenditure and number of R&D personnel, both have gone up in a major way. In the period 2006-2010, the R&D expenditure went up by 20 per cent annually while the number of R&D personnel went up by 87 per cent.[13]

The Ministry of Science and Technology (MOST) is the major nodal agency in China's life sciences and biotechnology research system. Figure 6.1 gives a schematic representation of the biotechnology R&D organizational set up.

6.2.1 Institutions and Human Resources

Higher education institutions established many R&D centres to carry out S&T activities. There are various forms of these institutes: over 2/3 were established independently by higher education institutions, and some were jointly established with other higher education institution, and some with domestic or foreign enterprises, etc. In 2005, R&D institute of all forms established by higher education institutions were 3936. In terms of the composition of R&D institute, 78 per cent covered the fields of science, engineering, agriculture and medicine, and 22 per cent touched the field of social sciences and humanities. About 4.1 million personnel were engaged in S&T programmes in 2006 out of which 1.5 million were engaged in R&D. Most of these institutes focus on R&D activities, among which state laboratories, state key laboratories and state specialized laboratories highlight scientific research, while other R&D institutes are engaged in knowledge innovations as well as S&T activities pertaining to technological innovation.[15]

Table 6.1 gives the list of main institutional actors in biotechnology in China.

6.3 Programme Framework and Funding

For the development of biotechnology Chinese government has initiated many programmes. Some of the most significant programmes included the "863 High-tech Plan," the "973 Plan," Natural Science Foundation of China, the Initiative of National Key Laboratories on Biotechnology, the Special Foundation for Transgenic Plants Research and Commercialization, the Key Science Engineering Programme, the Special Foundation for High-tech Industrialization (or Commercialization), the Bridge Plan, and others.

The Ministry of Agriculture and Ministry of Health also fund progammes related to biotechnology. The NSTP has three major components which generally support biotechnology and other related initiatives. The National Nature Science Foundation of China is another source for supporting biotechnology. The research under programme 863 is on biology and medicine while the National Key Technologies R&D Programme focuses on agriculture alone. The focus under programme 973 is on basic research aspects of biotechnology which is also being supported by the National Basic Research Programme through its grant for protein research projects. The National Nature Science Foundation of China (NNSFC) provides allocations for capacity building for young scientists and to some extent also supports basic research.

From 2006 to 2010, China's government expenditure for S&T increased 25 per cent annually and Gross Domestic Expenditure on S&T Research and Development increased from 300 billion Yuan to 706 billion Yuan, according to 1.76 per cent of China's GDP.[16]

6.3.1 Hi-Tech Research and Development Programme (863 Programme)

It was launched by the Ministry of Science and Technology in 1987 as a leading science and technology initiative and was termed as the National Hi-Tech R&D Programme. Its generic areas of funding are agriculture, medical, animal and environmental sectors but the programme 863 is also a major programme to support biotechnology and within that medicine related research in China. The budget

Table 6.1 Top Ranking Institutions in China

Top Ranking Institutions based on Publications in 'Biotechnology and Applied Microbiology' in the period 2001-2012
Chinese Academy of Sciences
Zhejiang University
Shanghai Jiao Tong University
Tsing Hua University
China Agricultural University
East China University of Science and Technology
Chinese Academy Of Agricultural Sciences
Jiangnan University
Central South University
Shandong University

Source: Thomson Reuters' Web of Science Database, 2013.

for this programme has continuously expanded from 3.8 billion yuan in 2006 to 5.7 billion yuan in 2009. In 2009, about 296 million yuan (5.2 per cent) was for biotechnology and 268 million yuan (4.7 per cent) for agriculture (Table 6.2).

6.3.2 National Key Technologies R&D Programme

In 2009, the fund was 29 billion yuan, of which 5 billion yuan came from the centre finanace. In this programme, the total budget for Biotechnology is around 1.46 billion yuan, and 0.97 billion yuan (19 per cent) was allocated for the development of agriculture biotechnology. This programme also provided support to the development of select areas of medical biotechnology as well.[18]

6.3.3 Programme 973

This programme is also termed as National Basic Research Programme. In this programme, the primary focus are on agriculture, population and health, protein research, development and reproduction. In 2009, central allocation on this Programme was 2.6 billion yuan, and the share of biotechnology in the allocation was about 0.89 billion yuan.[19]

6.3.4 National Nature Science Foundation of China (NSFC)

This Foundation is largely working in terms of enhancing basic research capacities in China and also trying to create strong base of scientists and technical manpower to work at junior level. The scientists have tried to ensure that the system should help in term of tapping potential of Chinese students. The budgetary allocation for this programme in 2009 was 4.4 billion yuan, out of this nearly 1.5 billion yuan (34per cent) is for life sciences (Table 6.4). In 2010, 13 thousand general projects were approved with total 4.5 billion yuan. Among the projects, 3163 projects were in medical area with 1 billion yuan amounting to 22 per cent of total budgets and 2250 projects were in biotechnology area with 0.73 billion Yuan amounting to 16 per cent of the total.[20]

6.3.5 Innovation Fund for Technology based firms (IFT)

The Ministry of Science and Technology launched this programme in 1999. The budgetary allocation for this programme went up to 353 million yuan in 2010. This programme has focused on firms dealing in agriculture, medical, animal

Table 6.2: Budget of 863 Programme and the Share of Biotechnology Programmes

Year	Total Budget (million $)	Share of Biotechnology Programmes (%)
2000	112.5	25
2001	206.25	27
2002	537.5	33
2003*	384.4	26.8
2004*	468.75	22.6
2005*	511.9	18.5
2006*	772.72	33.8
2007*	794.58	17.21
2008*	744.1	15
2009*	835.77	9.9

Note: *www. most.gov.cn; Annual Report of The State Programmes of Science and Technology Development (2007, 2008, 2009, 2010) and Zhe (2010).[17]

Source: Xielin and Jinhui (2007) based on Annual Reports on 863 Programme, www.863.org.cn.

Table 6.3: Key Biotechnology Supporting Programmes in China

S. No.	Agency	Programme Details	Biotechnology Allocation
(i)	National Hi-Tech R&D Programme	863 programmes	0.57 billion Yuan (2009)
(ii)	National Key Technologies R&D Programme	-	1.46 billion Yuan (2009)
(iii)	National Basic Research Programme	973 programmes	0.89 billion Yuan (2009)
(iv)	National Nature Science Foundation of China (NNSFC)*	-	1.18 billion Yuan (2009)

Note: *budget for general programme.
Source: Annual Report of the State Programs of Science and Technology Development 2010.

and environmental biotechnology. The programme requires private sector recipients of this fund to make equal amount of investment for R&D purposes. These initiatives have provided a major boost to the growth of the private sector.[21]

6.3.6 Biotechnology Development Plan

The government continues to invest heavily in biotechnology. It committed over $238 million in life sciences and biotechnology from 1996 to 2000, and significantly increased this amount to $795 million from 2001 to 2005. In the Twelfth Five-Year Plan (2011-2015), biotechnology is set to receive $1.7 trillion in government funding, and at least $1.5 billion for new drug development alone. Development priorities will include biopharmacy, bioengineering, bioagriculture and biomanufacturing.[22] The goal of this plan is to consolidate biological research and industrial foundation, participate actively in the international biology industry development, and improve biology industry to sever as one of China's pillar industry. Some of key issues are as follows.[23]

1) To improve the biological technology and industrial development coordination mechanism. Resources of different national science and technology plan will be connected and integrated more scientifically and effectively.
2) To establish a multi-channel financing mechanism and strengthen the support of financial and taxation policy. The Chinese central government will

Table 6.4: Budget of NSFC and Expenditure on Life Science and Biotechnology, US$ Million

Year	Total Budget	Expenditure on life science and biotechnology
2004	281.2	93.7
2005	337.7	112.6
2006*	431.30	145.70
2007*	426.44	142.18
2008*	578.35	193.39
2009*	641.02	216.52
2010*	868.19	137.13
2011*	1710.99	271.00

Note: *The total budget includes general programme, major programme and young scientist fund.

Source: Xielin and Jinhui (2007) and based on Annual Reports of NSFC from www.nsfc.gov.cn; Annual Report of National Natural Science Foundation of China 2006-2011.

establishment the emerging industry fund to guide social investment.

3) To encourage the combination among enterprises, universities and institutes enterprises, institutes and universities are encouraged to jointly develop and transform biological technology, build national engineering laboratory.

4) To perfect the system of intellectual property. The government will intensify IPR protection, improve the biological resources and technology by intellectual property laws and regulations, and optimize the procedures for IPR to shorten the approval time.

5) To expand international and regional cooperation. The government will support various research organizations to actively participate multinational corporations for development of new products, and encourage them and foreign research organizations to establish R&D centers both in China and other countries.

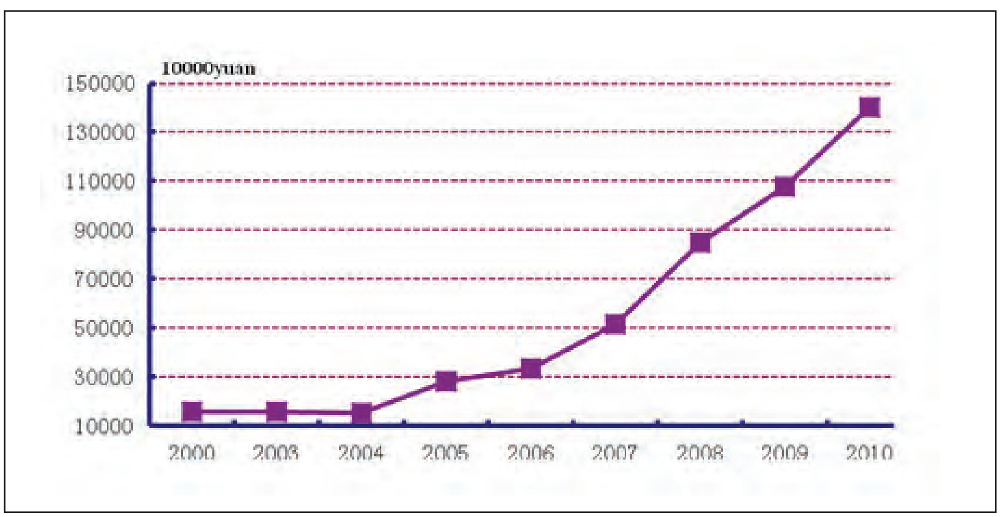
6.4 Biotechnology Industry

Against the background of improvement in intellectual property protection, multinational companies have begun moving parts of their R&D operations to China to cut research costs, speed up new products launches and improve market access. Twenty seven of the world's 30 multinational pharmaceuticals now have manufacturing and sales operations in China.[24]

Bio-industry has received a major boost as more and more expenditure is done for developing new products. About 0.15 billion yuan were invested annually in developing new products but the amount was not enhanced distinctly from 2000 to 2004. After 2004, the condition was changed markedly and the annual average increasing rate is 53 per cent. In 2010, the expenditure reached to 1.4 billion, accounting for 59 per cent of the total expenditures on biotechnology activities and revealing the accelerating progress of industrialization (Figure 6.2).

For China's biotechnology agriculture market, the value is almost 51 billion yuan in 2008, including biotechnology breeding (70 per cent), animal vaccine (10 per cent), biotechnology forage (8 per cent) and biotechnology pesticide (12 per cent).[25]

Figure 6.2: Expenditure for Developing New Products



Source: National Bureau of Statistics, National Development and Reform Commission, Ministry of Science and Technology, 2009. China Statistics Yearbook on High Technology Industry (2011). Published by China Statistics Press. The statistic data is based on "Manufacture of Biotechnology and Biochemical Products".

6.5 Publications and Patents

China is one of the leading countries in biotechnology publication.

China's Publications in Research Area 'Biotechnology and Applied Microbiology' in the period 2001-2012 was 24544.

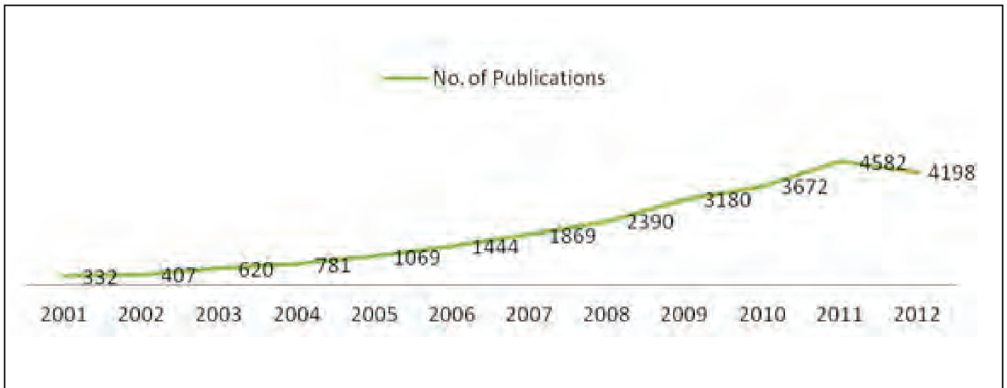
The following figure (Figure 6.3) gives the picture of China's publication in research area 'Biotechnology and Applied Microbiology' in the period 2001-2012.

In China, attention on patents as an important index of S&T activities' outcome, especially in relation to demonstrate R&D contribution, is growing at a high pace. The number of applications for Biotechnology Patents was just 840 in 1995 after which it increased continuously and reached 5000 mark in 2000 (Figure 6.4). However, the number did drop to about 900 in 2006. The increased patents also reveal the industrial progress that is based on the technical advancement.

China's share in biotechnology patents filed under PCT in the period 2008-10 was 3.12 and China's revealed technological advantage in biotechnologies decreased from 4.4 in 1998-2000 to just 0.5 in 2008-2010.[26]

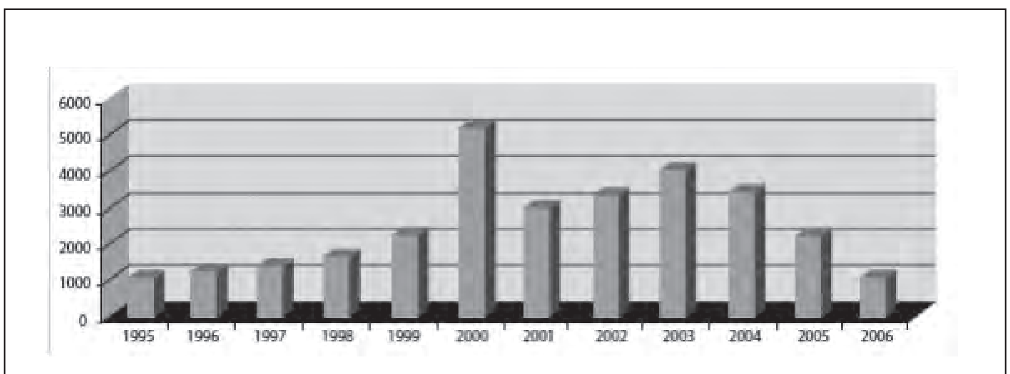
Figure 6.5 presents China's patenting in Biotechnology in USPTO in the period 2001-2012.

Figure 6.3: Publication in Research Area 'Biotechnology and Applied Microbiology'



Source: Thomson Reuters' Web of Science Database, 2013.

Figure 6.4: Number of Patent Applications for Biotechnology



Source: Prabuddha Ganguli, Ben Prickril, Rita Khanna, Technology Transfer in Biotechnology: A Global Perspective Bonn: Wiley-VCH.

6.6 Regulation of Biotechnology

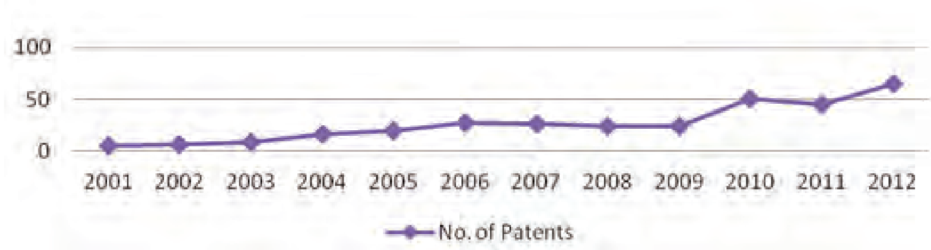
The first biosafety regulation, "Safety Administration and Regulation on Genetic Engineering," was issued by the Ministry of Science and Technology (MOST) in 1993. This regulation consisted of general principles, safety categories, risk evaluation, application and approval, safety control measures, and legal responsibilities. After the above regulation was decreed, MOST required relevant ministries to draft and issue corresponding biosafety regulations on biological engineering (i.e., the Ministry of Agriculture for agriculture and the Ministry of Public Health for food safety). Following MOST's guidelines, the MOA issued the Implementation Regulations on Agricultural Biological Engineering in 1996. This regulation is similar in many aspects to the US GMO biosafety regulations. Labeling was not part of this regulation, nor was any restriction imposed on imports or exports of GMO products. The regulation also did not regulate processed food products that use GMOs as inputs.

Since 1999-2000, nearly all biotechnology research programmes have expanded their scope into biosafety issues, particularly for the following programmes: 863, 973, and the Special Foundation for Transgenic Plants Research and Commercialization. A number of national institutes under the Ministry of Agriculture, the Ministry of Public Health and the State Environmental Protection Agency have launched various biosafety programmes, including capacity building for biosafety management and risk assessment, research studies on environmental safety and food safety, detection technology for GMOs and GMO products, and monitoring of international practices.

With the continued development of agricultural biotechnology, rising GMO imports and in response to consumers' concerns, China has periodically amended its biosafety regulations since 2001. In May 2001, the State Council decreed a new regulation to replace the previous one issued by MOA in 1996. This amended national "Regulation on the Safety Administration of Agricultural Transgenic Organisms," includes trade regulation and labeling of GM farm products, which became effective after 23 May 2001. Based on this new regulation, the MOA issued three implementing regulations on biosafety management, trade, and labeling of GM products that became effective after 20 March 2002.

These amended regulations from 2002 encompassed trade and labeling of GM products, and were promulgated in response to rising imports of GM products, particular GM soybean and edible oils, and

Figure 6.5: Patents Granted in Biotechnology at USPTO in the period 2001-2012



Source: Thomson Innovation Database, 2013.

the growing presence of GM foods in the market. These regulations established a "zero tolerance level for unapproved GM products" in both import and labeling. Labeling requirements now pertain to 17 products from 5 crops. They are soybean seeds, soybeans, soy flour, soy oil, soy meal; corn seeds, corn, corn oil, corn flour; rape seeds for planting, rape seed, rape seed oil, rape seed meal; cotton seeds for planting; tomato seeds, fresh tomatoes, and tomato sauce. Detailed regulations and procedures for GM product import approval authorizations have also been developed and implemented since 2002.[27]

The MOA is the primary institution in charge of implementing the agricultural biosafety regulations. The governing body under MOA is the Leading Group on Agricultural GMO Biosafety Management, which oversees the Agricultural GMO Biosafety Management Office (BMO). The biosafety assessments are conducted by the National Agricultural GMO Biosafety Committee (BC). Currently, the BC meets three times each year to evaluate all biosafety assessment applications related to experimental research, field trials (small scale trial), environmental release (medium scale field trial), pre-production trial (large scale field trial), commercialization of agricultural GMOs, and events for import. The BC undertakes biosafety assessments. Based on the BC's technical assessments and other considerations (e.g., social, economic and political factors), the BMO prepares the recommendations to the MOA's Leading Group which is tasked with taking approval or disapproval decisions.

It can be said that while the Ministry of Science and Technology is mainly responsible for biotechnology research, the Ministry of Agriculture is the primary institution in charge of the formulation and implementation of biosafety on agriculture biotechnology and their commercialization, particularly after 2000 and the Ministry of Public Health is responsible for food safety management of biotechnology products. The State Environmental Protection Authority has taken up the responsibility of international Biosafety Protocol and most of international activities. China signed the Cartagena Protocol in August 2000 and ratified it in June 2005.

6.7 Summing Up

Government's active role in funding biotechnology R&D is showing the results in terms of innovative products and trade. The large pool of trained human resource and strong infrastructure in China are helping in promoting biotechnology research and product development in a huge way. The establishment of biotechnology-related industrial clusters across the country and providing industries with incentives and conducive environment is having a positive effect on biotechnology trade related growth.

Endnotes

1 WDI, World Bank Data 2013.

2 International Monetary Fund, World Economic Outlook Database, April 2013.

3 International Monetary Fund, World Economic Outlook Database, April 2013.

4 International Monetary Fund, World Economic Outlook Database, April 2013.

5 CIA The World Factbook, May 2013.

6 WDI, World Bank Data, 2013.

7 Global R&D Funding Forecast 2013, Battelle and RDMag.com, 2012.

8 Global R&D Funding Forecast 2013, Battelle and RDMag.com, 2012.

9 WIPO and INSEAD, The Global Innovation Index 2012.

10 World Bank, Knowledge for Development, 2013.

11 WDI, World Bank Data, 2013.

12 WDI, World Bank Data, 2013.

13 MOST (2010). *China Science and Technology Development Report.* Scientific and Technical Documentation Press.

14 Johnson, R.A. (2012). "Emerging Trends and Drivers in the Global Biotechnology Industry". BWC Briefing, Geneva, Switzerland.

15 Zhe, Li (2010). "History, Hot Spots and International Cooperation of Biotechnology in China". 5th Asian Biotechnology Development Conference Presentation, Candy , Sri Lanka.

16 MOST (2010). *China Science and Technology Development Report*. Scientific and Technical Documentation Press.

17 Zhe, Li (2010). "History, Hot Spots and International Cooperation of Biotechnology in China". 5th Asian Biotechnology Development Conference Presentation, Candy , Sri Lanka.

18 Zhe, Li (2011). "Developemnt of Biotechnology in China", *Asian Biotechnology Development Review,* Vol. 13, No. 1, March. New Delhi: RIS.

19 *ibid.*

20 *ibid.*

21 Zhe, Li (2010). "History, Hot Spots and International Cooperation of Biotechnology in China". 5th Asian Biotechnology Development Conference Presentation, Candy , Sri Lanka.

22 Cao, C. (2010). "Biotechnology in China". Available at: www.apcss.org/wp-content/uploads/2012/12/Cong-Cao.pdf.

23 Zhe, Li (2010). "History, Hot Spots and International Cooperation of Biotechnology in China". 5th Asian Biotechnology Development Conference Presentation, Candy , Sri Lanka.

24 Shan, James (2008).

25 Zhe, Li (2010). "History, Hot Spots and International Cooperation of Biotechnology in China". 5th Asian Biotechnology Development Conference Presentation, Candy , Sri Lanka.

26 OECD, Biotechnology Statistics Database, December 2012.

27 Huang, J. and J. Yang (2011). "China's Agricultural Biotechnology Regulations—Export and Import Considerations". International Food and Agricultural Trade Policy Council, Washington DC, USA.

Chapter 7:
India

7.1 General Introduction

India is a lower middle income level country in South Asia region.[1] It has the third largest GDP (PPP) in the world [GDP, Current Prices (USD in trillions): 1.8[2]; GDP, Purchasing Power Parity (USD in Trillions): 4.7[3]; GDP (PPP) Share of World Total (%): 5.6[4]]. Its economy is dominated by services sector [GDP Composition by Sector (%)[5]: Agriculture: 17, Industry: 18, Services: 65 (2012 estimate)], however, agriculture is the major employment sector [Employment (% of total employment)[6] 2010: Agriculture: 51.1, Industry: 22.4, Services: 26.6].

As far as R&D in India is concerned, the expenditure in R&D is not much given its economy size as it spends less than 1 per cent of its GDP on R&D [India's Gross Expenditure on R&D in 2012 (US$ in billions, PPP)[7] was 40.3 and its expenditure on R&D in 2012 (per cent of GDP, PPP)[8] was 0.85]. The number of researchers per million of its population was also below average than most of the other countries [Researchers in R&D (per million people)[9] in India was 135.8 in 2005].

India's ranking in Global Innovation Index is 64 and its ranking in Knowledge Economy Index is 110 [Knowledge Economy Index (KEI) 2012 Ranking[10]; Global Innovation Index 2012 Ranking[11]].

7.2 Biotechnology in India

India is among the first countries in the developing world to have declared the importance of biotechnology as a tool for advancing growth in the agriculture and health sectors. The Government of India established the National Biotechnology Board in 1982 as the apex body to identify priority areas and evolve a long term plan for the development of biotechnology which later graduated to the Department of Biotechnology. The National Biotechnology Strategy was approved by the Government of India in 2007-08.

7.2.1 Institutions and Human Resources

A number of post graduate courses on biotechnology are being offered at 70 universities across the country in 2012-13.[12] To provide all-India representation, maintain uniformity and ensure selection of quality students, admissions for PG programmes in biotechnology are done through a Common Entrance Test conducted by Jawaharlal Nehru University at 53 centres across the country.

Table 7.1 gives the list of top performing institutes in India in the field of biotechnology.

New Human resource development initiatives:[13]

- Introduction of BET a new JRF scheme-500

- Improvement of undergraduate life science education-Star College Competitive Grant-60
- New PG courses in applied disciplines-12
- New Post Doctoral Fellowships (PDF) programme-394 (20 NE)
- Attracting scientist from abroad
- Welcome Trust-DBT-70
- Ramalingaswamy fellowships-90
- Support to young scientist and researchers- 150 R&D projects
- Schemes for gain full employment of women scientists- 90- Ist batch
- Renewed Biotech industry training for PG students-2223
- University life sciences redesign scheme (12 State and 3 central)

New Institutions[14]

- Translational Health Science Technology Institute, Faridabad
- Institute for Stem Cell Science and Regenerative Medicine, Bengaluru
- National Institute of Agri-food Biotechnology and Food Bioprocessing Unit, Mohali
- Regional Centre for Biotechnology Training and Education (UNESCO), Faridabad
- Institute of Biomedical Genomics, Kalyani
- National Institute of Animal Biotechnology, Hyderabad

7.3 Programme Framework and Funding

The National Biotechnology Board was set up in 1982 as in apex agency to spearhead the development of biotechnology in India. It was chaired by a Science Member of the Indian Planning Commission with representation from almost all prominent S&T agencies in the country. The NBB was formed with the specific purpose of the identification of priority areas and for evolving a long term plan for the country. The NBB, through the " Long Term Plan in Biotechnology for India" in April 1983, spelt out priorities for biotechnology in India in view of national objectives such as self sufficiency in food, clothing and housing, adequate health and hygiene, provision of adequate energy and transportation, protection of the environment, gainful employment, industrial growth and balance in international trade. Later, in 1986, NBB graduated to the Department of Biotechnology.

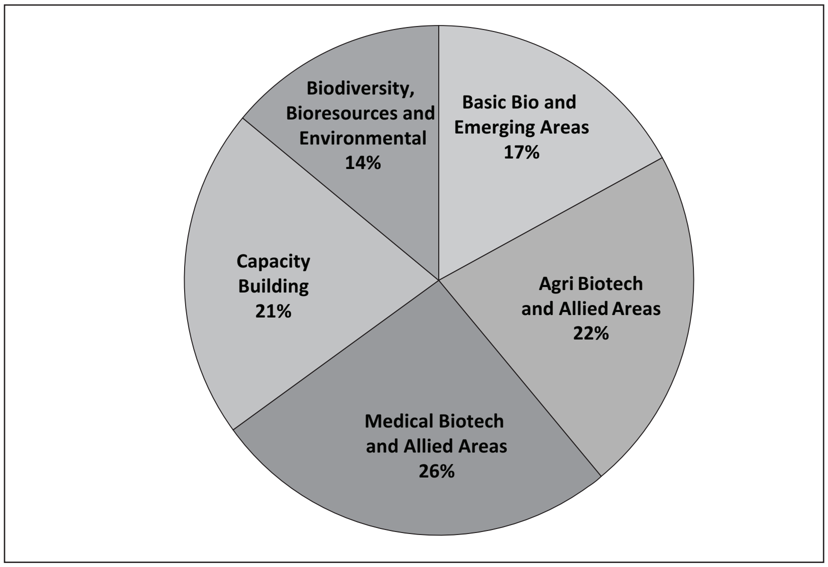
At present, there are seven major agencies in India responsible for financing and supporting research in the realm of biotechnology apart from other sciences.

Table 7.1: Top Ranking Institutions in India

Top Ranking Institutions based on Publications in 'Biotechnology and Applied Microbiology' in the period 2001-2012
Council of Scientific and Industrial Research (CSIR)
Indian Institutes of Technology (IITs) (Delhi, Kanpur, Mumbai, Chennai, Kharagpur)
University Of Delhi
Banaras Hindu University
Indian Agricultural Research Institute
Bhabha Atomic Research Center
Indian Institute Of Science (IISC) Banglore
University of Mumbai
University of Pune
Anna University Chennai

Source: Thomson Reuters' Web of Science Database, 2013.

Figure 7.1: Sector-wise Allocation of Budget during the 12th Plan Period (2007-12)



Source: Presentation by SR Rao at 6th ABDC, Hyderabad, India, 2012.[15]

They are:

- Department of Biotechnology (DBT)
- Department of Science and Technology (DST)
- Indian Council of Agriculture Research (ICAR)
- Indian Council of Medical Research (ICMR)
- University Grants Commission (UGC)
- Department of Scientific and Industrial Research (DSIR)
- Council of Scientific and Industrial Research (CSIR)

The DBT, DST and DSIR are part of the Ministry of Science and Technology, while ICMR is with the Ministry of Health, ICAR with the Ministry of Agriculture and UGC with the Ministry of Human Resource Development.

Figure 7.1 shows that medical biotech and allied services have got maximum budget share followed by agri-biotech and allied services.

The Department of Biotechnology was allocated INR 1317.72 crores for the year 2012-13.[16] In the 12th Five-Year Plan, DBT's budgetary support has been raised by 143 per cent from the 11th Plan support. An indicative plan outlay of INR 11,804 crore at current prices for the Twelfth Five Year has been made for the DBT.[17]

7.3.1 National Biotechnology Development Strategy

The National Biotechnology Strategy was approved by the Government of India during the year 2007-08. With this strategy, government recognizes that biotechnology is a sunrise sector and hence, needs focused attention. The key elements of this strategy are as follows:[18]

- Reinforcing the regulatory framework through establishing a National Biotechnology Regulatory Authority;
- Ensuring Inter-ministerial coordination;
- Promoting biotech industries by investing 30 per cen of DBT's budget on public-private partnership programmes, expanding Small Business Innovation Research Industry (SBIRI) scheme;
- Building world-class human capital through programmes such as Star

Colleges in Life Sciences, UNESCO Centres, focus on the young, reversing brain-drain, centers of excellences in biotechnology, etc.;

- Launching new initiatives for technology transfer and IP-related capacity building;
- Meeting basic societal needs; and
- Leveraging international partnerships.

7.4 Biotechnology Industry

According to a recent report, the Indian biotechnology industry has evolved over the last three decades to a mid maturity stage. Over the last decade the sector's revenues have rapidly increased from US$ 500 million in 2003 to US$ 4 billion in 2011, growing at an average rate of 20 per cent year-on-year. If a favourable business environment is created, the biotechnology and healthcare sectors combined will be able to grow at a rate of 25-30 per cent and have the potential to generate revenues of US$ 100 billion by 2025.[19]

The size of Indian Biotech Industry is continuously increasing. The industry has gained momentum and is on the roll. This is further evident from the fact that about 10-12 years back there was no biotechnology industry to speak of in India. However, since 2002, there is promising growth of Indian biotechnology industry[20] (Figure 7.2).

Chaturvedi noted that while in 2001 the number of biotechnology industry in agriculture was 85 and in human health 43; by 2003, this ratio increased to 132 in agriculture and142 in human health.[21] There were more than 400 biotechnology firms in 2010, employing some 50,000 scientists. On the emergence of bioinformatics market in India, he further says that 'some of the major ICT firms have also joined the biopharmaceutical industry facilitating convergence of biopharma sector with bioinformatics as a result of this, the biotechnology clusters have fast emerged in the areas, which were already regarded as a forte of ICT firms.'[22]

The segment-wise total revenue of Indian biotechnology industries are shown in Table 7.2.[23]

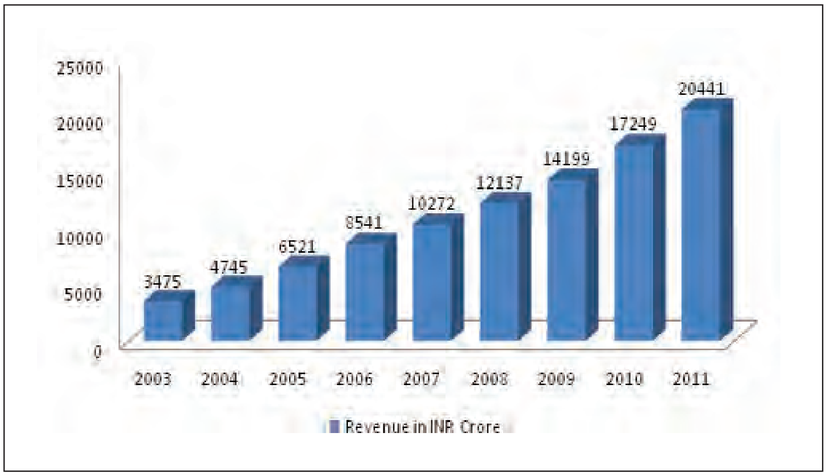
Biotechnology plays a crucial role in providing solutions to the food security, fuel security and healthcare, which are important issues for India. In particular, biotechnology opportunities for India predominantly lie in biologics, especially biosimilar and vaccine manufacturing, stem cells, medical devices and diagnostics, contract research and manufacturing. Other areas of future growth includes integrating scientific evidence-based traditional knowledge into healthcare, agribiotechnology and green biotechnology, especially bioremediation and bioenergy.[24]

Table 7.2: Indian Biotech Market Segment Revenue Growth

Segment	2011-12	2010-11	% change
	TotalRevenue (In INR Crore)	Total Revenue (In INR Crore)	
Biopharma	1 2679.00	10645.00	19.00%
Bioservices	3749.00	3245.97	15.50%
Bioagri	3050.00	2480.00	23.00%
Bioindustrial	696.00	625.94	11.20%
Bioinformatics	266.00	252.43	9.60%
Total	**20441.00**	**17249.34**	**18.50%**

Source: Biospectrum-ABLE Survey, 2011-12.

Figure 7.2: Growth in Biotech Industry Revenue, 2002-2012



Source: Biospectrum-ABLE Survey, 2011-12.

7.5 Patents and Publications

India has shown a gradual progress in biotechnology innovation indicators over a period of time.

India's share in biotechnology patents filed under PCT in the period 2008-10 was 1.11 per cent which is clearly an improvement on its 2006 share of just 0.9 per cent.[25]

Figure 7.3 depicts India's performance in biotechnology patenting in the period 2001-2012.

Patents Granted in 'Biotechnology' in USPTO in the period 2001-2012 were 387.

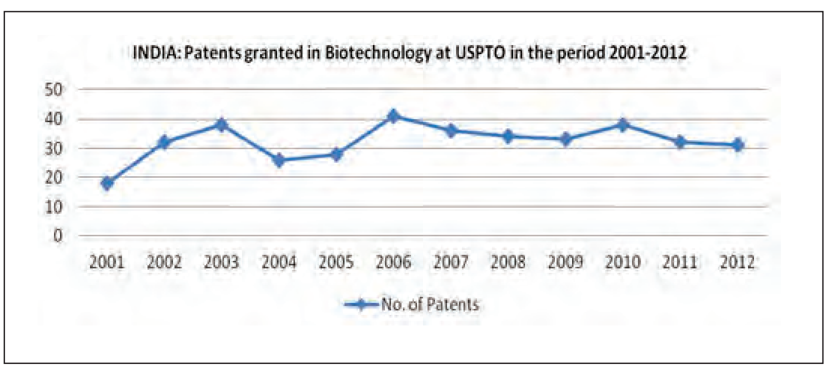
India's revealed technological advantage in biotechnologies in the period 2008-10 was 1.1, which is better than that of Korea, Japan and China.[26]

Figure 7.4 shows India's publications in research area 'Biotechnology and Applied Microbiology' in the period 2001-2012, which in total was 11,775.

7.6 Regulation of Biotechnology

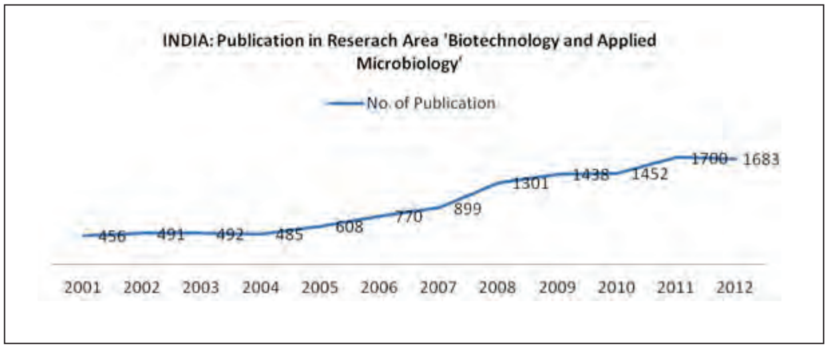
India is a signatory to the Cartagena Protocol on Biosafety and ratified it on 23 January 2003. The India Biosafety Clearing House (IND-BCH) has been established as per Article 20 of the Cartagena Protocol on Biosafety, in order to facilitate the exchange of scientific, technical environmental and legal information on living modified organisms (LMOs). The following is a list of Acts and Rules governing biotechnology development in the country.

Figure 7.3: Patents Granted in Biotechnology at USPTO



Source: Thomson Innovation Database, 2013.

Figure 7.4: Publications in Research Area 'Biotechnology and Applied Microbiology'



Source: Thomson Reuters' Web of Science Database, 2013.

- Rules for the manufacture, use, import, export & storage of hazardous micro organisms, genetically engineered organisms or cells, 1989
- Drugs and Cosmetics Rules - 1988 (eight amendment)
- Schedule–Y of Drugs and Cosmetics Act
- Seeds Policy – 2002
- Protection of Plant Varieties and Farmers' Rights Act, 2001
- DGFT Notification No. 2 (RE-2006) /2004-2009, 2006
- Food Safety and Standards Act 2006
- Plant Quarantine Order, 2003

To establish Biotechnology Regulatory Authority of India a draft bill titled 'Biotechnology Regulatory Authority of India (BRAI) Bill, 2012' has been prepared by the Indian government. According to this Bill, the Authority will be an autonomous and statutory agency to regulate the research, transport, import, manufacture and use of organisms and products of modern bio-technology. Setting up of Inter-ministerial Governing Board to oversee the performance of the Authority and a National Biotechnology Advisory Council of stakeholders to provide feedback on use of organisms and products of biotechnology in society is also been provided in the Bill. Before giving final approval, the Bill envisages an elaborate risk assessment process involving scientific panels of experts and representatives of concerned ministries including a special public review system for evaluation of applications.[27]

7.7 Summing Up

India is making significant strides in biotechnology. The government's initiatives since 1980s have paid off in establishing India as a major player in the field of biotechnology. India's biotechnology industry outlook also seems to be very promising given the annual increment in revenues. Recent efforts by the government to establish biotechnology clusters, academia-industry partnership and innovation centres are commendable. Regarding risk assessment and regulation, India has recently introduced a Bill on establishing Biotechnology Regulatory Authority of India, which is a very important step towards ensuring bio-safety.

However, there are some of the issues which need to be taken care of for better harnessing the biotechnology sector. Reid and Ramani (2012) proposes that instead of diffused vision, there can be a selection of niches such as vaccines and bioinformatics for attaining international leadership. The policies to encourage foreign investment can also be fine tuned to promote knowledge sharing. For example, technology transfer agreements can be made mandatory for MNCs or made to reinvest a certain percentage of revenues emanating from Indian market in local universities. Also, there needs to have an incentive programmes to encourage collaboration and interaction between research centres and industries. Further, patents are the key to attract venture capital funding and MNC investments. So, patenting activities should be taken seriously by the Indian players. Contract Research Orgainsatios (CRO) industry serves as a golden opportunity for Indian players. There needs to be a solid world-class infrastructure to utilize this opportunity.[28]

According to a recent report by ABLE on Indian biotechnology, India has the potential to become a global hub for R&D and manufacturing in all aspects of biotechnology, unless the challenges in the domains of regulation, infrastructure, translational routes, skills and market pull are addressed properly.[29]

Endnotes

1 WDI, World Bank Data, 2013.

2 International Monetary Fund, World Economic Outlook Database, April 2013.

3 International Monetary Fund, World Economic Outlook Database, April 2013.

4 International Monetary Fund, World Economic Outlook Database, April 2013.

5 CIA The World Factbook, May 2013.

6 WDI, World Bank Data, 2013.

7 Global R&D Funding Forecast 2013, Battelle and RDMag.com, 2012.

8 Global R&D Funding Forecast 2013, Battelle and RDMag.com, 2012.

9 WDI, World Bank Data, 2013.

10 World Bank, Knowledge for Development, 2013.

11 WIPO and INSEAD, The Global Innovation Index, 2012.

12 DBT Annual Report 2012-13.

13 Presentation by SR Rao at 6th Asian Biotechnology Development Conference, Hyderabad, India, 2012.

14 Presentation by SR Rao at 6th Asian Biotechnology Development Conference, Hyderabad, India, 2012.

15 Presentation by SR Rao at 6th Asian Biotechnology Development Conference, Hyderabad, India, 2012.

16 DBT Annual Report 2012-13.

17 Twelfth Five Year Plan (2012-17), Planning Commission, Vol. 1, p.100.

18 National Biotechnology Development Strategy, DBT, http://dbtindia.nic.in/biotechstrategy/National%20Biotechnology%20Development%20Strategy.pdf.

19 ABLE Report, 2012, 'Indian Biotechnology', Association of Biotechnology Led Enterprises, Bangalore.http://ableindia.in/admin/attachments/reports/The_Report.pdf.

20 Biospectrum-ABLE Survey, 2011-12, July 2012, CyberMedia, Biospectrum, Bangalore. http://ableindia.in/Bio_survey_2012_updated.pdf

21 Chaturvedi, S. (2006). "Dynamics of Biotechnology Research and Industry in India" in OECD Science, Technology and Industry Working Papers, 2005/2006.

22 Chaturvedi, S. (2010), "Emerging Indian Entrepreneurship in Biotechnology and National Innovation System: Exploring linkages and Prospects". *International Journal of Technology and Globalization*, 5: 76-92.

23 Biospectrum-ABLE Survey, 2011-12, July 2012, CyberMedia, Biospectrum, Bangalore. http://ableindia.in/Bio_survey_2012_updated.pdf

24 ABLE Report, 2012, 'Indian Biotechnology', Association of Biotechnology Led Enterprises, Bangalore. Available at: http://ableindia.in/admin/attachments/reports/The_Report.pdf

25 OECD, Biotechnology Statistics Database, December 2012.

26 OECD, Biotechnology Statistics Database, December 2012.

27 PIB Release, Press Information Bureau, Govt. of India, http://pib.nic.in/newsite/erelease.aspx?relid=84347.

28 Reid, S. and SV Ramani (2012). "The Harnessing of Biotechnology in India: Which Roads to Travel?", *Technological Forecasting and Social Change,* 79 (4), pp. 648-664.

29 ABLE Report, 2012, 'Indian Biotechnology', Association of Biotechnology Led Enterprises, Bangalore.http://ableindia.in/admin/attachments/reports/The_Report.pdf

Chapter 8:
Indonesia

8.1 General Introduction

Indonesia is a lower middle income country[1] in East Asia and Pacific region [GDP, Current Prices (US$ in Billions): 878[2]; GDP, Purchasing Power Parity (US$ in Trillions): 1.2[3]; GDP (PPP) Share of World Total (%): 1.5[4]]. Industry play a major role in its GDP [GDP Composition by Sector (%)[5]: Agriculture: 15.4, Industry: 46.5, Services: 38.1 (2012 estimate)]. However, Services is the major employment sector in Indonesia [Employment (% of total employment)[6] 2011: Agriculture: 35.9, Industry: 20.6, Services: 43.5].

In the realm of R&D, Indonesia does not spend much [Indonesia's Gross Expenditure on R&D in 2012 (US$ in Billions, PPP)[7] was 2.4 and its expenditure on R&D, 2012 (% of GDP, PPP)[8] was 0.2]. Its low rank in Knowledge Economy Index and Global Innovation Index points the lack of sufficient infrastructure, human resource etc in Indonesia [Indonesia's Knowledge Economy Index (KEI) 2012 Ranking[9] was 108 and its Global Innovation Index 2012 Ranking[10] was 100]. The number of researchers per million of its population is also below 100. [Researchers in R&D (per million people)[11] were 89.6 in 2009.]

8.2 Biotechnology in Indonesia

Indonesia is a country that is well endowed with natural resources and is rich in biodiversity. It is rich in terms of marine biodiversity, agricultural biodiversity and forest biodiversity. Hence there is enormous scope for application of biotechnology in these sectors and in using the biodiversity as a resource. In terms of application of biotechnology Indonesia has a long way to go. The private sector in Indonesia is not developed enough to use or apply biotechnology. The scope for applications in other sectors like health/ medical is recognized by the strategy on biotechnology.

8.3 Programme and Institutional Framework

The national policy was first formulated in 1990 and biotechnology was identified as a priority sector. Four centers were identified as centers of excellence in biotechnology and Inter-University Centers in Biotechnology on agricultural, industrial and medical biotechnology were established. Indonesian biotechnology Consortium with 33 institutions was founded. The consortium drafted the strategy programme for biotechnology in Indonesia in 2004. In 2005 the regulation on GM products was passed. The industry is in nascent stage. There are five public sector research institutions engaged in biotechnology R&D. Three private sector firms are engaged in R&D. The activities of these firms (Charoen Pokphand, Thailand; Cargill, United States; and Dupont, United States) are limited to some high value horticultural crops and hybrid corn. East-West seeds are the largest producer of vegetable seeds.[12]

Indonesia's spending on science and technology is not adequate. The financial crisis of 1998 affected Indonesia and as a result the allocations on agricultural research were reduced in the subsequent years. Private sector spends only 19 per cent of the agricultural R&D and in biotechnology R&D is much less. Through various schemes government is trying to accelerate development of R&D in biotechnology. According to V.V. Krishna: "The current investment of around 0.2 per cent of GDP on R&D is very inadequate to meet the objectives and challenges outlined in the government's S&T policy, particularly those concerning the new technologies. In a relative sense, much of Indonesia's strength in innovation is in the agriculture and related areas of research. In a situation of low levels of R&D investment and efforts during the last three decades, over emphasis on developing high technology and high capital-intensive sectors such as nuclear and aviation industries has further compounded the S&T and R&D problems for Indonesia".[13]

Table 8.1 gives the list of top performing institutes in Indonesia in the field of biotechnology.

Indonesia imports about $1 billion of transgenic products from the USA alone and this includes Bt cotton, herbicide tolerant soya and soya meal, Bt corn and food products from transgenic crops.[14]

External funding and assistance is another source of support to biotechnology R&D. Funding through World Bank loans, Rockefeller Foundation, USAID and bilateral projects has been available but mostly in capacity building, infrastructure development and human resources development than in major research programmes per se. Netherlands has supported training of students from Indonesia for PhD in Netherlands. Indonesia is exploring the possibility of cooperation with ASEAN countries, particularly with Korea. Marine biotechnology has been identified as a thrust area. However, it is acknowledged that funding is the constraint and biotechnology in Indonesia, particularly R&D is largely driven by the government.

Table 8.1: Top Ranking Institutions in Indonesia

Top Ranking Institutions based on Publications in 'Biotechnology and Applied Microbiology' in the period 2001-2012
Bogor Agricultural University
Gadjah Mada University
University of Indonesia
Indonesian Institute of Science
Bandung Institute of Technology
Brawijaya University
Airlangga University
Udayana University
Sepuluh Nopember Institute of Technology
University of Lampung

Source: Thomson Reuters' Web of Science Database, 2013.

According to one report as on2003 there were about fifteen projects involving transgenics in Indonesia, in different stages.[15] The potential of microbial resources for biotechnology utilization in Indonesia is well known. The isolates from microbial resources find wide use in agriculture and veterinary. For example, Bt (Bacillus thuringiensis) is used in controlling sugarcane borer, rice stem borer, cotton bollworm. The appropriate strains have to be identified first and then bioinsecticide, biofungicide can be developed for application on a large scale. Another application of microbial resources is the development of bio-fertilisers, plant regulators and organic decomposers. Such applications are less controversial than GMOs and are acceptable to all types of farmers. For example, Bt is used inorganic farming to control bollworm. Using these microbial resources genetically modified plants, organisms can be developed and the microbial diversity is important to develop appropriate solutions. Indonesia in view of its rich microbial diversity has used these resources and various biofertilizers, bio-insecticides, and plant regulators have been commercialized in Indonesia. Table 8.2 gives the list of the applications that are in use in Indonesia.

These can be used as a stepping stone for development of microbial resources in biotechnology. The major limitation in using these resources in the absence of biotechnology is that the desired traits are not transferred to plants and this

Table 8.2: Products Based on Microbial Resources

Biofertilizer Emas	The function of this fertilizer is to increase the efficiency of fertilizer application (N, P, and K). The bioactivator of this biofertilizer is bacteria: *Azospiriliumlipoferum*, *Azotobacter beijerinckii*, *Aeromonaspunctata*, and *Aspergilus niger*. It is used mostly for estate crops.
Biofertilizer RhiPhosan	This biofertilizer is used to improve the nitrogen fertilizer from the air and to promote the liquidation of P and C fertilizer in the soil. It can also produce photo hormonal Indol Acetate Acid (IAA), which will increase root growth. Its bioactivators are *Brandyrhizobiumjoponicum* and *Aeromonaspunctata*. It is used mostly for secondary crops and cover
Organic Decomposer OrgaDec	OrgaDec is a bioactivator that decomposes the organic materials in a short period of time and is antagonistic to some root diseases. It consists of Trichodermapseudokoningii and Cytophagasp. OrgaDec is used mostly to decompose organic material with a high cellulose content (cocoa and palm tree waste, paddy straw, leaves, bud, and other materials).
PlantRegulator NoBB	NoBB consists of a plant regulator which can stimulate the function of cambium forcell fission and recovery of latex vessels. It also helps in the recovery of the skin of the rubber tree from Brown Bast. NoBB can be used to increase the productivity of rubber estates.
Biofungicide Greemi-G	Greemi-G consists of two green microbes (Trichodermaharzianum and Trichodermapseudokoningii) which can be used to manage the impact of Ganoderma for palm oil trees, JAP for rubber and Phytophthora for cocoa
Bioinsecticide BioMeteor	The bioactivator of this product is Metharhizium anisopliae, which can manage plant pests in soil, such as Dorysthenesssp. (bokortebu)and Xystrocera festiva (bokor sengon).
Bioinsecticide NirAma	NirAma consists of the bioactivator Paecilomyces fumosoroseus. It is used mostly to manage plant pests such as Heliopeltis antonii, fire worm, Ectropis bhurmitra, Antitrygodes divisaria, Hyposidra talaca, Metanastriahyrta, Homonacoffearia, Poicilocoryssp.,Spodoptera litura, and Meloidogynesp.

Source:**“**AgriculturalBiotechnologyDevelopmentinIndonesia”byIwanRidwan,*BusinessPotential for Agricultural Biotechnology Products,* 2007, Asian Productivity Organization, Tokyo.

necessitates repeated application of bio-insecticides. In terms of value addition and large scale production the industry is growing.

But in the long run this alone would not be sufficient. The challenge lies in isolating the relevant genes and transferring them into products or plants. Moreover, microbial resources per se are not patentable and are found in many environments. Developing processes that result in purified microbes not found in nature and that can be used in many industries is necessary to maximize the benefits from these resources. Thus, at some point or other the policy makers will have to frame a policy framework that encourages innovations based on these resources without sacrificing sustainability.

As Indonesian agriculture is diversified in terms of crops it should give more importance to develop these resources in a big way and try to develop industries where innovation and value addition are given due importance. In this biotechnology has a crucial role to play. It is suggested that Indonesia should use the multilateral initiatives in biotechnology to develop this sector.

To begin with the focus should be to move to the next stage of applying biotechnology in agriculture even when the earlier applications like bio-fertilisers and bio-insecticides should be developed further on a large scale. The commercial cultivation of transgenics should be encouraged and the government should decide on grant of approval for cultivation of Bt cotton, Roundup Ready Soybean as early as possible.

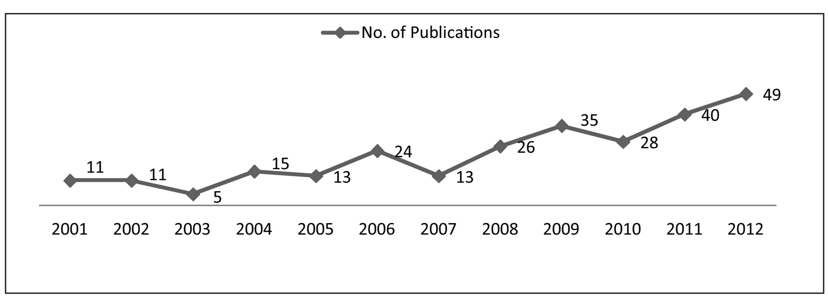
The current research projects in biotechnology should be reviewed and expedited. Wherever financial constraints are holding up projects increased allocations should ensure timely completion of projects. Since the research projects are on traits that are important or can enhance productivity, the transfer of results for commercial application is necessary to gain most from the research.

Indonesia should identify niche areas where it can derive the maximum benefits. Linkages between transgenics research and development and research and development in microbial resources should be developed.

Indonesia embarked upon using biotechnology more than two decades ago but it has not made much headway in using biotechnology. Time has come to move forward from this state and to gain maximum from biotechnology.

As Iwan Ridwan points out: “The strategic approach of biotechnology development for industrialization in Indonesia will be addressed from two

Figure 8.1: Publication in Research Area ‘Biotechnology and Applied Microbiology’



Notes: Publications in Research Area ‘Biotechnology and Applied Microbiology’ in the Period 2001-2012: 270.

Patents: NIL

Source: Thomson Reuters’ Web of Science Database, 2013.

levels: macro and micro approaches. On the macro level, the first element is positioning biotechnology in terms of technology capacity and the industrial stage of development. Worldwide competition among research institutes and business enterprises in the field of biotechnology is severe. To be significantly competitive, the specific area of biotechnology to be focused on should be determined with care. These condelement is national capacity building, including the development of human resources, small- and medium-sized enterprises for the domestic market, and large-sizedones with the possibility of entering the global market under joint ventures, foreign direct investment, or licensing."

Commercialization of GM crops is not yet wide spread although transgenic rice, transgenic sugar, transgenic potato have been field tested. The government has decided that more field tests at various locations have to be done. The research projects include development of drought tolerant rice, pest resistant soyabeans, and virus resistance for tomatoes. But how soon these will be field tested and commercialized is not clear. The Indonesian experience in biotechnology has been confined to using tissue culture and production of bio-fertilizers and bio-pesticides.

8.4 Biosafety

Indonesia had signed and ratified Cartagena Protocol in 2004. It has biosafety regulations in place. The regulation for Bio-safety of Transgenic Products No 21/2005 was promulgated but the rules have not been fully implemented. In this regard, the Biosafety Committee for Transgenic Products has been established in 2010 by the Presidential Regulation No. 39. It is a necessary mechanism to complete outstanding and new biotechnology regulations.[16]

Similarly, there are food labeling rules but these have not been fully implemented. In 2008 the National Agency of Food and Drug Control issued the guidelines for food safety assessment for transgenic products. However it is not clear as to how the overall framework will be harmonized with commitments under the Cartagena Protocol. Although it seems that the labeling norms require that food products containing more than 5 per cent content derived from transgenic processes should be labelled whether this is enforced is not clear.

The biosafety policy has implications for cultivation of transgenic crops in Indonesia besides trade in transgenics. The policy framework should be implemented as early as possible so that there is certainty. For exporters and importers the certainty will send clear signals. If Indonesia wants to export GM food products to markets like the USA it has to implement a comprehensive framework on regulation, approval, labelling and trade in biotechnology, particularly in tarnsgenics. Since it imports significant quantities of food products including GM food, development of a vibrant agricultural biotechnology sector can result in less imports and more exports in biotechnology sector. Indonesia should try to expedite commercialization of agricultural biotechnology even as it implements the biosafety norms.

8.5 Publications and Patents

Figure 8.1 gives the picture of Indonesia's publication in research area 'Biotechnology and Applied Microbiology' in the period 2001-2012.

8.6 Summing Up

Indonesia has potential for using biotechnology in various sectors. It is likely that in the coming decade it will achieve a breakthrough in this as more GM plants are approved and the investments in infrastructure and capacity building begin to yield results. But to gain maximum for biotechnology Indonesia will have to develop and apply a strategic plan for biotechnology sector.

Endnotes

[1] World Development Indicator, World Bank Data 2013.

[2] International Monetary Fund, World Economic Outlook Database, April 2013.

[3] International Monetary Fund, World Economic Outlook Database, April 2013.

[4] International Monetary Fund, World Economic Outlook Database, April 2013.

[5] CIA The World Factbook, May 2013.

[6] WDI, World Bank Data, 2013.

[7] Global R&D Funding Forecast 2013, Battelle and RDMag.com, 2012.

[8] Global R&D Funding Forecast 2013, Battelle and RDMag.com, 2012.

[9] World Bank, Knowledge for Development, 2013.

[10] WIPO and INSEAD, The Global Innovation Index 2012.

[11] World Development Indicator, World Bank Data, 2013.

[12] Gert-Jan Stads, Haryono, and Siti Nurjayanti (2007). "Agricultural R&D in Indonesia: Policy, Investments and Institutional Profile". *Asti Country Report,* November. International Food Policy Research Institute and Indonesian Agency for Agricultural Research and Development.

[13] V. V. Krishna. *The Republic of Indonesia.* http://portal.unesco.org/education/es/files/55596/11999604295Indonesia.pdf/Indonesia.pdf

[14] GAIN Report Indonesia: Agricultural Biotechnology Annual dated 15 July 2009 USDA-Foreign Agricultural Service.

[15] *Agricultural Biotechnology in Indonesia: An Assessment* Vol. II: Appendices Prepared for Cornell University under Sub contact No. 426187039, Agricultural Biotechnology Support Project II James Chapman Hector Quemada Lawrence Kent Muhammad Herman, September 2003, Development Alternatives MD: Bethesda.

[16] GAIN Report, 2011, Jonn Slette and Titi Rahayu, USDA Foreign Agricultural Service, Indonesia, Agricultural Biotechnology Annual 2011. http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Agricultural%20Biotechnology%20Annual_Jakarta_Indonesia_10-18-2011.pdf

Chapter 9:
Japan

9.1 General Introduction

Japan is a high income level country and a member of OECD[1]. It has the fourth largest GDP in the world [GDP, Current Prices (USD in Trillions): 5.9[2]; GDP, Purchasing Power Parity (USD in Trillions): 4.6[3]; GDP (PPP) Share of World Total (%): 5.5[4]]. Services sector plays a major role in its GDP [GDP Composition by Sector (%)[5]: Agriculture: 1.2, Industry: 27.5, Services: 71.4 (2012 estimate)] as well as in its employment scenario [Employment (% of total employment)[6] 2011: Agriculture: 3.7, Industry: 25.3, Services: 69.7].

In R&D, Japan is one of the top leading countries in terms of expenditure [Japan'a Gross Expenditure on R&D in 2012 [GERD] (USD in Billions, PPP)[7] was159.9 and its expenditure on R&D, 2012 (per cent of GDP, PPP)[8] was 3.48]. Japan's high ranking both in Knowledge Economy Index and Global Innovation Index justifies its expenditure in R&D [Japan's Knowledge Economy Index (KEI) 2012 Ranking[9] was 22 and its Global Innovation Index 2012 Ranking[10] was 25].

As far as human resource in research is concerned, Japan has one of the highest number of researchers per million of its population in the world. [Researchers in R&D (per million people)[11] were 5179 in 2009.]

9.2 Biotechnology in Japan

Japan is a leading country in many sectors including electronics with significant share in the global market. For instance in communication devices its share is 53 per cent, in automobiles its share is 31 per cent, in robots it is 40 per cent. In photo masks for liquid crystals and silicon wafers its share is above 70 per cent.[12] It has embarked upon an ambitious plan to promote biotechnology and life sciences and emerge as a world leader in some applications. Although Japan's industrial prowess and capability for innovation are unquestionable in biotechnology, it lags behind the USA and Europe. In Asia countries like Korea, China and India are fast catching up in developing biotechnology applications and the state in them is also giving importance to biotechnology. But Japan has some advantages over these countries as it's capacity to innovate and introduce new products is unparalleled in Asia.

9.3 Programme Framework, Human Resource and Funding

9.3.1 BioStrategy 2002

The Japanese government had set an ambitious target of creating at least 1000 new biotech companies. The biotechnology market will reach 25 trillion Yen. The BioStrategy 2002 focused on four sectors (Bio-Medical, Bio-Agricultural, Bio-Ecological, and Bio-informatics).

The policy framework aimed to achieve this by promoting joint ventures, research collaborations, industrial partnerships, and encouraging venture capital, development clusters, and increased collaboration between academic institutions and industries. JETRO identified seven major bio-clusters in Japan. Each cluster consists of research institutes including Centers of Excellence (COEs), universities, and companies in biotechnology and life sciences. Each of the clusters will also specialize in a core technology/application and the synergy between academic and industry in the clusters is expected to make them leading centers of innovation. For example Kinki Bio-Cluster project has Genome based drug discovery, and regenerative medicine as the core technologies. There are three COEs and the presence of pharmaceutical and chemical industries in the vicinity is considered as an added advantage. The funding from government has increased considerably for research in biotechnology/life sciences.

9.3.2 National Bioresource Project

The National Bioresource Project envisages systematic collection and preservation of all bioresources including stem cells and genetic materials. The government has also funded the translational research programme in a big way. Instead of allocating financial resources in all sectors, the government has identified priority areas and is supporting basic research and developing world-class research facilities. Since 2000, the support for life sciences through government funding has steadily increased.

In this the approach of the Japanese government is no different from that of governments like Korea and the idea of clusters for biotechnology is not new. The policy can be understood as a response to concerns expressed about lack of growth in biotechnology in Japan and fears about Japan lagging behind the USA in life-sciences research and missing the post-genomic revolution in health sciences. Although Japan has world class universities and is doing exceeding well in terms of publications, concerns have been expressed about the mismatch between scientific capability in basic sciences and developing applications/commercializing the research done in universities. The new policy framework supports new ventures and start ups are expected to play an important. Another significant aspect of the policy is the goal of listing 100 Initial Public Offers, originating from universities/start-ups based in universities. The government is also supporting development of human resources. The goal is to create an attractive environment for firms, both domestic and foreign, and to attract capital to invest in biotechnology.

The policy framework has been supplemented by changes in the regulatory regime and laws. The changes made in 2005 in Pharmaceutical Affairs Law (PAL) simplified procedures for approval for manufacturing and importing of medicines. Outsourcing of manufacturing to domestic/overseas manufacturers was allowed. The objective behind the changes was to open up new business opportunities and to derive benefits from outsourcing including lowering the cost of production. In 1999 the Japanese version of Bayh-Dole Act that facilitates commercialization of technologies and transfer of technology from universities to industry was passed. Guidelines on clinical research on gene therapy and ethical guidelines on clinical research were issued. Similarly changes were made in intellectual property laws. Thus between 1998 and 2005 major changes in the regulatory regime were brought in to create a liberalized milieu for development of biotechnology and commercialization of research.

Life sciences have been identified as one of the four priority areas and five ministries are playing an important role in this. About 60 per cent of the Millennium projects were allotted to biotechnology before the development of comprehensive national strategy for biotechnology. The 3rd Basic Plan for S&T identified the following areas in life sciences as strategic priority area: (i) research on complex biological systems, (ii) translational and clinical research, (iii) cancer therapies, (iv) infectious diseases, (v) safe foods, (vi) bio-processing and (vii) research infrastructure. The third basic plan gives more emphasis to innovation than the previous two.

The government's increased funding to biotechnology is evident in the budgetary allocations for 2009. Funding for clinical studies on cancer increased by 90 per cent in 2009. [13]

Table 9.1 gives the list of top performing institutes in Japan in the field of biotechnology.

9.4 Biotechnology Industry

The biotechnology market in Japan is considered as the second largest in the world, next to USA. The market size of the Japanese biotechnology industry in 2010 was $ 36.2 billion, with a 11.1 per cent growth rate over the period 2006-2010.[14] In 2005 it was estimated that the biotechnology market in Japan is about 1.76 trillion yen. Medical Sales had the ranked first with a 42.5 per cent share. The Market is expected to grow to $ 62.6 billion by 2015.[15]

Number of biotechnology firms in Japan was 523 in 2010.[16]

In Japan the pharmaceutical companies, huge food companies, chemical industries, heavy engineering giants and IT drive biotech research in Japan. The number of start ups is less when compared to USA. In USA since the early 1980s there has been a vibrant biotechnology industry thanks to the start ups and support from venture capital. Many of the start ups struggle to survive but in terms of innovation and commercialistion the US biotech industry is a global leader. In Japan most of the biotech companies are first either incubated as a venture or started as a project by large companies. Once they are ready to do business on their own they are spun out as separate entities. These spin outs often form a network to support the parent company.[17]

For example companies in pharmaceutical sector and chemical industry are major players in the biotechnology and life science industry. Companies in the food industry and diagnostic industry are also engaged in

Table 9.1: Top Ranking Institutions in Japan

Top Ranking Institutions based on Publications in 'Biotechnology and Applied Microbiology' in the period 2001-2012
University of Tokyo
Kyoto University
Osaka University
Kyushu University
Hokkaido University
National Institute of Advanced Industrial Science and Technology
Tohoku University
Nagoya University
University Of Tsukuba
Riken

Source: Thomson Reuters' Web of Science Database, 2013.

biotechnology industry. Some of the major companies that are involved in biotechnology include Astellas Pharma Inc., Eisai Co. Ltd., Daiichi Sankyo Pharmaceutical Co. Ltd., Takeda Pharmaceutical Industries Ltd., Chugai Pharmaceutical Co. Ltd., Asahi Kasei Corporation, Mitsui Chemicals Inc., Mitsubishi Chemical Corporation, Lion Corporation, Ajinomoto Co. Inc., Kyowa Hakko Kogyo Co. Ltd., and Kirin Brewery Co. Ltd.[18]

Compared to the US drug MNCs or giants like Roche, GSK, Novartis, the Japanese pharmaceutical companies can be considered as middle-sized. The large domestic market was their major market and they did not become specialized or internationalized firms.

But during the last two decades the government policy on drug pricing and the growth and increased presence of foreign firms posed challenges to the pharmaceutical firms. Expenditure on R&D tripled in the last decade and the firms eyed on the lucrative global market than to rely largely on the domestic market. By 2006 about 50 per cent of the sales were aboard, from less than 35 per cent in 2001. The industry also went through a spate of mergers and acquisitions and is undergoing major transition now. The top ten pharmaceutical firms in Japan figure among the 50 largest firms in the world although none of them are in the top 10 league.[19]

Total biotechnology R&D expenditures in the business sector in Japan was 1230.1 Million USD (PPP) in 2010.[20]

Percentage of small biotechnology firms in Japan was 44.4 in 2010 which comes to be around 232.[21]

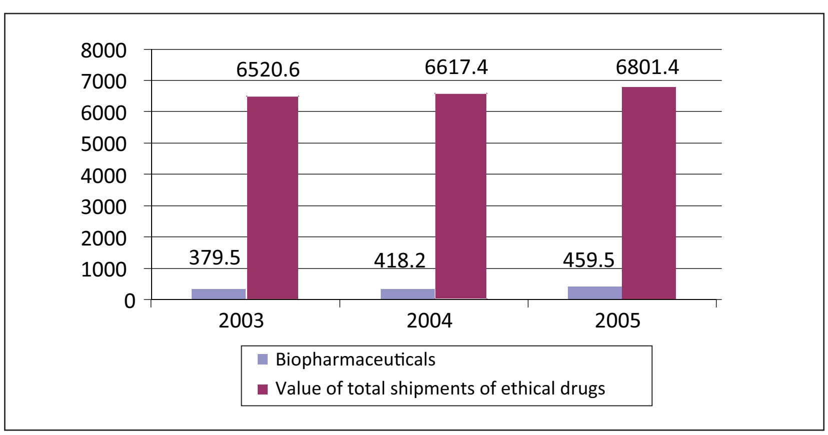
The lack of dedicated biotech firms in Japan is well acknowledged. Shortage of venture capital, non-availability of trained scientists and engineers is cited as one of the reasons for this. According to one report:

> *'The make up of the Japanese venture capital sector is different from that in western countries: - the number of venture capitals is quite limited; - many of them are subsidiaries of banks or securities companies; - the scale of funds available is comparatively small (than, for instance, that of the U.S.); - money invested in individual companies is also comparatively small; and - there are a limited number of venture companies focused on bio businesses'.*[22]

But the picture is changing now with more venture capital funds flowing into biotechnology.

The market for biopharmaceuticals was 459.4 billion yen in 2005 (Figure 9.1). Of the approved drug products they account for 5 to 10 per cent which is lower

Figure 9.1: Market Size of Biopharmaceuticals



Source: JETRO (2007).

than their share in USA. The bioservices market in 2005 was 24.34 billion yen and is increasing at the rate of 10.5 per cent per annum.

9.5 Patents and Publications

Japan has a significant presence in biotechnology patents, particularly in patent applications related to microorganisms, enzymes, biochemical and glyco-technology. In glycol engineering it accounts for 46 per cent of the patents.

Japan's share of biotechnology PCT applications in the period 2008-2010 was 11.49 per cent.[23]

Total PCT Applications filed by Japan in the period 2004-2006 was 68011, out of which 3720 were Biotechnology PCT Applications.[24] In terms of revealed technological advantage in biotechnologies, Japan's share decreased from 0.7 in 1998-2000 to 0.6 in 2008-10.[25]

Figure 9.2 depicts Japan's performance in biotechnology patenting in the period 2001-2012.

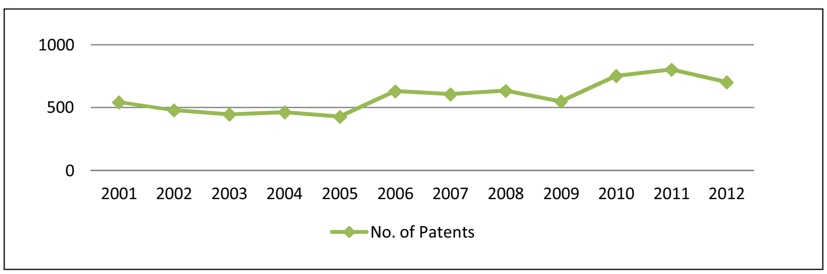
Japan is one of the leading countries in terms of publication in biotechnology. Figure 9.3 depicts Japan's publication activity over a period of time.

Japan's total publications in research area 'Biotechnology and Applied Microbiology' in the period 2001-2012 was 23856.

9.6 Regulation of Biotechnology

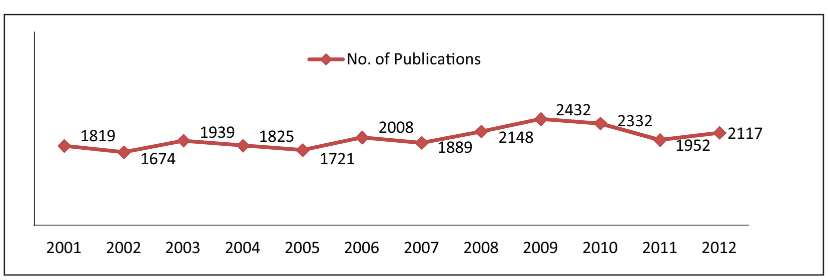
Japan has signed and ratified Cartagena Protocol. It has established a regime for regulating import and use of LMO's under the protocol. During 2006-2008 there were 42 trials and of this herbicide tolerant trait trails accounted for 26. Japan has regulations on labeling of GMO products.[26]

Figure 9.2: Patents Granted in Biotechnology at USPTO



Note: Patents Granted in 'Biotechnology' in USPTO in the Period 2001-2012: 7046.
Patents Granted in 'Biotechnology' in EPO in the Period 2001-2012: 4306.
Source: Thomson Innovation Database, 2013.

Figure 9.3: Publications in Research Area 'Biotechnology and Applied Microbiology'



Source: Thomson Reuters' Web of Science Database, 2013.

Box 9.1: Kinki Bio Cluster

Number of Bio Ventures: 110

1. **Presence of distinguished COEs**
   Kyoto University, Osaka University
   Tissue Engineering Research Center, AIST
   The Kobe Medical Industry Development Project (Institute of Biomedical Research and Innovation, RIKEN (Centre for Development Biology), etc.
2. **Accumulation of related industries**
   Key industries such as pharmaceutical/chemical, electromechanical/electronic parts, precision machinery, food and textile
   Small and medium-size enterprises that have advanced skills (example: SMEs in Higashiosaka City)

Core Technologies

Genome based drug discovery, regenerative medicine

↓

Promising Industrial Areas/Ideas

Biomedicine (drug discovery, regenerative medicine)
Bio environment (microbial bio, plant bio)
Bio tool/information (advanced analytical equipment)

Source: http://www.jetro.go.jp/en/invest/attract biotechnology/bio.pdf

9.7 Summing Up

Japan's thrust on biotechnology including state support for basic research and promotion of cluster approach and brining in changes in regulatory regimes indicate that Japan is determined to use biotechnology in a big way. To what extent the ambitious targets will be achieved and whether Japan is as innovative as USA in biotechnology is yet to be seen.[27]

Endnotes

1 WDI, World Bank Data 2013.
2 International Monetary Fund, World Economic Outlook Database, April 2013.
3 International Monetary Fund, World Economic Outlook Database, April 2013.
4 International Monetary Fund, World Economic Outlook Database, April 2013.
5 CIA The World Factbook, May 2013.
6 World Development Indicator, World Bank Data, 2013.
7 Global R&D Funding Forecast 2013, Battelle and RDMag.com, 2012.
8 Global R&D Funding Forecast 2013, Battelle and RDMag.com, 2012.
9 World Bank, Knowledge for Development, 2013.
10 WIPO and INSEAD, The Global Innovation Index 2012.
11 World Development Indicator, World Bank Data, 2013.
12 Samajima , Masahiro (2008).
13 JBA (2009).
14 http://www.businesswire.com/news/home/20111007005435/en/Research-Markets-Biotechnology-Japan---MedicalHealthcare-Sales
15 http://www.businesswire.com/news/home/20111007005435/en/Research-Markets-Biotechnology-Japan---MedicalHealthcare-Sales
16 OECD, Biotechnology Statistics Database, December 2012.
17 Japan's Bio-Market. http://www.perf.ciba.lg.jp
18 Industrial Biotechnology in Japan. http://akseli.tekes.fi
19 Stenberg (2007).
20 OECD, Biotechnology Statistics Database December 2012.
21 OECD, Biotechnology Statistics Database December 2012.
22 Mitsumori (2005).
23 OECD, Biotechnology Statistics Database December 2012.
24 OECD, Biotechnology Statistics Database 2009.
25 OECD, Biotechnology Statistics Database December 2012.
26 http://www.bch.biodic.go.jp/english/law.html
27 Yumiko Okamoto (2007). Paradox of Japanese Biotechnology : Can Formation of Bioclusters be a Solution.

Chapter 10:
Korea

10.1 General Introduction

Republic of Korea (Korea) is a high income level country and a member of OECD.[1] Its GDP is 12th largest in the world [GDP, Current Prices (USD in Trillions): 1.1[2], GDP, Purchasing Power Parity (USD in Trillions): 1.6[3], GDP (PPP) Share of World Total (%): 1.9[4]]. Services sector plays a dominant part whereas role of agriculture is minimal [GDP Composition by Sector (%)[5]: Agriculture: 2.7, Industry: 39.8, Services: 57.5 (2012 estimate)]. Employment-wise also services sector leads other sectors [Employment (% of total employment)[6] 2010: Agriculture: 6.6, Industry: 17.0, Services: 76.4].

Korea is one of the leading countries in terms of expenditure on R&D [Korea's Gross Expenditure on R&D in 2012 [GERD] (USD in Billions, PPP)[7] was 55.8 and its expenditure on R&D in 2012 (per cent of GDP, PPP)[8] was 3.45]. It also has a very high number of researchers per million of its population. [Researchers in R&D (per million people)[9] were 5481 in 2010 in Korea].

As far as, Knowledge Economy Index and Global Innovation Index are concerned, Korea is well placed [Korea's Knowledge Economy Index (KEI) 2012 Ranking[10] was 29 and its Global Innovation Index 2012 Ranking[11] was 21]. This reflects the conducive and facilitating conditions prevailing in for research, development and innovation in Korea.

10.2 Biotechnology in South Korea

Korea has emerged as a major biotechnology country in the Asia-Pacific region and its biotechnology industry is trying to be globally competitive. From the initial stages in the early 1980s the Korean biotechnology industry has come a long way. The supportive policy framework of the government played a major role in development, diversification of the biotechnology industry and R&D activities in the industry and in academia. The efforts made since the 1980s have borne fruit and Rand Corporation identified Korea as one of the countries that could acquire all the sixteen significant technologies including biotechnology by the year 2020. Thus, Korea is well prepared for harnessing the technological convergence of nanotechnology, biotechnology and information technology.

10.3 Investments and Policy Environment

In 1983 Korea enacted Biotechnology Promotion Law and the 1980s also witnessed the setting up of various biotechnology departments and research institutes, making it one of the pioneering countries in Asia to identify and develop biotechnology as a promising sector. The nineties saw further consolidation of this and development of biotechnology industry in Korea. This decade also witnessed the proclamation of Bioindustry Vision 2000 and advances in bioprocess technology and commercialization of various products.

Since 2000 Korea has further encouraged Biotechnology as a Key National Strategic Industry. The National Bioindustry Action Plan was launched. Investments by public sector and private sector in biotechnology went up considerably even as the industry moved up in the value addition chain and brought out new and modified bioproducts. Korea was well equipped to capitalize on the post-human genome mapping developments in biotechnology and the genomics revolution in biosciences did not bypass Korea.

The Ministry of Education provides the largest amount of funds followed by Ministry of Knowledge Economy (MKE), Ministry of Environment (ME), Ministry of Food, Agriculture, Forestry and Fisheries (MAF), Public research institutes and Ministry of Health, Welfare and Family Affairs. The size of Korean Biotech Market has almost doubled from US$ 12 billion in 2004 to US$ 22 billion in 2009.[12]

So, the public R&D expenditure rose from US$ 415 million in 1994-97 to US$ 946 million in 2007, with the cumulative expenditure of US$ 5610 million during 1994-2007. The Ministry of Education, Science and Technology (MEST) was a major funding agency and other ministries also contributed to the funding. In terms of sector wise allocation Life Science was a major beneficiary of pure public R&D expenditure and Life Sciences and health accounted for a major share of this expenditure which amounted to US$ 836 million.

In the financial year 2008, total expenditure on R&D by biotechnology-active firms, (million PPP $), was $ 957.5[13] million. Biotech R&D as a per cent of total business expenditure on R&D was 3.2. Biotechnology R&D expenditures by the public sector (million PPP$), 2008 was 1908[14], which accounts for about 58 per cent of the total expenditure on biotechnology.

Biotechnology R&D expenditures by the public sector (Millions USD PPP) was 2468.4 in 2010, which is about 100 Millions more than 2006 expenditure (2375.1 Millions USD PPP).[15]

Korea's biotechnology R&D expenditures by the public sector as a percentage of total public-sector R&D was 19.75 in 2010, which was 18.7 in 2006.[16]

In the financial year 2006, total biotechnology R&D expenditures in the business sector increased to 709 million PPP$. Total biotechnology R&D expenditure was 2375.1 million PPP$, where public expenditure was 1446.8 million PPP$ (18.7 per cent).

Total biotechnology R&D expenditures in the business sector in Korea increased to 1082.7 Million USD (PPP) from 709 Million USD (PPP).[17]

In the recent years this momentum has been maintained as would be evident from the following statistics:[18]

1. Government support has doubled between 2006 to 2010 with an annual increase of 16.4 per cent from $.67 billion to $ 1.42 billion;
2. The second-stage of Bio-Vision was promoted in 2011; and
3. In 2009 26.4 per cent of funding was provided by the Ministry of Health and Welfare while 37.5 per cent was from the Ministry of Education, Science and Technology.

10.4 Private Sector R&D and Other Investments

In the financial year 2008, total expenditure on R&D by biotechnology-active firms, (million PPP $), was $ 957.5[19] million. Biotech R&D as a per cent of total business expenditure on R&D was 3.2. Biotechnology R&D expenditures by the public sector (million PPP$), 2008 was 1908[20], which accounts for about 58 per cent of the total expenditure on biotechnology.

In the financial year 2006, total biotechnology R&D expenditures in the business sector increased to 709 million PPP$. Total biotechnology R&D expenditure was 2375.1 million PPP$, where public expenditure was 1446.8 million PPP$ (18.7 per cent).

The biotechnology industry has grown at an average rate of 26.1 per cent since 1994 and the production was valued at 5636 billion won, while exports accounted for 2728 billion won. A good portion of the exports were high value added products.

Table 10.1 shows the trend of biotechnology R&D expenditure over the years 2002 to 2006. In absolute terms, with the increase in total R&D expenditure, expenditure on biotechnology R&D also increased. In real terms, biotechnology R&D expenditure maintained around 27.3 per cent in 2006 which is not significantly different from the 27.1 per cent in 2003. Of the 709.3 million PPP$, in 2006 in Biotech R&D expenditure, dedicated biotech R&D firms spent $266.5 million PPP$. Biotech R&D as per cent of total business expenditure in R&D was just 3 per cent in 2006. But share of public biotechnology R&D in total biotechnology R&D expenditure was 60.9 per cent in 2006 .

Percentage of biotechnology R&D expenditure incurred by small biotechnology R&D firms in Korea was only 15 per cent in 2010, whereas percentage of biotechnology R&D expenditure incurred by medium and large biotechnology R&D firms was 85 per cent.[21]

In 2009 the total investment of biotechnology industry was valued at 1180 billion won and investments in R&D were also significant. The number of biotechnology enterprises is 853 and many companies have taken the capital market route to mobilize resources. For example, now about 70 biotechnology companies are listed in KOSDAQ.

Percentage of biotechnology R&D investments by application in Korea in 2010 was as follows:[22]

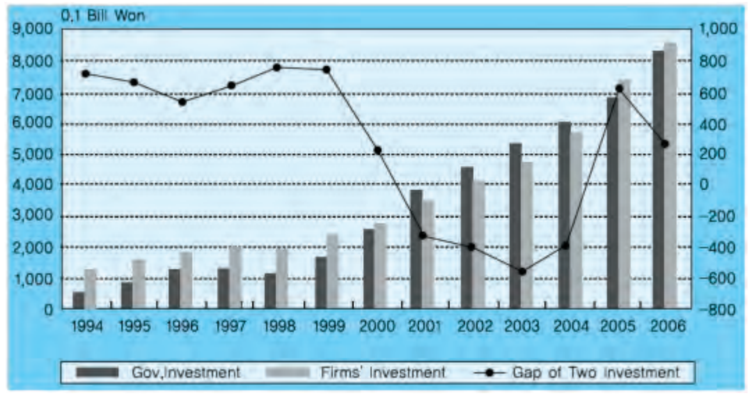
- Health: 55.5 per cent
- Agriculture: 1.9 per cent
- Food and Beverages: 15.5 per cent
- Natural Resources: 0.0 per cent
- Environment: 2.3per cent
- Industrial Processing: 1.7 per cent
- Bioinformatics: 3.9 per cent
- Other: 19.2 per cent

Table 10.1: Biotechnology R&D Firms and R&D Expenditures

Year	2002	2003	2004	2005	2006
Biotech R&D firms	510	528	596	638	627
Dedicated Biotech R&D firms	503	250	279	312	265
%Dedicated Biotech R&D firms	99	47	47	49	42
Total R&D expenditure (million PPP$)	-	1582.8	2376.0	2714.1	2596.3
Biotech R&D expenditure (million PPP$)	386.6	429.7 (27.1%)	503.7 (21.2%)	601.6 (22.2%)	709.3 (27.3%)
Spent by Dedicated Biotech R&D firms (million PPP$)	386.5	158.7	210.3	258.5	266.5

Source: OECD, biotechnology statistics, January 2009.

Figure 10.1: Public and Private Investment in the Korean Bio-industry



Source: *Biotech Policy Research Center, 2008; KIET, Annual Biotechnology Industry Survey, 2008.*

The value of production has increased from 1735 billion won in 1994 to 56,362 billion won in 2009 while imports were valued at 18,292 billion won. This indicates that while imports are about 33 per cent of production, exports being 2728 billion won, Korea has the capacity to make substantial value addition and has the capacity to export a major portion of the production.

In terms of R&D investments in biotechnology Korea ranks 4th among OECD countries and about 30 per cent of the BERD is devoted to biotechnology.[23] In terms of specialization health biotechnology is dominant in Korea as 60 per cent of the biotechnology R&D is devoted to health.[24]

Public biotech R&D accounts for almost 61 per cent of the total biotech R&D expenditure. Public sector expenditure on biotechnology R&D was US$ 1446.8 million PPP in 2006. These figures indicate that the biotechnology industry is yet to mature and is still dependent on government support, and the heavy investment in R&D by public sector may be because of the inability of the private sector to invest heavily in R&D. In terms of value addition also per cent of biotech R&D as a per cent of value added was just 0.093 in 2006 which is much lower than that of countries like France and Sweden.

From Table 10.2, we see that life science has the largest share in receiving public R&D which is about 37.5 per cent, followed by health (26.5 per cent), agri-food (11.9 per cent), industrial (11.9 per cent) and bio-fusion with an 11.7 per cent.

Figure 10.1 shows the trend of Public and Private Investment in the Korean bio-industry over the years 1994 to 2006.

The growth rates of public and private investment in biotechnology have

Table 10.2: Distribution of Pure Public R&D Expenditures (2007 US$ millions)

	Life science	Health	Agri. Food	Ind. Process	Bio-fusion	Sum
2007	274	178	101	104	91	748
2008	314 (37.5%)	221 (26.5%)	107 (12.8%)	100 (11.9%)	94 (11.3%)	836
change, %	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.

fluctuated over the years as shown in Figure 10.1. The national market is not big enough to attract significant amounts in R&D and hence returns on R&D may not be high, unless the industry develops products that have a demand elsewhere also. Venture capital is also a source of investment in biotechnology although the share of life sciences is just 6 per cent of the all venture capital investments.

Thus the constraints on commercialization are obvious and Korean firms have to compete with well established MNCs in foreign markets. Thus the biotechnology industry in Korea is in the early stages of R&D when compared with firms in the USA or Europe or Japan where they have a long history of R&D and successful commercialization of R&D

10.4.1 Biotechnology Employment and Firms

In terms of number of employees most of the firms have less than 50 employees and these firms constitute 63 per cent of the total number of firms. Similarly in terms of biotech R&D firms 60 per cent of the firms have less than 50 employees. Figure 10.2 will give a clearer picture as to how many are employed in different sectors of biotechnology.

Number of biotechnology firms in Korea was 885 in 2010, out of which 325 were dedicated biotechnology firms.[25]

Biotechnology Firms by Applications in Korea in 2006 was as follows:[26]

- Health: 241
- Agriculture: 25
- Food and Beverages: 187
- Environment: 109
- Industrial Processing: 51
- Bioinformatics: 42
- Other:118

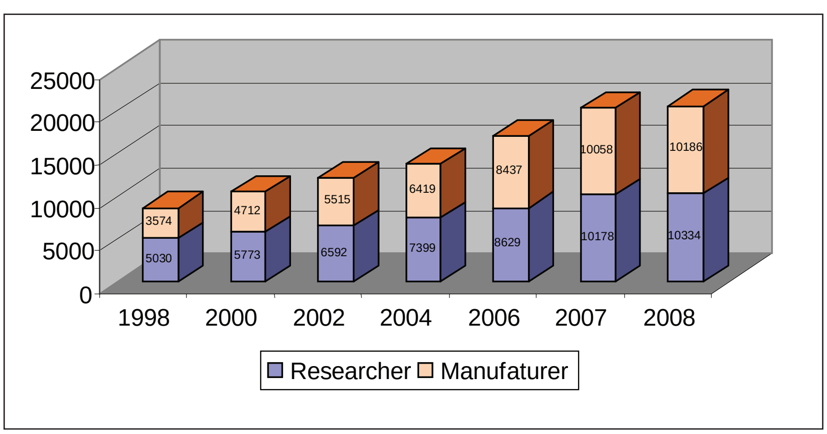
As far as biotechnology employment in biotechnology firms is concerned, there were 17066 biotech employees and 8629 biotech R&D employees in 2006.[27]

10.5 Human Resources

In 2007 about 2000 persons were employed in biotechnology industry of which 50 per cent was in research and the rest in manufacture. The number of graduates in biotechnology has increased considerably over the years. In 2007 bachelor degree holders accounted for 66.5 per cent, masters 24.1 per cent and PhD 9.4 per cent, and the total number of students was about 30,000.

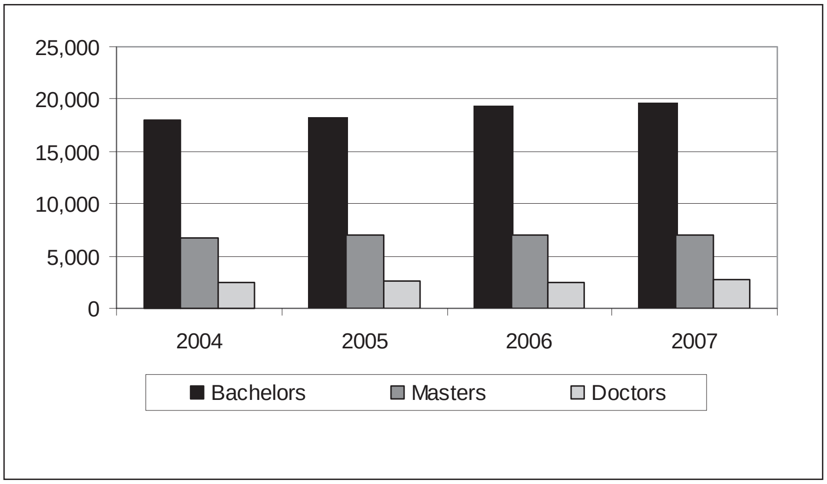
Figure 10.3 shows the number of graduates, post graduates and Ph.Ds in

Figure 10.2 Biotech Employment by Application Field
(Unit: persons)



Source: Dongsoon Lim, 2010.

Figure 10.3: Graduated Students from Biotechnology and Bio-engineering



Source: Biotech Policy Research Center, 2008; Annual Education Statistics (www.std.kedi.re.kr), 2008.

Biotechnology from the years 2003 to 2007. The increase has been significant as shown by the figure.

In terms of human resources Korea is doing well. The number of graduates from biotechnology related departments was 31,740 and of this 30 per cent have Post Graduate or higher qualifications. Similarly, number of employees in biotechnology firms is about 22000 and those employed in R&D form 50 per cent of total employees. (Figure 10.4)

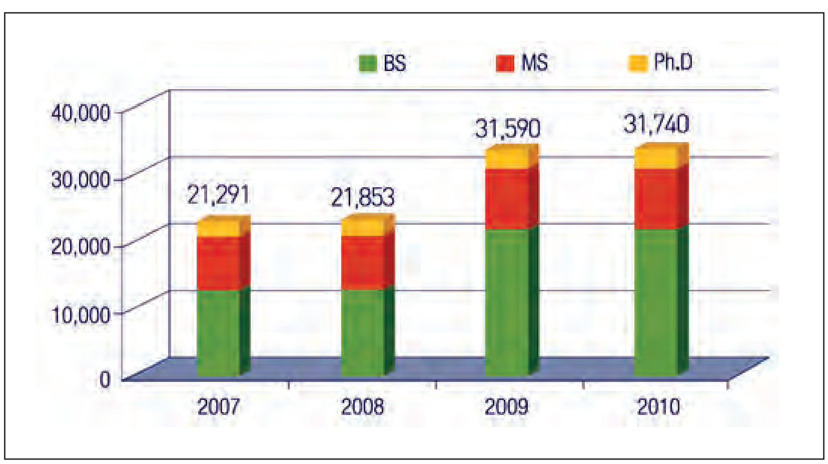
Table 10.3 gives the list of top performing institutes in Korea in the field of biotechnology.

10.6 Patents and Publications

In terms of professional publications in biotechnology and bio-engineering the papers have increased from 420 in 1994 to 4909 in 2007 as shown in Figure 10.5. This shows that investment in biotechnology has resulted in knowledge generation and in publications. Figure 10.7 shows the number of publications in biotechnology and applied microbiolgy from 2001 to 2012.

Figure 10.7 depicts Korea's performance in biotechnology patenting in the period 2001-2012.

Figure 10.4: Human Resource in Biotechnology



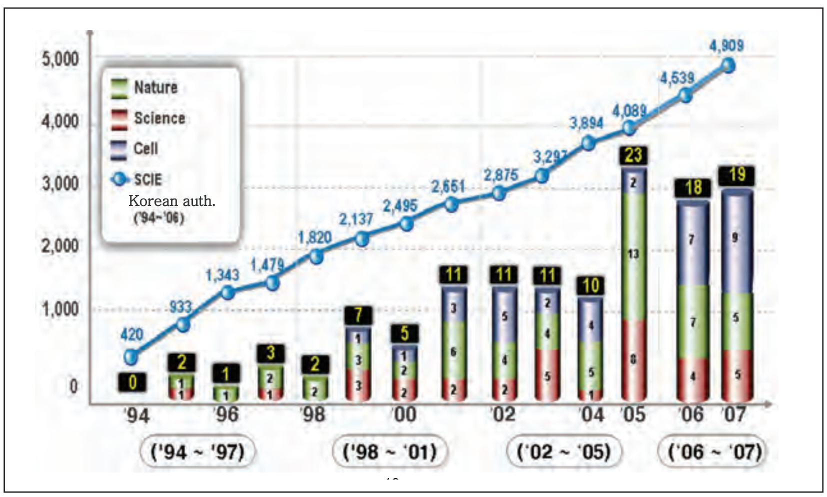
Source: Biotech Policy Research Center (2011).

Table 10.3: Top Ranking Institutions in Korea

Top Ranking Institutions based on Publications in 'Biotechnology and Applied Microbiology' in the period 2001-2012
Seoul National University
Korea University
Korea Advanced Institute of Science and Technology
Konkuk University
Yonsei University
Korea Research Institute of Bioscience and Biotechnology
Chonnam National University
Inha University
Chungnam National University
Kyungpook National University

Source: Thomson Reuters' Web of Science Database, 2013.

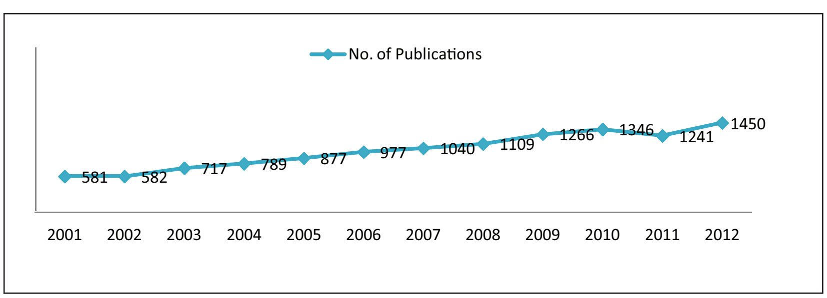
Figure 10.5: Professional Papers of Biotechnology and Bio-engineering



Note: Publications in Research Area 'Biotechnology and Applied Microbiology' in the Period 2001-2012: 11975.

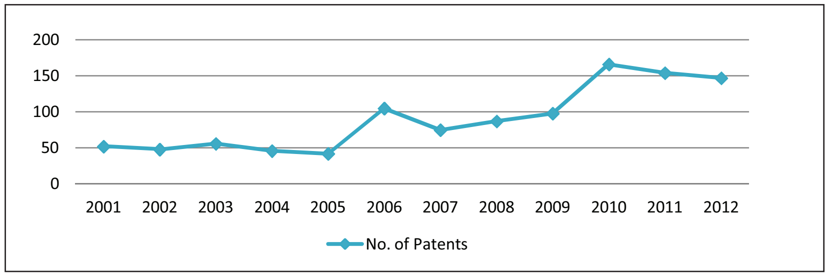
Source: Biotech Policy Research Center, 2008.

Figure 10.6: Publications in Research Area 'Biotechnology and Applied Microbiology'



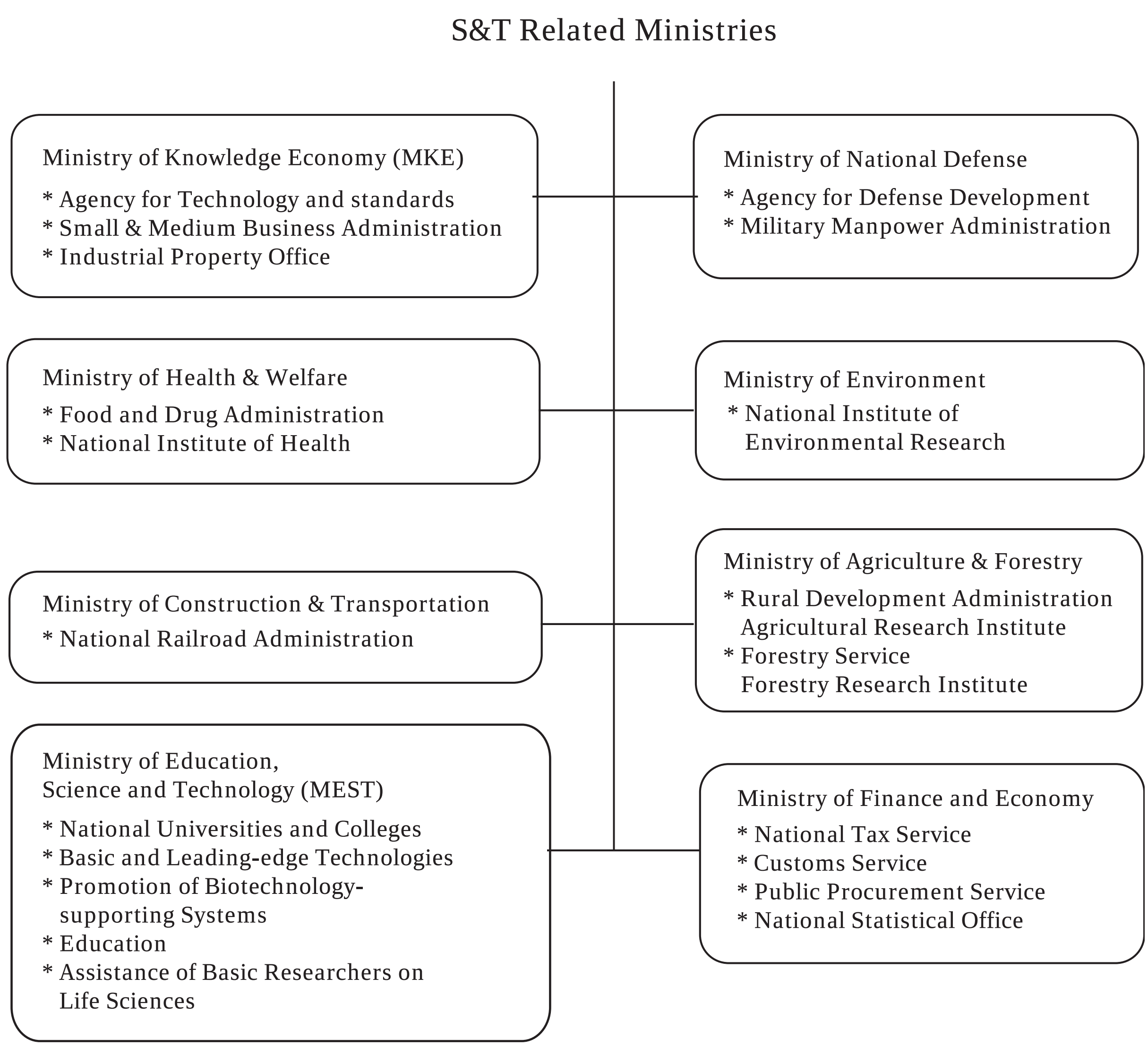
Source: Thomson Reuters' Web of Science Database, 2013.

Figure 10.7: Patents Granted in Biotechnology at USPTO



Source: Thomson Innovation Database, 2013.
Notes: Patents Granted in 'Biotechnology' in USPTO in the Period 2001-2012: 1076.
Patents Granted in 'Biotechnology' in EPO in the Period 2001-2012: 405.

Figure 10.8: S&T Related Organization Chart



Source: Lim, Dongsoon (2009).

Korea's share in biotechnology patents filed under PCT in the period 2008-10 was 3.74.[28]

10.7 Bioindustry Regulatory Framework

Since 1980s, the Korean Government has been constantly involved in coming up with strong fundamentals for developing the biotechnology industry in Korea.[29] The Korean Science and Technology administration system on biotechnology is clearly shown below. The Ministry of Knowledge Economy and the Ministry of Education, science and Technology (MEST) are the two major ministries[30] (Figure 10.8).

The Korean government has been successful in establishing the required infrastructure and it did introduce biosafety, biosecurity and bioethics laws in an attempt to facilitate compliance of biotechnology and bio industry.[31] But this does not mean that the present infrastructure is sufficient. The Korean government also has a strong stance for protection of IPR.

The Korean government implemented the Biosafety and Bioethics Act in 2004, which bans human cloning experiments.[32] Korea also enacted the Act on cross-border Movement of LMOs in 2001 as to implement Cartagena Protocol to the Convention on Biological Diversity.[33] Moreover, importation and manufacturing of GMOs requires government approval and biosafety regulations.

10.8 Summing Up

Korea's national biotechnology strategy indicates that the state is playing an important role in deciding the key sectors for growth of biotechnology. Korea is focusing on biomedical technology. Despite the setback in stem cell research on account of fabrication and falsification of data, it is proceeding ahead with full support to research in biomedical technologies. The industry relies on the continued support from state to grow and diversify. In terms of patents and publications also Korea is doing well and has improved its position. But the challenge lies in keeping the pace of growth and catching up with countries like USA. Whether Korea can repeat the success it had in consumer electronics and automobiles, in biotechnology are yet to be seen. In fact one scholar has pointed out that the Korea's ambitious plans in biotechnology have not met the expectations and has analyzed[34] the reasons for it. Korea's potential in biotechnology is not in doubt and whether, it can reach the high targets. it has set for itself and also grow at this pace and emerge as a competitor to the USA and Europe is an interesting question.

Endnotes

1 World Development Indicator, World Bank Data 2013.

2 International Monetary Fund, World Economic Outlook Database, April 2013.

3 International Monetary Fund, World Economic Outlook Database, April 2013.

4 International Monetary Fund, World Economic Outlook Database, April 2013.

5 CIA The World Factbook, May 2013.

6 World Development Indicator, World Bank Data, 2013.

7 Global R&D Funding Forecast 2013, Battelle and RDMag.com, 2012.

8 Global R&D Funding Forecast 2013, Battelle and RDMag.com, 2012.

9 WDI, World Bank Data, 2013.

10 World Bank, Knowledge for Development, 2013.

11 WIPO and INSEAD, The Global Innovation Index 2012.

12 Bio Technology Industry in Korea, http://www.osec.ch/sites/default/files/BB__E_biotech_skorea_180711.pdf.

13 OECD (2011).

14 OECD (2011).

15 OECD, Biotechnology Statistics Database, December 2012.

16 OECD, Biotechnology Statistics Database, December 2012

17 OECD, Biotechnology Statistics Database December 2012.

[18] Dongsoon Lim. 6th ABDC Presentation and other resources from web.

[19] OECD (2011). Biotechnology Statistics Database.

[20] OECD (2011). Biotechnology Statistics Database.

[21] OECD (2012). Biotechnology Statistics Database, December.

[22] OECD, Biotechnology Statistics Database, December 2012.

[23] OECD (2011) Biotechnology Statistics Database.

[24] OECD (2011) Biotechnology Statistics Database

[25] OECD (2012). Biotechnology Statistics Database, December.

[26] OECD, Biotechnology Statistics Database, 2009.

[27] OECD, Biotechnology Statistics Database, 2009.

[28] OECD (2012). Biotechnology Statistics Database, December.

[29] Lim (2009). “Biotechnology Industry, Statistics and Policies in Korea”. *Asian Biotechnology and Development Review,* Vol. 11, No. 2.

[30] Lim (2009).

[31] Lim (2009).

[32] Lim (2009).

[33] Lim (2009).

[34] Joseph Wong (2010).

Chapter 11:
Lao PDR

11.1 General Introduction

Lao PDR is a lower middle income level[1] country in East Asia and Pacific Region [GDP, Current Prices (USD in Billions): 9.2[2]; GDP, Purchasing Power Parity (USD in Billions): 19.2[3]; GDP (PPP) Share of World Total (%): 0.02[4]]. Agriculture has a decent contribution in its GDP [GDP Composition by Sector (%)[5]: Agriculture: 26, Industry: 34, Services: 40 (2012 estimate)] and it gives the maximum employment [Labor Force by Occupation (%)[6]: Agriculture: 75.1, Industry: N/A, Services: N/A (2010 estimate)]. This makes Lao PDR a predominantly agriculture driven economy.

As far as human resource in R&D is concerned, Lao PDR had very less number of researchers per million of its population. [Researchers in R&D (per million people)[7] in Lao PDR were 15.8 in 2002.] Lack of basic infrastructure and human capital is reflected on its low ranks in Knowledge Economy Index and Global Innovation Index [Lao PDR's Knowledge Economy Index (KEI) 2012 Ranking[8] was 131 and its Global Innovation Index 2012 Ranking[9] was 138].

11.2 Specific Initiatives

Lao PDR completed a joint project by participating in an ADB TA project (No. 6214-REG) entitled "Strengthening Capacity and Regional Cooperation in Advanced Agricultural Science and Technology in the Greater Mekong Sub-region (GMS)" This sub-regional project has brought countries in the sub-region to work more closely in agricultural technology, including biotechnology. The National Science Technology Agency (STEA), the NEA, has established a National Authority for Science and Technology (NAST), as the national coordinating institution at the central level, for the research, development and management of biotechnology, genetic engineering, biosafety and advanced technology. NAST also has a Biotechnology Center to support its work on biosafety.

11.3 Human Resources

Lao PDR is generally dependent international agencies and bodies like IRRI.

Centres of excellence in biotechnology are non-existent.

11.4 Patents and Publications

There is no significant activity in this on biotechnology. Publications were Insignificant and no patents were granted.

11.5 Biosafety

The government of Lao PDR acceded to the Convention on Biological Diversity on September 20, 1996 and the Cartagena Protocol on Biosafety on 1 November 2004. In preparation to be able to comply with its obligation as Party of the CPB, Lao PDR participated in a GEF/UNEP funded project to develop National Biosafety Framework (NBF) and successfully completed the project in December 2004.

This draft NBF was used to prepare a Biosafety Law, which was considered initially at the Lao Government Meeting on 30 August 2005. However, this draft Biosafety Law is yet to be approved. Additionally, biosafety being new to the country, awareness among the policy makers and public is low. More attention has to be directed at enhancing public awareness before they can participate actively and meaningfully in decision-making. The goal of this project is to assist Lao PDR to have a workable and transparent regulatory regime for biosafety by 2010 and to fulfill its National Socio-economic Development Plan to 2020 and obligations as Party to the CPB. However, a National Coordination Committee on Biosafety has been formed by minister's decree number 0163, on 26 January 2011 and the National Strategy and Action Plan for Biotechnology has also been developed.[10] At present, there is inadequate capacity in Lao PDR in human resource, institutional and national infrastructure for Lao PDR to fulfill her obligations as Party to the CPB.

Lao PDR is also participating in a GEF-funded project on "Building Capacity for Effective Participation in the "Biosafety Clearing House". The National Authority for Science and Technology (NAST) has been the coordinating mechanism between all the above initiatives and will also continue as the National Competent Authority (NCA) for this project.

In addition, the government of Lao PDR will establish a Biosafety Fund to support activities beyond the project life.

11.6 Summing Up

Lao PDR is a landlocked country where modern biotechnology R&D activities are still nascent in its national R&D institutions. For some years to come it has to depend on agencies like IIRI on capacity building. There is a need to have a strong commitment from its government to build the capacity and infrastructure for harnessing the benefits of biotechnology.

Endnotes

1 WDI, World Bank Data 2013.

2 International Monetary Fund, World Economic Outlook Database, April 2013.

3 International Monetary Fund, World Economic Outlook Database, April 2013.

4 International Monetary Fund, World Economic Outlook Database, April 2013.

5 CIA The World Factbook, May 2013.

6 CIA The World Factbook, May 2013.

7 WDI, World Bank Data, 2013.

8 World Bank, Knowledge for Development, 2013.

9 WIPO and INSEAD, The Global Innovation Index 2012.

10 UNEP/GEF project titled: Support the implementation of National Biosafety for Lao PDR, 2011, ftp://ftp.unon.org/.../3642_PIR_2010_Lao%20PDR_FY11%20update

Chapter 12:
Malaysia

12.1 General Introduction

Malaysia is an upper middle income level country[1] in East Asia and Pacific Region [GDP, Current Prices (USD in Billions): 303[2]; GDP, Purchasing Power Parity (USD in Billions): 498[3]; GDP (PPP) Share of World Total (%): 0.6[4]]. Industry has a significant contribution in its GDP [GDP Composition by Sector (%)[5]: Agriculture: 11.9, Industry: 41.2, Services: 46.8 (2012 estimate)] and it serves as a major source of employment [Employment (% of total employment)[6] 2010: Agriculture: 13.3, Industry: 27.6, Services: 59.2].

Malaysia's expenditure on R&D is less than 1 per cent [Malaysia's Gross Expenditure on R&D in 2012 [GERD] (USD in Billions, PPP)[7] was 3.3 and its expenditure on R&D in 2012 (per cent of GDP, PPP)[8] was 0.7]. As far as human resource in R&D is concerned, Malaysia has a decent number of researchers per million of its population [Researchers in R&D (per million people)[9] were 364 in 2006 in Malaysia] when compared to other developing countries.

Malaysia is among top 50 countries worldwide when it comes to Knowledge Economy Index as well as Global Innovation Index, which is very important for its industry-intensive economy growth [Malaysis'a Knowledge Economy Index (KEI) 2012 Ranking[10] was 48 and its Global Innovation Index 2012 Ranking[11] was 32].

12.2 Biotechnology in Malaysia

Malaysia has identified biotechnology to be the new engine of growth. Being endowed with a rich biodiversity, cost-competitive skilled labour markets, good transportation and ICT infrastructure along with a strong support in R&D, Malaysia does present a favourable destination for foreign biotechnology companies. It cannot be denied that biotechnology in Malaysia is still in its infancy in some sectors Nevertheless, recognising the immense potential benefits which biotechnology can bring, the country is making every effort to improve its competitiveness in a global setting. This is clearly reflected by the Malaysian government's launching of a 15-year National Biotechnology Policy (NBP) in April 2005.[12] The policy envisages three phases with third phase beginning in 2015. As in many Asian countries it is the state that is the driving force in policy making and in investing in biotechnology.

The objectives of the Biotechnology Policy are:

1. Generate new engine of growth for the nation by creating value that is competitive, innovative and consistent with Vision 2020;

2. Formulate an economic, legislative and regulatory framework that will support the core biotechnology sectors;

3. Identify implementation strategies in order to establish Malaysia as a competitive nation with leading edge businesses;

4. Develop biotechnology to enhance healthcare and medical support for a better quality of life for all Malaysians; and

5. Extract greater value from agriculture and natural resources by utilizing Malaysia's unique biodiversity/ natural environment.[13]

This should be seen in the context of New Economic Model which envisages propelling Malaysia into a high income with sustained economic growth and high technology led development.

Agricultural Biotechnology: Malaysia has not permitted growing of any GM plants/crops. The focus is more on plantations and forest biotechnology. While tissue culture and other similar technologies have been used, genetic modification techniques are in laboratory stage only. [14]

12.3 Human Resources and Capacity Building

The Malaysian biotechnology industry thrives on more than 65 life science and biotechnology companies that are being supported by 14 academic institutions and another 24 research institutes.[15] More than 50 government ministries and organizations are involved in Malaysian life science activities.[16] Due to its strong economic ties with agriculture, much of the life science research in Malaysia focuses on agriculture. Several major industries are built around agricultural products. In addition to support for local industry, Malaysia has strong life science research programmes in nutraceuticals and botanical extracts that are exported to the U.S. and Europe.[17] Several universities in Malaysia have strong teaching and research programmes in life sciences and engineering.

Though lack of human capital and skilled workers has been a limiting factor, there are a good number of scientists and support staff to start with unlike many other developing countries. Local research institutes and universities not only offer good facilities but also a number of excellent projects that could be taken to the next level of developmental stage for example into commercialization with the correct collaboration with the industry.[18]

Table 12.1 gives the list of top performing institutes in Malaysia in the field of biotechnology.

Table 12.1: Top Ranking Institutions in Malaysia

Top Ranking Institutions Based on Publications In 'Biotechnology And Applied Microbiology' In The Period 2001-2012
University of Putra Malaysia
University of Sains Malaysia
University of Malaya
University of Kebangsaan Malaysia
University of Technology Malaysia
International Islamic University Malaysia
University of Pertanian Malaysia
University of Malaysia Sabah
University of Tunku Abdul Rahman
University of Technology Petronas

Source: Thomson Reuters' Web of Science Database, 2013.

12.4 Specific Initiatives

Malaysia is one of the countries where the government has pledged strong support and commitment to develop this sector. Various incentives and funding mechanisms are in place to encourage local companies as well as to attract foreign players. Under the Ninth Malaysia Plan (2006-2010), US$548 million has been allocated for the development of biotechnology industry in Malaysia. Emphasis will be placed on research, development and commercialization, strategic technology acquisition, business and entrepreneurship, development and infrastructure.[19] The Malaysian government has also allocated $3 billion in its budget, 2008 to enhance healthcare, increase the supply of medicine, intensifying research and enforcement activities and strengthen healthcare biotechnology.[20]

12.4.1 The National Biotechnology Policy

The National Biotechnology Policy was launched in 2005 to provide a comprehensive framework for the development of bioechnology in Malaysia. The main objectives are to develop human resources to meet the industry's skill needs and to nurture entrepreneurship and the development of niches in agriculturae biotechnology, healthcare biotechnology, industrial biotechnology and bioinformatics.[21]

12.4.2 The Ninth Malaysia Plan 2006-2010

The Ninth Malaysian Plan aims to at least double the number of biotechnology and biotechnology-related companies to 400 in 2010. Furthermore, the Ninth Malaysian Plan will focus on implementing the New Biotechnology Policy (NBP) to develop Malaysia's niches in agriculture biotechnology, healthcare-related biotechnology, industrial biotechnology as well as bioinformatics.[22]

The government has allocated RM2 billion under the Ninth Malaysian Plan to cover the development of biotechnology industry within the areas: agriculture, healthcare, industry and bio-informatics. Of the RM2 billion 45.9 per cent will be used to develop the physical infrastructure and the remaining 54.1 per cent will be for R&D and commercialization as well as business development programmes.[23] Moreover, under the 2006 Budget the Malaysian government has announced the setting up of the Malaysian Life Science Capital Fund which will be launched with RM100 million under the expectation that government-linked companies and private investors, both foreign and local, top up the fund.

12.4.3 New Biotechnology Policy

The New Biotechnology Policy (NBP) was launched in 2005 to promote growth of the biotechnology outlined in the 9 thrusts namely, Agriculture Biotechnology Development, Healthcare Biotechnology Development, Industrial Biotechnology Development, R&D and Technology Acquisition, Human Capital Development, Financial Infrastructure Development, Legislative and Regulatory Framework Development, Strategic Positioning and Government Commitment.[24] The policy constitutes three phases:

Phase 1 (2005-2010) – Capacity Building: the establishment of advisory and implementation councils, education and training of knowledge workers, business development and industry creation in agricultural biotech, healthcare biotech, industrial biotech and bio-informatics

Phase 2 (2011-2015) – Science to business: involves developing expertise in the discovery and development of new drugs based on natural resources

Phase 3 (2016-2020) – Global Presence: will focus on taking Malaysian companies globally and this sector is expected to contribute 5 per cent of GDP.

12.4.4 Malaysian Biotech Corporation

The Malaysian Biotech Corporation (MBC), established in 2005, acts as the implementing agency responsible for furthering Malaysia's biotechnology objectives with the focus on companies that are in the biotech industry or want to get into the industry.[25] The primary tasks are to attract biotech investments, source partnerships opportunities and support local biotech entrepreneurs in setting up their business. The MBC is located under the Ministry of Science, Technology and Innovation (MOSTI). The Malaysian Biotech Corporation has RM300 million for funding – divided into RM100 million for commercialization, RM100 million for technology acquisition, RM50 million for entrepreneur development and RM50 million for intellectual property framework development.[26]

12.4.5 Bioparks and Clusters

Malaysia has established Economic Regions and Development Corridors such as NCER (Northern Corridor Economic Region), SCORE (Sarawak Corridor of Renewable Energy and within them biotechnology parks and complexes are also being set up. For example, in ECER the objective is to develop Asia's largest biorefinery complex and first commercial bio-isobutanol plant in Asia.

12.4.6 Industrial Biotechnology

Realizing the potential of industrial biotechnology major investments are being made and this includes setting up bio-methionine plant and plants for producing industrial chemicals from bioresources.

12.4.7 BIOTEK

A National Biotechnology Directorate (BIOTEK) was established to replace the National Working Group, when the number of biotechnologists and the number of research activities increased. Under BIOTEK, the National Biotechnology programme was coordinated by 7 Biotechnology Cooperative Centers (BCCs). These BCCs include agricultural, veterinary, medical, food, molecular biology, industrial and environmental and pharmaceutical biotechnology.[27]

12.4.8 Bionexus

Recently, the Government of Malaysia has been moving towards an infrastructure that builds on existing institutions rather than a single one.It has come up with the concept of "BioNexus", which is essentially a network of centers throughout the country, comprised of companies (both local and foreign) and institutions that specialize in specific biotech-subsectors.[28] Initially, three centers of excellence will be established as part of the BioNexus.The BioNexus initiative allows the Malaysian government to grant BioNexus status on selected companies, local and foreign, providing benefits including eligibility for financial incentives and assistance, access to shared equipment facilities, and administrative support through BiotechCorp.[29] Bionexus status companies numbering 217 generate about RM 721 million as revenues and employ 2824 persons. Of this 99 are in agricultural sector while the number of companies in Health care is 74. Bionexus Partnership Programme (BBNP) is a public-private partnership with 56 BNP laboratories and three centres of excellence. The total number of units is 56.[30]

12.4.9 BioMalaysia

BioMalaysia is a key event for the Malaysian biotechnology industry. The event is hosted annually and it is organized

Table 12.2: BioNexus Companies by Application Fields

Sectors	Healthcare	Agriculture	Industrial	Bioinformatics	Total
Number of BioNexus companies	36	31	22	3	92

Source: BiotechCorp (2008).

by the Ministry of Science, Technology and Innovation (MOSTI), BiotechCorp and Protemp Exhibitions Sdn Bhd. [31]The event is further supported by Malaysian Biotechnology Information Centre (MABIC) and Malaysian BioIndustry Organization (MBIO). The event comprises a conference and an exhibition. In BioMalaysia 2008, 60 prominent industry experts from all over the world and more than 1,000 business leaders, scientist, executives, investors and industry leaders were represented.[32] The exhibition featured more than 8,500 visitors and 150 exhibitors from Malaysia and around the world.[33] BioMalaysia offers strategic experiences and resources that could take Malaysia closer to achieving its scientific and business objectives in biotechnology.

12.4.10 Financial incentives

Malaysia provides competitive financial incentives under existing packages, which are also applicable to biotech proposals. Additional attractive incentives to support biotechnology ventures at all stages of development amongst the incentives are incentive for the holding company, tax exemption for biotechnology companies, 100 per cent income tax exemption for a period of up to 10 years for approved biotech companies, investment tax allowance, etc.[34]

12.5 Biotechnology Industry

Biotechnology in Malaysia is expected to generate US$75 billion (RM270 billion) in revenue for the country by 2020.[35] The biotechnology industry is expected to contribute approximately 2.5 per cent to the GDP of the country by 2010, 4.0 per cent by 2015 and 5.0 per cent by 2020.[36] Furthermore, it is estimated that the industry will create 280,000 new jobs, both directly and indirectly, by 2020. In addition, it is expected that 100 biotechnology companies will be established in Malaysia over the next 15 years.[37] Kuala Lumpur-based BiotechCorp was established in 2005 to play the leading role in building the biotechnology business in Malaysia by creating a conducive environment and actively promote foreign direct investments in biotechnology.[38] The Biotechnology sector now is valued at RM 5.4 billion in investments with RM 13.5 billion in revenues, about 55000 jobs and contributes about 2.2 per cent to GDP.[39]

When compared to Korea or Japan, the biotech industry in Malaysia is still in its infancy but with the strong commitment from the government the industry is poised to grow. The pharmaceutical and healthcare sector has emerged as one of the fastest growing biotech sectors in Malaysia.[40] This sector comprises the development of vaccines and therapeutics, contract research and manufacturing, medical devices, diagnostics and drug delivery technologies. With the skyrocketing rise in the cost of clinical trials, many companies are shifting their activities offshore and Malaysia is seen as an attractive destination. Malaysia also boasts a strong foundation in diagnostics products using homegrown technology. The medical devices sector is another area that has been flourishing, the bulk involved in rubber-based medical supplies and consumables.

BiotechCorp developed 92 BioNexus companies, up 119 per cent from the 42 BioNexus companies in the previous period. Total approved investment in BioNexus increased 18 per cent to RM1.3 billion (USD 375.7 million) from RM1.1 billion (USD 317.9 million).[41] BioNexus companies continue to attract international investments from UK, US, France, Germany, Italy, Belgium, India, China, Japan, Taiwan,Hong Kong, Singapore, Thailand, Australia and New Zealand.

Of the 92 BioNexus companies, 47 generated total unaudited revenue of RM378.6 million (USD 109.4 million) for the reporting period – which represents the first full year of financial reporting for BioNexus companies.[42] BioNexus companies continue to expand competencies in agricultural, healthcare, industrial biotechnology and bioinformatics. As one group, BioNexus companies is a significant contributor in the creation of knowledge workers - recording a substantial 382 per cent increase in knowledge workers to 1,851 from 384 in the previous period.

Table 12.2 shows the segmentation of the 92 BioNexus companies into the different areas of biotechnology.There are 36 companies in Healthcare, 31 in Agriculture, 22 in Industrial and 3 in Bioinformatics.

In funding the biotechnology business, BiotechCorp provides grants for seed funding, research and development matching and international business development. At the end of the review period, RM52.2 million (USD 15.1million) were approved for 25 BioNexus companies, up from RM6.25 million (USD 1.8 million) for four BioNexus companies in the previous financial year. There is a further 15 grant applications in the pipeline amounting to RM32 million (USD 9.2 million) pending approval.[43]

Malaysia's biotech industry is largely driven by the development of oil palm and it is expected to grow 22 per cent annually. The industry is currently valued at RM1.3 billion.[44] In the National Budget 2009, RM13.7 billion is allocated to enhance healthcare, which includes increasing the supply of medicines, intensifying research and enforcement activities, further strengthening the growth of healthcare biotechnology which accounts for RM326 million approved investment up to date. There are many expectations for Malaysian biotechnology industry in 2009. The Pharmaceutical industry in Malaysia is expected to surpass RM1.2 billion in 2009.

From Table 12.3, it is clear that the Malaysian public funded biotech companies have witnessed significant growth in 2008 compared to the previous year in terms of number, market capitalization and revenue generation. The number of companies increased by 18 per cent while market capitalization increased by 32 per cent. In terms of revenue, the companies saw an increase of 9 per cent, the corresponding figures being shown above.

As table 12.4 shows, the BioNexus companies saw an enormous increase in terms of number, market capitalization, knowledge workers and revenue generated. Number of companies increased by a huge 119 per cent, from 42 in 2007 to 92 in 2008.Similarly for revenues, market capitalization and knowledge workers, the increases are magnanimous given by 187 per cent, 68 per cent and 382 per cent respectively, while investment saw a decent increase of 18 per cent.

Figure 12.1 shows investment in different sectors, where industrial firms receive the largest share and bioinformatics the smallest.The total investment amounted to RM 1.3 billion

Table 12.3: The Malaysian Biotechnology Industry - Growth in Number of Biotechnology Companies, Revenue Generation, Investment and Knowledge Workers

Public-listed Biotechnology & Life Sciences Companies	2008	2007	% increase
Number of Companies	13	11	18%
Market Capitalization	RM1.7 billion	RM2.5 billion	32%
Market Capitalization versus total Bursa Malaysia Market Capitalization	0.26%	0.23%	13%
Revenue Generation	RM2.4 billion	RM2.2 billion	9%

Source: BiotechCorp (2008).

Table 12.4: Growth of BioNexus companies

BioNexus Companies	2008	2007	% increase
Number of Companies	92	42	119%
Public Companies	2	1	100%
Market Capitalization	RM218.5 million	RM676.5 million	68%
Revenue Generation	RM378.6 million	RM131.8 million	187%
Knowledge Workers	I851	384	382%
Investment	RM1.3 billion	RM1.1 billion	18%

Source: BiotechCorp (2008).

in 2008 where investment in Healthcare is RM346 million, RM412 million in Agriculture, RM541 million in Industrial and RM 36.4 million in Bioinformatics.

12.5.1 Recent Developments in Private Enterprise

In Malaysia, there are several companies developing novel pharmaceutical products. One of these, Bioven, has established relationships with multiple institutes in Cuba and is actively developing products from those Cuban partners for approval and distribution in Malaysia and elsewhere.[45] Another, Duopharma, manufactures more than 300 items for use in Malaysia and for export, including small-volume injectables and generic pharmaceuticals. GENERTI Biosystems fabricates molecular diagnostics and is focused on blood disorders. Additionally, two companies, Alpha Biologics and Inno Biologics have recently been established to provide contract manufacturing services to the global biopharmaceutical industry.

The industry is also going for international collaboration. BioTech Corp is wooing investors and industries from India to set up units in Malaysia.[46]

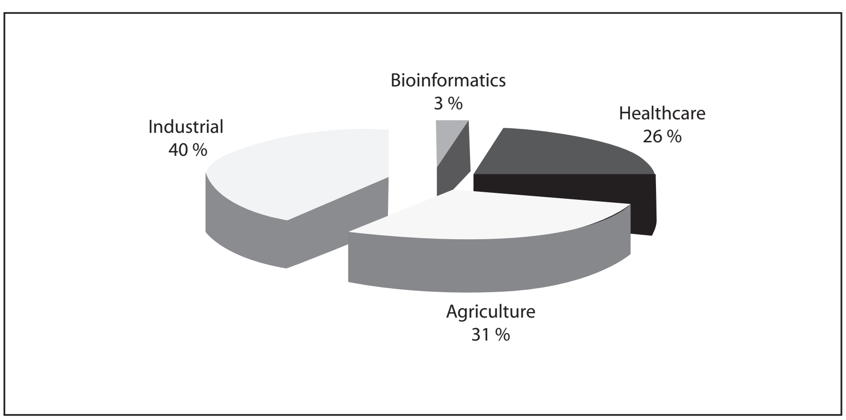
12.5.2 Investment Capital and Funding

The Government remains the largest source of funding for biotechnology projects and companies, offering 17 funds totalling RM4.7 billion for the period under review. Of this, only RM1.6 billion or 34.2 per cent has been utilised as on 31 December 2008, while RM3.1 billion or 65.8 per cent are available for application. It is expected that the utilization rate will increase due to the growth in the biotechnology industry.

In the context of supporting private sector initiatives in the biotechnology industry, the Government will continue to provide infrastructure and technological facilities. For this purpose, a sum of RM236 million is provided in the 2008 Budget.[47]

Private funding for biotechnology in Malaysia is largely provided by venture capital funds.

Figure 12.1: Sector Wise investment in BioNexus Companies (2008)



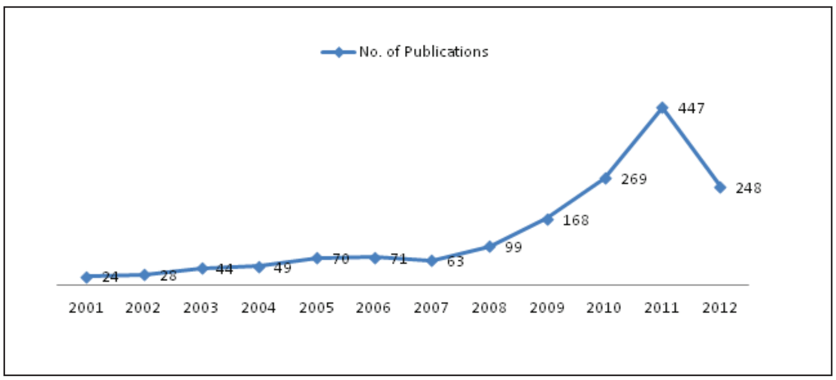
Source: BiotechCorp (2008).

As on 31 December 2008, RM212 million had been utilised from the available venture capital funds for biotechnology and life sciences totaling RM394 million. Within the sectors of life sciences, the sub-sectors of biofuels, bioinformatics and healthcare (primarily biopharmaceuticals) continue to generate interest of local venture capitalists. A number of Malaysian venture capitalists have invested in BioNexus status companies, namely those in healthcare biotechnology.The role of the Malaysian capital market as a key funding source for the local biotechnology industry, remains under developed, with only two Initial Public Offerings in 2008, namely Sunzen Biotech Berhad (a BioNexus status company) and Asia Bioenergy Technologies Berhad. Nevertheless, a total of RM20.9 million was raised from the Initial Public Offering exercise of these two companies.

12.6 Publications and Patents

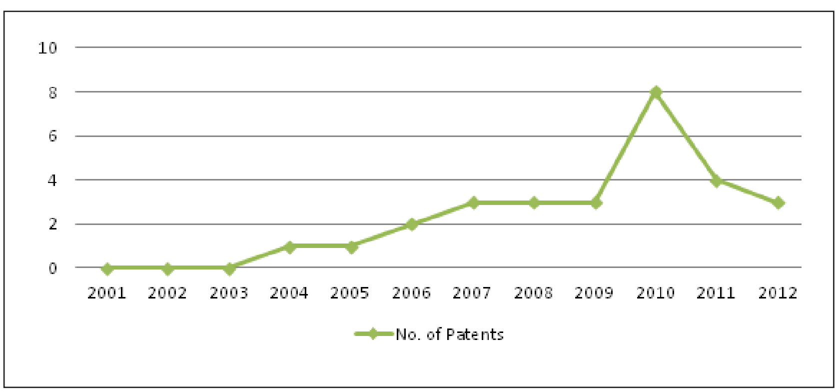
Publications in research area 'Biotechnology and Applied Microbiology' in the period 2001-2012 were 1580 (Figure 12.2). Figure 12.3 depicts Malaysia's performance in biotechnology patenting in the period 2001-2012.

Figure 12.2: Publications in 'Biotechnology and Applied Microbiology'



Source: Thomson Reuters' Web of Science Database, 2013.

Figure 12.3: Patents Granted in Biotechnology at USPTO



Notes: Patents Granted in 'Biotechnology' in USPTO in the Period 2001-2012: 28.
Patents Granted in 'Biotechnology' in EPO in the Period 2001-2012: 16.

Source: Thomson Innovation Database, 2013.

12.7 Biosafety

The Biosafety Act 2007 was passed in August of 2007, although the accompanying regulations, which were envisaged to complement the Act, have yet to be gazetted.[48]As it happens with a large number of countries worldwide, the formulation and adoption of a formal Access & Benefit Sharing (ABS) framework is still under development. Malaysia needs to expedite this effort to enable the preservation of its biodiversity and to prevent bio-piracy.

In Pharmaceutical Regulations, a total of 9 initiatives were completed including participation in the APEC Harmonization of Medial Device Regulations, Review of Drug Development in Clinical Trials and Malaysian Guidelines on Biosimilars. In International Accreditation, a total of 9 initiatives were completed, including participation in the OECD Principles of Good Laboratory Practices with Ministry of Health and Standards Malaysia, Good Clinical Practice Workshops with Clinical Research Centre, Ministry of Health and Good Manufacturing Practice Workshops.[49]

Such initiatives would have surely had a strong impact in building an environment ready for the commercialization of biotechnology in Malaysia.

12.8 Summing Up

Hence, the Malaysian biotechnology sector, though still young, is expected to experience further growth with the government's strong supportive policies and institutional framework aided by the growing expertise and ongoing research activities. Biotechnology, having come a long way since the late 1980s, is one of the keys to Malaysia's future prosperity with the potential to generate enormous economic, health and environmental benefits and it would certainly help transform Malaysia into a highly developed nation by the year 2020.

Endnotes

1 WDI, World Bank Data 2013.

2 International Monetary Fund, World Economic Outlook Database, April 2013.

3 International Monetary Fund, World Economic Outlook Database, April 2013.

4 International Monetary Fund, World Economic Outlook Database, April 2013.

5 CIA The World Factbook, May 2013.

6 WDI, World Bank Data, 2013.

7 Global R&D Funding Forecast 2013, Battelle and RDMag.com, 2012.

8 Global R&D Funding Forecast 2013, Battelle and RDMag.com, 2012.

9 WDI, World Bank Data, 2013.

10 World Bank, Knowledge for Development, 2013.

11 WIPO and INSEAD, The Global Innovation Index 2012.

12 Smeltzer, Sandra. *'Biotechnology, the Environment, and Alternative Media in Malaysia',* The University of Western Ontario.

13 Rofina Yasmin Othman (2012). "The Biotechnology industry – Future Directions in Malaysia" National Biotechnology Division (BIOTEK), MOSTI. Available at: http://www.ibd.utm.my/wellness2012/pdf/presentation/ICBWI2010_D1P02_Prof_Dr_Rofina_Yasmin_Othman.pdf

14 Abdul Ghani Wahab (2012) USDA Foreign Agricultural Service. GAIN Report No. MY2008. Avaialble at: http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Agricultural%20Biotechnology%20Annual_Kuala%20Lumpur_Malaysia_8-24-2012.pdf

15 Wheelwright, Scott M. (2007). "Biotechnology in Malaysia". *BioProcess International.*

16 Wheelwright, Scott M. (2007). 'Biotechnology in Malaysia'. *BioProcess International.*

17 Wheelwright, Scott M. (2007). '"Biotechnology in Malaysia". *BioProcess International.*

18 Biospectrum Bureau: 'Malaysia to promote biotechnology' by BS Reporter / Chennai/ Hyderabad February 11, 2009. Available at: http://www.biospectrumasia.com/content/160109MYS8315.asp.

19 www.buyusa.gov/asianow/mbiotech.html.

20 Biospectrum Bureau, 'Malaysia to promote biotechnology' by BS Reporter / Chennai/ Hyderabad February 11, 2009. Available at: http://www.biospectrumasia.com/content/160109MYS8315.asp.

21 Siaw, Timothy (2007). '"Malaysia Realizes Botechnology pPotential' *Supplement-Life Science IP Focus , 5th Edition,* Malaysia.

22 Royal Danish Embassy, Trade Council of Denmark, 2009. www.ambkualalumpur.um.dk/.../TheBiotechnologyIndustry/.

[23] Royal Danish Embassy, Trade Council of Denmark, 2009. www.ambkualalumpur.um.dk/.../TheBiotechnologyIndustry/

[24] Royal Danish Embassy, Trade Council of Denmark, 2009. www.ambkualalumpur.um.dk/.../TheBiotechnologyIndustry/

[25] Royal Danish Embassy, Trade Council of Denmark, 2009. www.ambkualalumpur.um.dk/.../TheBiotechnologyIndustry/

[26] Royal Danish Embassy, Trade Council of Denmark, 2009. www.ambkualalumpur.um.dk/.../TheBiotechnologyIndustry/

[27] Ling, April, Wong Yuen and Deris, Irdawani. Biotechnology in Malaysia, www.symbiosiso.com/apr02_biotech.htm nline.

[28] Royal Danish Embassy, Trade Council of Denmark, 2009. www.ambkualalumpur.um.dk/.../TheBiotechnologyIndustry/

[29] Royal Danish Embassy, Trade Council of Denmark, 2009. www.ambkualalumpur.um.dk/.../TheBiotechnologyIndustry/

30 Presentation by Dr. Kodi Kandasamy, 6th Asian Biotechnology Development Conference, 2012, Hyderabad, India.

[31] Royal Danish Embassy, Trade Council of Denmark, 2009. www.ambkualalumpur.um.dk/.../TheBiotechnologyIndustry/

[32] Royal Danish Embassy, Trade Council of Denmark, 2009. www.ambkualalumpur.um.dk/.../TheBiotechnologyIndustry/

[33] Royal Danish Embassy, Trade Council of Denmark, 2009. www.ambkualalumpur.um.dk/.../TheBiotechnologyIndustry/

[34] Siaw, Timothy (2007). "Malaysia Realizes Botechnology Potential". *Supplement-Life Science IP Focus, 5th Edition,* Malaysia.

[35] Royal Danish Embassy, Trade Council of Denmark, 2009. www.ambkualalumpur.um.dk/.../TheBiotechnologyIndustry/

[36] Royal Danish Embassy, Trade Council of Denmark, 2009. www.ambkualalumpur.um.dk/.../TheBiotechnologyIndustry/

[37] Royal Danish Embassy, Trade Council of Denmark, 2009. www.ambkualalumpur.um.dk/.../TheBiotechnologyIndustry/

[38] Concept Public Relations India Pvt. Ltd. (February 10, 2009). 'Current global economic climate calls for strategic collaborations, in '*Malaysia To Enhance Partnerships With Indian Biotechnology And Life Sciences Companies'.*

[39] Presentation by Dr. Kodi Kandasamy, 6th Asian Biotechnology Development Conference, 2012, Hyderabad, India.

[40] Biospectrum Bureau: 'Malaysia to promote biotechnology' by BS Reporter/Chennai/ Hyderabad February 11, 2009. Available at: http://www.biospectrumasia.com/content/160109MYS8315.asp.

[41] BiotechCorp, 2008. Strengthening Value Creation, BiotechCorp Annual Report.

[42] BiotechCorp, 2008. Strengthening Value Creation, BiotechCorp Annual Report.

[43] BiotechCorp, 2008. Strengthening Value Creation, BiotechCorp Annual Report.

[44] Royal Danish Embassy, Trade Council of Denmark, 2009. www.ambkualalumpur.um.dk/.../TheBiotechnologyIndustry/

[45] Royal Danish Embassy, Trade Council of Denmark, 2009. www.ambkualalumpur.um.dk/.../TheBiotechnologyIndustry/

[46] Business Line (2009). "Malaysia looking for collaboration in biotech". http://www.thehindubusinessline.com/2009/02/12/stories/2009021250961700.htm

[47] Budget 2008. http://science.kukuchew.com/2007/09/07/malaysia-2008-budget-biotechnology-sector/

[48] BiotechCorp, 2008. Strengthening Value Creation, BiotechCorp Annual Report.

[49] BiotechCorp, 2008. Strengthening Value Creation, BiotechCorp Annual Report.

Chapter 13:
Nepal

13.1 General Introduction

Nepal is a low income level country[1] in South Asia region [GDP, Current Prices (USD in Billions): 19.4[2]; GDP, Purchasing Power Parity (USD in Billions): 40.5[3]; GDP (PPP) Share of World Total (%): 0.04[4]]. Agriculture has a significant share in its GDP [GDP Composition by Sector (%)[5]: Agriculture: 38.1, Industry: 15.3, Services: 46.6 (2012 estimate)] and it gives employment to about 3/4th of total employment in the country [Labor Force by Occupation (%)[6]: Agriculture: 75, Industry: 7, Services: 18 (2012 estimate)]. This makes Nepal basically an agriculture driven economy.

In R&D activities, Nepal did not have sufficient human resource [Researchers in R&D (per million people)[7] in Nepal was 58.7 in 2002] and this is corroborated in its low ranking in both Knowledge Economy Index and Global Innovation Index. [Nepal's Knowledge Economy Index (KEI) 2012 Ranking[8] were 135 and its Global Innovation Index 2012 Ranking[9] was 113.]

13.2 Biotechnology in Nepal

With the return of normalcy and political stability, Nepal has exhibited improved economic performance and greater commitment for technological improvement. In 2008, economic growth went up to 5.3 per cent which was a great improvement over the 2.7 per cent of 2007. The major push in this growth process has come from services and agriculture sector. The share of service sector in overall GDP is 48 per cent which has now expanded to 70 per cent and contributes around 3.6 per cent points to overall growth. Agriculture with 36 per cent share in overall GDP has shown strong growth with 4.7 per cent rate per annum. This has largely come from increased paddy production. Industry growth, however, has slacked at 1.9 per cent. But GDP growth rate shrank in 2010 to 3.5 from 5.3 per cent in 2008. Agriculture and services contribute a major share to GDP with manufacturing lagging behind.

Nepal has launched several initiatives for upgrading biotechnology infrastructure in Nepal. The Science and Technology Policy, 2004 has adopted policy of using science and technology to increase production and productivity, and strategies to carry out studies, research and development activities in the field of biotechnology. In 2006, the National Biotechnology Policy was launched by the government. The Nepalese government has undertaken measures for linking Nepal with international R&D establishments.[10] In 2009, Nepal has received membership for International Centre for Genetic Engineering and Biotechnology (ICGEB). Nepal has also launched joint biotechnology research projects with Asian Institute of Technology (AIT), Bangkok. Nepal's share of world's land is not more than 0.1 per cent while its share of flowering plant species is over 2 per cent. In this relatively small area, more than 700 species of medicinal and aromatic plants have been reported, of which 250 species are endemic to the country. Similarly, Nepal has all topographical regions starting from tropical to alpine regions.[11]

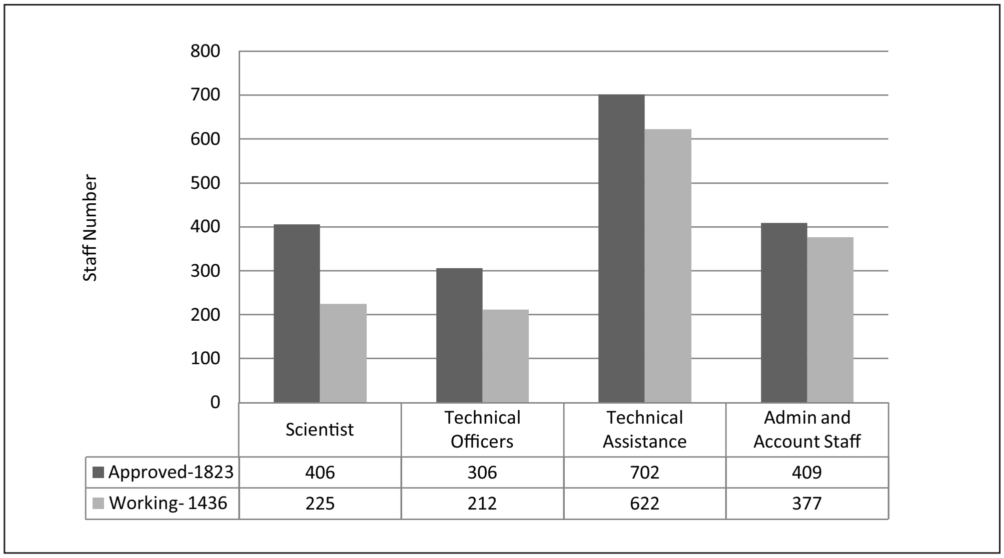
However, Nepal is worried about the research costs which are significant, and with the IPR issues surrounding the most promising biotechnology, multinational companies can obtain profits in relation to their costs.[12] Their primary interests are profit and their focus is primarily on larger and more capital-intensive markets. Therefore, the scope for developing new biotechnology products that involve licensing and hence royalties needs exploring. The Nepal Biodiversity Strategy, 2002 has given priority to conserve and sustainable use of the biodiversity of the nation, which is rich in biodiversity, and equitable sharing of benefits arising from the use of the biological resources. The Nepal Biodiversity Strategy Implementation Plan, 2006-2010 is a plan to implement the Nepal Biodiversity Strategy and thereby achieve the goals of sustainable use of biological resources and of alleviating poverty for conservation of biodiversity. This plan has set priority of the activities to be carried out for implementing the strategy and has also accorded priority to implement the plan through direct participation of all concerned stakeholders and people. Given the importance of agriculture to economy and livelihood, the need for improved varieties is obvious. But Nepal is importing food items from India and China and lack of improved varieties is a factor that inhibits increase in agricultural productivity.[13]

Table 13.1: Academic Institutional Framework in Nepal

University	Course
Kathmandu University	B.Sc. (Biotechnology)
Pokhara University	Biochemistry
Purbanchal University	B.Sc. (Biochemistry)
Tribhuvan University	B.SC. & M.Sc
Kathmandu University (Department of Biotechnology)	Post-Graduate: M.S. by Research in Biotechnology (2 years) -Under-Graduate: B.Tech in Biotechnology (4 years)
Himalayan White House College of Science & Engineering	Under-Graduate: B.Tech in Biotechnology (4 years) [affiliated with Purbanchal University, Nepal]
SAAN International College & Research Institute	-Under-Graduate: B.Sc. in Biotechnology (4 years) [affiliated with Purbanchal University, Nepal]
Lord Buddha Education Foundation	Under-Graduate: B.Sc. in Applied-Biotechnology (3 years) [affiliated with Sikkim Manipal University, India] - Post-Graduate: M.Sc. in Bioinformatics (2 years) [affiliated with Sikkim Manipal University, India]
Universal Science College	- Under-Graduate: B.Sc. Biochemistry (4 years) [affiliated with Pokhara University, Nepal]

Source: Biotechnology Society of Nepal (2009).

Figure 13.1 Manpower at NARC, Nepal in 2008



13.3 Institutional Framework and Human Resources

Nepal has also made substantive efforts to improve the institutional framework in the country (see Table 13.1). There are more than 50 biotechnology institutions with 4 universities apart from public sector institutions. The key public sector institutions are Department of Plant Resources (DPR), Thapathali; Nepal Agricultural Research Council (NARC), Singha Durbar Plaza; Nepal Academy of Science and Technology (NAST), Khumaltar; Fruit Development Directorate (FDD), Kirtipur; Central Veterinary Laboratory (CVL), Department of Livestock, Tripureshwor and Institute of Agriculture and Animal Science (IAAS), Rampur. The research on biotechnology is also diversified and the national survey indicates the availability of capacity in many institutions.[14] But this has not been transformed into a dynamic industry and/ or an academic environment that has brought in innovations needed by Nepal. Thus despite policy framework, investment and capacity, biotechnology in Nepal has not made much headway.

Nepal Agricultural Research Council (NARC) established in 1991 leads the agricultural research in the country to uplift the economic level of the people. NARC currently has a total of 2008 approved positions that includes scientists, technicians and administrative and finance staff (see Figure 13.1) The Institute of Agriculture and Animal Science (IAAS), Nepal, offers a B.Sc. Agriculture (Bachelor of Science in Agriculture), B.V.Sc. & A.H. (Bachelor of Veterinary Science and Animal Husbandry), M.Sc. Agriculture, M.Sc Animal Science and Doctor of Philosophy (Ph.D.) programmes at the central campus at Rampur. The two branch campuses at Lamjung and Paklihawa also offer initial two years of B. Sc. Agriculture course. The funds internally generated by IAAS or the grant money received from internal or external funding agencies on meritorious basis are the only resources being used for the research programmes. At present, more than 50 internally, nationally and internationally funded research programmes are in operation.[15] Tribhuvan University, Kathmandu University and many private campuses have been delivering B.Sc and M.Sc courses in biotechnology. Tribhuvan University has opened the M/Sc. biotechnology from middle of 2006.

Table 13.2: Top Ranking Institutions in Nepal

Top Ranking Institutions based on Publications in 'Biotechnology and Applied Microbiology' in the period 2001-2012
Tribhuvan University
Kathmandu University
Bp Koirala Institute of Health Sciences
Liver Foundation Nepal

Source: Thomson Reuters' Web of Science Database, 2013.

Most of the scientists and researchers involved in biotechnology are specialized in agriculture and botany. It is estimated that a total of 57 MS and 32 Ph D level researchers are engaged in biotechnology research and development.[16] Several Universities (Tribhuvan University, Kathmandu University, Purbanchal University and Pokhara University) now have realized the importance of biotechnology and offer undergraduate and graduate degrees in biotechnology.

Table 13.2 gives the list of top performing institutes in Nepal in the field of biotechnology.

A major issue in human resources is the brain drain from Nepal which results in migration of graduates and qualified youth to other countries for higher education and employment. Such a migration to is not confined to India or China. According to one observer such a migration is all the more acute among biotechnology graduates.[17]

13.3.1 Budgetary Allocations

The new government in Nepal has identified science and technology as the key sectors for economic growth of this land-locked country. Within S&T biotechnology has been identified as the main technology for optimum utilization of rich bioresources of Nepal alongwith reviving agriculture sector through this technology. In 2008, the budgetary allocation had increased 12 times but if we see Table 13.3, the allocations have consistently gone up since 2002-03. The share of biotechnology in 2002-03 was 22 per cent which increased to 52 per cent in 2004-05 and remained around 43 per cent in 2005-06. The budget for biotechnology has again gone up in subsequent years.

The Ministry of Environment, Science and Technology (MEST) has initiated construction of a major biotechnology laboratory in Kathmandu which is expected to be ready by the end of 2009. The MEST has also initiated a programme to use biotechnology for addressing continued energy crisis in Nepal. Nepal experiences power and fuel shortages, so the government will also devote a large part of the money to developing clean energy, including the use of a jatropha as a biofuel.[18]

Nepal has also explored ways for financing of most pressing challenges through external help. A project to improve fodder quality was launched in 2008 with NZAID (See box 13.1). Nepal has also expressed its solidarity and commitment toward several international efforts related to the environment

Table 13.3: Budgetary Allocation for Biotechnology in Nepal

Fiscal year	Biotechnology budget	Total S & T budget	% Share of Biotechnology in Total Budget
2002/2003	$26,000	$120,000	21.67
2003/2004	$6,000	$31,000	19.35
2004/2005	$23,000	$44,000	52.27
2005/2006	$ 12,000	$28,000	42.86

conservation. Consequently it has become a signatory to a number of international legal instruments. Agriculture remains the main sector in which majority of these projects are coming up and invariably have a biotechnology component linked to it. There are several external funding agencies active in Nepal. Some are Rockefeller Foundation, USAID, JICA, IFS, FAO, ODA (UK) and ADB.

A recent initiative is to set up National Biotechnology Centre to promote R&D in health, agriculture, environment and industry with an investment of $13 million over five years likely to give a fillip to biotechnology in Nepal.[19]

13.4 Publications and Patents

Publications in Nepal in the field of biotechnolgoy were insignificant and no patents were granted.

13.5 Biosafety

Nepal's biosafety policy is based on the precautionary principle.[20] Realizing the need of biosafety for the conservation of biodiversity it has made a provision of forming a biosafety sub-committee under the National Biodiversity Coordination Committee. Nepal signed the Cartagena protocol on Biosafety on 2 March, 2001.The Ministry of Forest and Soil Conservation (MFSC) has enforced Biosafety regulations 2062 BS throughout the Nepal since 25th May, 2005. Accordingly, the Government of Nepal gave high priority to Biosafety Policy in its budget policies and programmes statement for fiscal year 2006-07. The Government has identified various agencies responsible for different function in managing the biosafety requirements. As GMOs may be seed, plants animals for the agriculture or forestry purpose, and products of GMOs or products containing GMOs such as food, feed or pharmaceuticals, therefore, depending upon the types of the GMOs and products thereof, respective sectoral line agencies as presented in table 13.4 are designated by the Government as sectoral

Box 13.1 Cooperation for Fodder Development

Nepal has launched research based initiatives for improving the quality of fodder in Nepal. A memorandum of understanding (MoU) was signed on 9 March 2008 between Nepal Agricultural Research Council (NARC) and Institute for Crop and Food Research Limited (CFR) to implement the project 'Sustainable Animal Fodder System for Improving Household Incomes'. The objective of the project is to build technical capacity and familiarization for on-farm fodder extension packages among established clusters of farmers; to improve the quality of onfarm winter and summer fodder crop production and animal feeding systems; to improve animal health, fertility and milk yields; to reduce the heavy work loads of women farmers; and to sustain long-term improvements for the livelihoods of farmers and their families. Essentially the projects aims, in participatory way, to change farmers from gatherers of low quality fodders into producers of high quality fodder on their current land holdings, utilizing fallow winter fields between summer grain crops.

According to the agreement, NARC, in collaboration with CRF will: identify and organize the formation of appropriate farmer cluster groups, oversee organization of training needs and media materials for training of extension field staff and farmers, coordinate the technology transfer process to farmers, identify and manage potential soil sustainability issues, facilitate ongoing reviews of the technologies in accordance with the agreed project objectives, modify the technologies where and when appropriate, and facilitate the collection and collation of technical and social impact data for the monitoring, evaluation and reporting requirements of NZAID. The duration of the project is for three years from 1 January 2008 to 31 December 2010.

Source: NARC News Letter, Vol 15, 10 January-March 2008.

Table 13.4: Sectoral Competent Authorities and Responsible GMOs

Name of Institution	GMOs and Products thereof
Department of Agriculture	Plants, Micro-organism and Fish for Agriculture Purpose,
Department of Food Technology and Quality Control	Food and Feed
Department of Livestock and Animal Health	Animal, Birds and Forage
Seed and Quality Control Centre	Seed for Agricultural Purpose
Department of Plant Resources	Seed and Plant for Forestry Purpose
Department of Drug Administration	Pharmaceuticals

competent authority, responsible for the evaluation of the respective proposals and its risk assessment report, monitoring of the implemented proposals, ensure that the GMOs or its products permitted for testing, storage, use are properly labelled with the description of its composition, direction for use, potential risk, and management of the risks arising from implementation of the proposal.

The guideline aims to layout safety measures for study and research in laboratories and in the field trials, and in various industries using biotechnology. It also envisages guiding in handling, transport, export import of LMOs and their products. The guideline however doesn't have any legal binding and thus remains voluntary rather than regulatory.

13.6 Summing Up

Nepal is a country which was expected to make a headway in biotechnology but not much has happened despite favourable policy, investments in human resources and infrastructure. Given the potential of biotechnology to make significant contributions to agriculture and utilization of biodiversity it is essential that Nepal should not trail behind in applying biotechnology.

Endnotes

1 World Development Indicator, World Bank Data 2013.

2 International Monetary Fund, World Economic Outlook Database, April 2013.

3 International Monetary Fund, World Economic Outlook Database, April 2013.

4 International Monetary Fund, World Economic Outlook Database, April 2013.

5 CIA The World Factbook, May 2013.

6 CIA The World Factbook, May 2013.

7 WDI, World Bank Data, 2013.

8 World Bank, Knowledge for Development, 2013.

9 WIPO and INSEAD, The Global Innovation Index 2012.

10 http://www.most.gov.np/np/images/stories/policies/biotechpolicy-2063.pdf

11 Dhakal and Joshi (2007). "Research and Development of Agricultural Biotechnology in Nepal" in S. Chaturvedi and S.R.Rao (Eds) *Asian Biotechnology, Innovation and Development.* New Delhi: RIS.

12 NARC (2002). *NARC 2002 Vision for 20 Years: Agricultural Research for Sustainable Livelihood Development.* National Agricultural Research Council Kathmandu: Nepal.

13 Uma S. Shah and Amol Dahal (2011). "Biotechnology innovation and commercialization Contemporary challenges and opportunities in Nepal". *TechMonitor,* March-April, Pp 45-50.

14 National State of the Report on Biotechnology-Nepal Academy of Science and Technology (NAST), Khumaltar, Lalitpur, Nepal and Ministry of Environment, Science and Technology (MoEST), Government of Nepal, Singha Durbar, Kathmandu, Nepal, December 2008. www.nast.org.np/alluploads/National-State-of-the-Art-Report.pdf

15 http://www.iaas.edu.np/pages/research.htm accessed on 19th August 2009.

16 Dhakal and Joshi (2007).

17 http://raunakms.wordpress.com/2012/06/02/a-decade-in-nepali-biotech-bitter-side-of-a-tasty-fruit/

18 Guo (2008).

19 http://blogs.nature.com/tradesecrets/files/2012/04/April_12-map.jpghttp://www.scidev.net/en/south-asia/news/nepal-plans-biotechnology-centre.html

20 MFSC (2006). *MFSC National Biosafety Framework.* Minsitry of Forests and Soil Conservation Singhadurbar, Kathmandu, Nepal.

Chapter 14:
New Zealand

14.1 General Introduction

New Zealand is a high income level country[1] and a member of OECD [GDP, Current Prices (USD in Billions): 169[2]; GDP, Purchasing Power Parity (USD in Billions): 131[3]; GDP (PPP) Share of World Total (%): 0.15[4]]. Its economy is basically Services sector driven [GDP Composition by Sector (%)[5]: Agriculture: 4.8, Industry: 24.6, Services: 70.6 (2012 estimate)] and it is a major source of employment too [Employment (% of total employment)[6] 2009: Agriculture: 6.6, Industry: 20.9, Services: 72.5].

New Zealand spends more than 1 per cent of its GDP on R&D [New Zealand's Gross Expenditure on R&D in 2012 was 1.6 (USD in Billions, PPP)[7] and its expenditure on R&D in 2012 (% of GDP, PPP)[8] was 1.22].

As far as human resource in R&D is concerned, it has a decent number of researchers per million of its population. [Researchers in R&D (per million people)[9] in New Zealand were 4950 in 2009. This is reflected on its high ranking in both Knowledge Economy Index and Global Innovation Index. [New Zealand's Knowledge Economy Index (KEI) 2012 Ranking[10] was 6 and its Global Innovation Index 2012 Ranking[11] was 13.]

14.2 Biotechnology in New Zealand

Biotechnology in New Zealand is growing fast and has a long way to go when compared to Japan or China. As a small country with limited national market, New Zealand has to focus on global markets and develop linkages for the national biotechnology industry to survive and grow. Inevitably it has to focus on industries in which New Zealand has competitive advantage globally and develop innovative products for the global market. New Zealand thus is facing an unusual challenge in using biotechnology. In one sense its position is similar to the city republic Singapore. But the difference lies in the agriculture and dairy sectors, in which New Zealand has competitive advantage. New Zealand is giving importance to health biotechnology also. The state in New Zealand is actively supporting biotechnology industry and is also supporting the research in basic life sciences.

14.3 Industry structure

Number of biotechnology firms in New Zealand was 369 in 2011, out of which 135 were dedicated biotechnology firms.[12]

Biotech firms had a compound annual growth rate of 27 per cent during 2007-09.[13] The total income of core biotechnology organizations was about $ 600 million with exports contributing $ 300 million in 2009.[14] Although there is a policy framework that promotes biotechnology the industry relies on own funds to a very great extent than government funding. For instance, in case of funding for core biotechnology organizations in 2009 own funds amounted to 87 per cent of the expenditure.[15] Overseas funds were just 2.4 per cent while government funding was 5.3 per cent.[16]

In terms of usage of biotechnology 67 per cent were in R&D, 21 per cent was part of production process while 13 per cent was as part of product sold.[17] Process biotechnology including fermentation and bioprocessing is a major application of biotechnology. In terms of areas of application the status of biotechnology in 2007 is given in Table 14.1.[18]

Thus the industry is well diversified and the educational and R&D infrastructure in New Zealand is advantageous to the growth of the industry. In 2007 the Ministry of Research, Science and Technology produced Biotechnology Research Roadmap. In between 2008-10 the government funding for research was about $ 426 million.[19]

The public funding is directed through various agencies and bodies including the Foundation for Research, Science and Technology (FRST), Health Research Council, and Royal Society of New Zealand. The FRST approved $ 785 million for more than 24 research organizations. Public sector biotech R&D as percentage of total expenditure on biotech R&D was 61 per cent in 2005. Of the dedicated biotechnology firms by application health and agriculture together constituted 40 per cent.

14.4 Government Strategy

In 2003 the Ministry of Research, Science and Technology came out with a New Zealand Biotechnology Strategy and indicated that the biotechnology policy of the government would be guided by the following principles : (i) Benefit for New Zealand, (ii) Sustainable development, (iii) Responsibility and Ethics, (iv) Innovation, (v) Partnership and Participation (vi) Treaty of Waitangi, and (vii) Biosecurity and Biological Diversity.[20]

The Growth and Innovation Framework identified biotechnology, information and communication technology and creative industries as three enabling sectors crucial to the future of New Zealand with applications across the economy. The Biotechnology Taskforce was set up to focus on the commercial application of biotechnology. After consultations on the Strategy Discussion Paper, Biotechnology Taskforce Report, Report of the Royal Commission on Genetic Modification and review of biotechnology strategies of other countries, the Biotechnology Strategy was finalized.

One of the elements of the strategy is to strengthen the capability and the

Table 14.1: Areas of Applications of Biotechnology

Plant based biotechnology	6 per cent
Animal based biotechnology	51 per cent
Biomedical science and drug discovery	8 per cent
Marine biotechnology	2 per cent
Innovative foods and human nutrition	19 per cent
Environmental biotechnology	0 per cent
Bioprocess and biomanufacturing	13 per cent
Others (impacts and integration of biotechnology)	1 per cent

Source: NZBI 2010 Bioscience Industry Report.

actions on this include enhancing science and technology education, recruit and retain science entrepreneurs, invest in excellence in fundamental research, foster and use the Maori biological knowledge and innovative capacity, and develop commercial skills and experience. The strategy identified both traditional areas like plant based biotechnology and niche areas in biomedical technologies as areas in which New Zealand has existing strength. The strategy indicates that government can support building a critical mass in areas of strength and support clustering and developing alliances and collaboration.

The Biotechnology Taskforce's updated recommendations in 2007 suggested that unified industry body NZBIO could be set up to promote growth. It also suggested more research incentives in tax laws, expanding the NV Venture Investment Fund, and creation of Australia-New Zealand Biotechnology Partnership Fund (ANZBPF) to facilitate collaboration between Australia and New Zealand in biotechnology. New Zealand Trade and Enterprise (NZTE) was established in 2003 as an agency to boost economic development. NZTE has initiated many initiatives and administers the ANZBPF.

The funding from government for research, science and technology is routed through many ministries and the FRST under Ministry of Research, Science and Technology (MRST) is a major source of funding.

Table 14.2 gives the list of top performing institutes in New Zealand in the field of biotechnology.

Besides the national initiatives under the Biotechnology Strategy, there are many regional initiatives. In the Wellington region Grow Wellington is an initiative that helps firms and enables venture development. There are some public-partnerships in biotechnology. In terms of clusters and regions that are active in biotechnology, New Zealand lags behind. There are no clusters that could be compared with those in other countries. In terms of activity, Auckland is the most active region with 21 per cent of nation's total biotechnology investment.

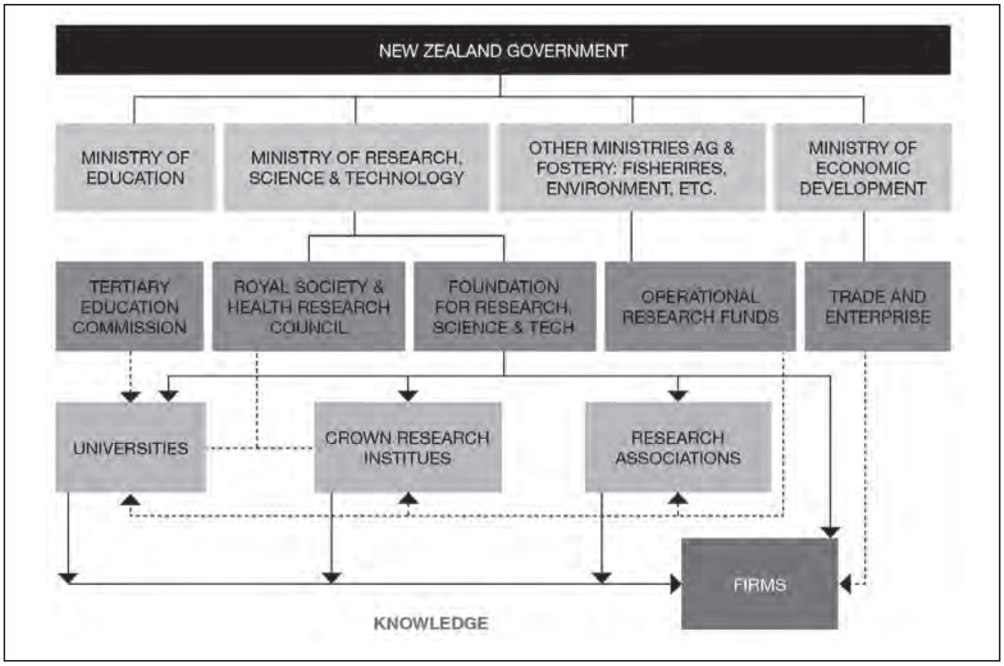
But lack of experts in biotechnology R&D is considered as a constraint in R&D by the industry. In the surveys conducted in 2005 and 2007 this was cited as a constraint by 24 per cent of the organizations.[22] It is not surprising therefore that the firms recruited staff from overseas with Europe contributing about 40 per cent. Venture capital and private equity investments have increased since 2005. In 2007 it was about $67 million, three times that of 2005.

Table 14.2: Top Ranking Institutions in New Zealand

Top Ranking Institutions based on Publications in 'Biotechnology and Applied Microbiology' in the period 2001-2012
University of Auckland
Massey University
University of Otago
University of Canterbury
Lincoln University
Agresearch
University of Waikato
Landcare Research
New Zealand Institute of Crop Food Research
Scion

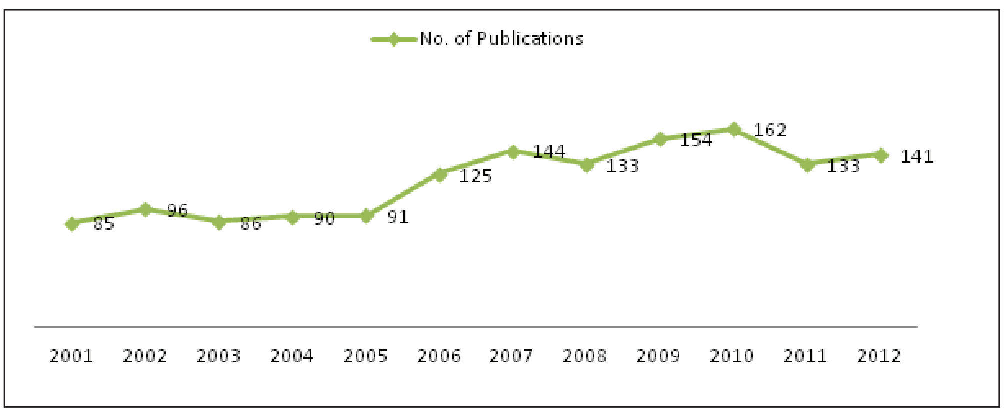
Source: Thomson Reuters' Web of Science Database, 2013.

Figure 14.1: Biotechnology Research and Funding from Government[21]



Source: http://www.nzbio.org.nz/portals/2/images IndustryReports/MakingBiotechWork.pdf

Figure 14.2: Publications in research area 'Biotechnology and Applied Microbiology'



Source: Thomson Reuters' Web of Science Database, 2013.

Although there was no public offering the biotechnology companies raised $100 million from secondary offerings in 2006. Access to capital was cited as another major constraint to biotechnology R&D.

14.5 Publications and Patents

Publications in Research Area 'Biotechnology and Applied Microbiology' in the period 2001-2012 were 1440 (Figure 14.2).

Figure 14.3 graph depicts New Zealand's performance in biotechnology patenting in the period 2001-2012.

Patents Granted in 'Biotechnology' in USPTO in the Period 2001-2012 were 153.

Patents Granted in 'Biotechnology' in EPO in the Period 2001-2012 were 66.

New Zealand's share in biotechnology patents filed under PCT in the period 2008-10 was 0.38.[23]

New Zealand's revealed technological advantage in biotechnologies was 1.8 in 2008-10.[24]

14.6 Biosafety and Regulation

New Zealand signed the Cartagena Protocol in 2000 and ratified it in 2005. Biosafety regulations are in place in New Zealand. Between 2006 and 2008, field trial for 14 GM crops was approved. Of these herbicide tolerant trait trials were 5. The share of public sector in this was 100 per cent.[25] In regulating biotechnology the government's strategy is sensitive to the issues of transparency and preservation of biotechnology. Many agencies are involved in regulating biotechnology (e.g. Environmental Risk Management Authority, the Gene Technology Advisory Committee and Food Standards Australia New Zealand).

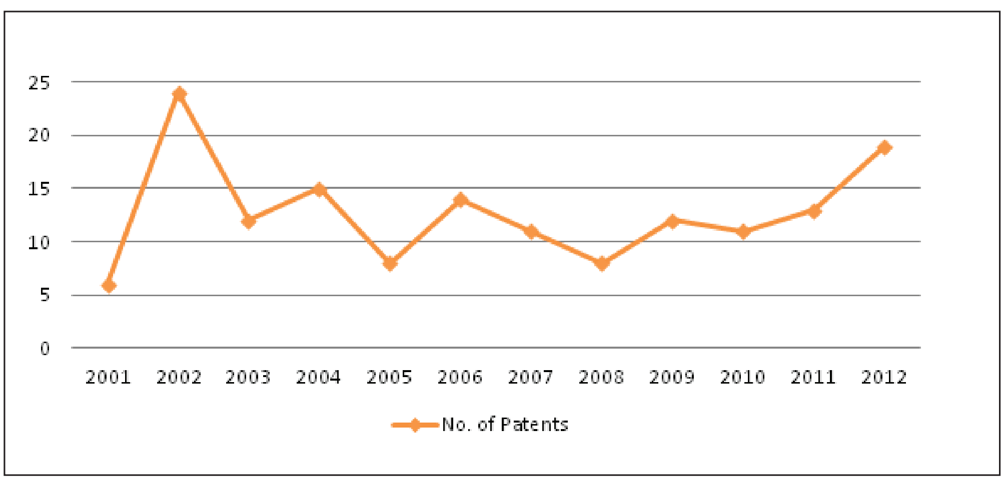
14.7 Summing Up

In New Zealand, biotechnology as in many countries in AP is heavily promoted by the government as part of the broader economic strategy. Besides this there is a specific national strategy also. Public sector funding is a major source of funding in basic research. In terms of employment biotechnology's contribution is small. The presence of a diversified biotechnology industry with many firms engaged in R&D activity is an important aspect of biotechnology in New Zealand. In terms of employment the contribution of biotechnology is small but it has potential to create value addition in other industries and stimulate employment growth in other sectors.

Although some constraints like lack of sufficient funding and non-availability of trained personnel may not be unique to New Zealand they can derail the plans to use biotechnology for economic development. The biotechnology industry in New Zealand has to focus on global markets but in terms of size it is miniscule when compared to the industry in Japan or USA. On the other hand the industry can still be a global player in niche areas and can offer specialized services.

Thus, biotechnology in New Zealand is an emerging industry with much potential to grow and diversify and contribute to economic development.

Figure 14.3: Patents Granted in Biotechnology at USPTO



Source: Thomson Innovation Database, 2013.

Endnotes

1 WDI, World Bank Data 2013.

2 International Monetary Fund, World Economic Outlook Database, April 2013.

3 International Monetary Fund, World Economic Outlook Database, April 2013.

4 International Monetary Fund, World Economic Outlook Database, April 2013.

5 CIA, The World Factbook, May 2013.

6 WDI, World Bank Data, 2013.

7 Global R&D Funding Forecast 2013, Battelle and RDMag.com, 2012.

8 Global R&D Fund=ing Forecast 2013, Battelle and RDMag.com, 2012.

9 WDI, World Bank Data, 2013.

10 World Bank, Knowledge for Development, 2013.

11 WIPO and INSEAD, The Global Innovation Index 2012.

12 OECD, Biotechnology Statistics Database, December 2012.

13 OECD, Biotechnology Statistics Database, December 2012.

14 OECD, Biotechnology Statistics Database, December 2012.

15 OECD, Biotechnology Statistics Database, December 2012.

16 OECD, Biotechnology Statistics Database, December 2012.

17 Statistics New Zealand Biotechnology Survey for the year 2006 and 2008.

18 Statistics New Zealand Biotechnology Survey for the year 2006 and 2008.

19 NZBI 2010 Bioscience Industry Report.

20 New Zealand Biotechnology Strategy 2003 and other related documents at www.morst.gov.nz

21 Making Biotechnology Work for New Zealand, Grow Wellington Ltd 2008.

22 Making Biotechnology Work for New Zealand, Grow Wellington Ltd 2008.

23 OECD, Biotechnology Statistics Database, December 2012.

24 OECD, Biotechnology Statistics Database, December 2012.

25 UNU-MERIT GM field trial database, Maastricht, the Netherlands, April 2009.

Chapter 15:
Pakistan

15.1 General Introduction

Pakistan is a lower middle income level country[1] in South Asia [GDP, Current Prices (USD in Billions): 231[2]; GDP, Purchasing Power Parity (USD in Billions): 515[3]; GDP (PPP) Share of World Total (%): 0.6[4]]. Services sector has more than 50 per cent share in its GDP [GDP Composition by Sector (%)[5]: Agriculture: 20.1, Industry: 25.5, Services: 54.4 (2012 estimate)], whereas Agriculture gives employment to around 50% of total employed people [Employment (% of total employment)[6] 2008: Agriculture: 44.7, Industry: 20.1, Services: 35.2].

Pakistan's expenditure on R&D expenditure is less. Expenditure on R&D in 2009 (% of GDP, PPP)[7] was 0.46 and human resource in R&D is also below average. [Researchers in R&D (per million people)[8] in Pakistan were 161 in 2009]. This speaks of its low ranking both in Knowledge Economy Index and Global Innovation Index [Pakistan's Knowledge Economy Index (KEI) 2012 Ranking[9] was 117 and its Global Innovation Index 2012 Ranking[10] was 133].

15.2 Biotechnology in Pakistan

Pakistan started to work on biotechnology in the early 1980s and since then biotechnology has received continuous support from the government. The Government of Pakistan has invested more that US$ 20 million in biotechnology research and maintains a large network of 31 state owned biotechnology research centres.[11] Although most of the research is focused on agriculture, there are initiatives in other sectors also. The biotechnology industry in Pakistan is not well developed. The biotechnology in Pakistan to a great extent is government driven with participation of many universities and institutes. The first major initiative was the National Institute for Biotechnology and Genetic Engineering (NIBGE) at Faisalabad foundedin1987 by the Pakistan Atomic Energy Commission (PAEC). Since then many centers and universities have been established to do research in biotechnology. The National Commission on Biotechnology was formed in 2001.[12]

15.3 Specific Initiatives

The potential for biotechnology was realized in the early 1980s.[13] After that many research centers were setup and most of them were devoted to agricultural biotechnology, with research focus on crops that are of economic importance to Pakistan. This is understandable given the importance of agriculture's contribution to GDP and in terms of employment.[14] Tissue culture was one of the first applications of biotechnology in Pakistan. The institutes and centers were funded mostly by the various ministries/departments of the government including University Grants Commission and Ministry of Science and Technology (MOST). At present there are 29 departments/institutes/centers involved in biotechnology. Of the 29, 21 are university departments and the rest are R&D organizations. Of these four are focusing on development of GM crops. In terms of investment more than US$ 25 million has been invested during the last five years in biotechnology R&D. The Institute of Agricultural Biotechnology and Genetic Resources, Islamabad, is doing research on transgenic Basmati Rice. Earlier it had developed technology for use of tissue culture in date palm resulting in increase in exports of date palm. Research to tackle the Banana Bunchy Top Virus (BBTV) problem is also undertaken. Most of the crop improvement efforts using biotechnology are on rice and cotton. Virus-resistance and salinity tolerance GM cotton varieties have been developed and are under going trials. The private sector involvement in GM crops is minimal. Monsanto is active in Pakistan and has not released any GM crop for cultivation. In use of tissue culture in agriculture the success is limited to just two or three crops and the activities in this are yet to reach commercial scale in other plants.

Although there has been significant investments in Pakistan in creating centers and institutes, not all of them are capable of taking up advanced biotechnology R&D. Limited financial resources is a constraint. Moreover biotechnology applications in different sectors of the industry are confined to mostly first generation biotechnology. Thus although the importance of biotechnology was realized in early 1980s itself Pakistan has a long way to go in using as well as in benefiting from biotechnology. This should be understood in the larger context of the problem of low-yields in agriculture and the problems in the agriculture innovation system including the lack of trained personnel in agricultural R&D. According to one author the proportion of agricultural scientists with PhD is just 10 per cent of total agricultural scientists in Pakistan. Another factor is the low level of investment in agricultural innovation system. [15]

Although Pakistan has not embarked on commercialization of agricultural biotechnology in a big way, major advances are expected in the coming years as many trials have been approved. In May 2010 eight Bt cotton (MON 531) varieties have been approved by the Government of Pakistan (GoP) for general cultivation. A number of Genetically Modified Crops are currently under development with public/ private/ multinational seed companies in Pakistan. Bt cotton varieties are cultivated in almost 8.5 million acres in Pakistan. This is almost 100 % of the cotton cultivated area in Pakistan.[16] Furthermore, BT corn trial has also been allowed to Monsanto by the Technical Advisory Committee of the National Bio-Safety Committee (NBC) of Pakistan in March, 2012.[17]

The importance of biotechnology in Pakistan's agriculture has been recognized by IFPRI which argues that current technologies and current best practices alone will not be sufficient by 2030 when the population is expected to be in the range of 23- 260 million and other problems like declining water resources, and land degradation are likely to intensify further.[18]

15.4 Human Resources

According to one estimate there are 504 scientists involved biotechnological R&D in Pakistan, of which 50 are Post-Doctoral

Table 15.1: Top Ranking Institutions in Pakistan

Top Ranking Institutions based on Publications in 'Biotechnology and Applied Microbiology' in the period 2001-2012
Quaid I Azam University
University of Punjab
University of Agriculture Faisalabad
University of Peshawar
University of Karachi
National Institute of Biotechnology and Genetic Engineering
Bahauddin Zakariya University
National Agriculture Research Centre
Hazara University
Kohat University of Science and Technology

Source: Thomson Reuters' Web of Science Database, 2013.

scientists and 188 are PhD holders. Between 1985-1995, MOST supported S&T Fellowship programme for 100 PhDs and biotechnology was given 3 per cent of the fellowships. It is expected that among the PhD students and post-doctoral scientists being trained abroad under various bilateral projects and through schemes of the Higher Education Commission of Pakistan, a significant number will return to Pakistan and contribute to its growth in biotechnology. The new initiatives in human resources for S&T include schemes for hiring faculty from abroad, split PhD scheme and more fellowships for pursuing PhD in sciences.[19]

Table 15.1 gives the list of top performing institutes in Pakistan in the field of biotechnology.

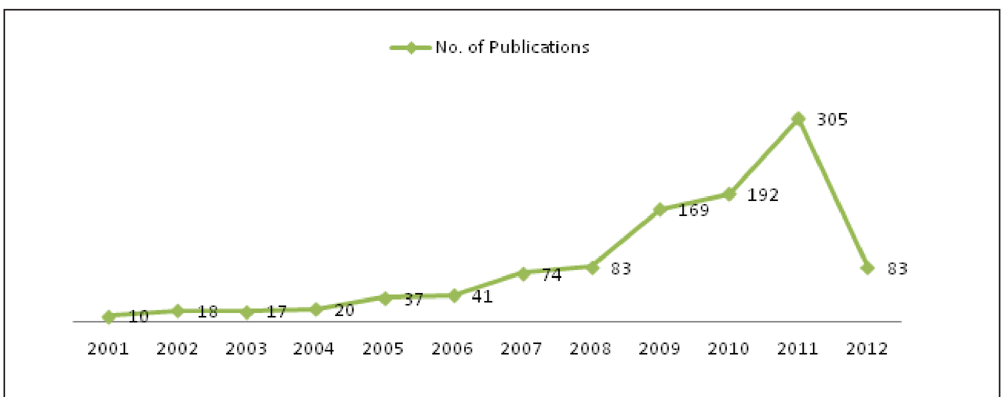
15.4.1 Biosafety

Pakistan has biosafety rules in place. National Biosafety Guidelines have been issued in 2005. Pakistan has established a comprehensive biotech framework, so far, 35 Institutional Biosafety committees have been notified. Pakistan is also a signatory to Cartagena Protocol and maintains a framework for handling GMOs. However the capacity in terms of infrastructure and human resources is lacking.[20]

15.5 Publications and Patents in Biotechnology

Publications in Research Area 'Biotechnology and Applied Microbiology' in the period 2001-2012 were 1049 (Figure 15.1) and no patents were granted.

Figure 15.1: Publications in Research Area 'Biotechnology and Applied Microbiology'



Note: **Patents:** NIL.

Source: Thomson Reuters' Web of Science Database, 2013.

15.6 Capacity Building and Bilateral Efforts

Pakistan has been a beneficiary of many bilateral efforts including projects supported through bilateral and multilateral initiatives. Among others USAID, Rockefeller Foundation, ADB helped Pakistan since the early 80s in capacity building efforts, particularly in human resources development.

15.7 Summing Up

Although biotechnology is more than two decades old in Pakistan, it is yet to reach the critical stage of being applied on a large scale in any sector or contributing to increased productivity of agriculture. The reasons are many. Pakistan's experience indicates that while investments and policies are necessary, they themselves cannot achieve much when there are other constraints and when the National Innovation System is not equipped to absorb and benefit from a new technology.[21]

Endnotes

1 WDI, World Bank Data 2013.

2 International Monetary Fund, World Economic Outlook Database, April 2013.

3 International Monetary Fund, World Economic Outlook Database, April 2013.

4 International Monetary Fund, World Economic Outlook Database, April 2013.

5 CIA The World Factbook, May 2013.

6 WDI, World Bank Data, 2013.

7 World Bank Data, 2013.

8 WDI, World Bank Data, 2013.

9 World Bank, Knowledge for Development, 2013.

10 WIPO and INSEAD, The Global Innovation Index 2012.

11 GAIN Report (2009). *Pakistan Agricultural Biotechnology Annual,* USDA GAIN Report No. PK9012, http://gain.fas.usda.gov/Recent%20GAIN%20Publications/AGRICULTURAL%20BIOTECHNOLOGY%20ANNUAL_Islamabad_Pakistan_9-15-2009.pdf

12 Chaturvedi (2007).

13 "Biotechnology in Pakistan – An overview", *Seed Quest,* April 2008,

14 Yusuf Zafar (2007). "Development of Agriculture Biotechnology in Pakistan". *Journal of AOAC International.*

15 Muhammad Iqbal and Munir Ahmad (2006). Science & Technology based Agriculture Vision of Pakistan and Prospects of Growth. http://www.pide.org.pk/pdf/psde20agm/science%20%20technology%20based%20agriculture%20vision%20of%20pakistan%20and%20prospects%20of%20growth.pdf

16 Pakistan, Biotechnology- GE Plants and Animals, USDA GAIN Report 2010, http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biotechnology%20 %20GE%20Plants%20and%20Animals_Islamabad_Pakistan_8-2-2010.pdf

17 NBC allowed BT corn trial, 10th March 2012, Pakistan Biotechnology Information Center (PABIC), http://www.pabic.com.pk/NBC%20Allowed%20BT%20Corn%20Trial.html

18 Vision 2030, Chapter 6 P4 http://www.parc.gov.pk/ifpri/Resources/vision_2030.pdf

19 http://www.unesco.org/science/psd/thm_innov/forums/s&t_governance_pakistan.pdf

20 Pakistan, Biotechnology- GE Plants and Animals, USDA GAIN Report 2010, http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biotechnology%20-%20GE%20Plants%20and%20Animals_Islamabad_Pakistan_8-2-2010.pdf

21 See v for an analysis of the agricultural innovation system in Pakistan.

Chapter 16:
Philippines

16.1 General Introduction

Philippines is a lower middle income level country[1] in East Asia and Pacific region [GDP, Current Prices (USD in Billions): 250[2]; GDP, Purchasing Power Parity (USD in Billions): 424[3]; GDP (PPP) Share of World Total (%): 0.5[4]]. Services sector plays a major role in its GDP [GDP Composition by Sector (%)[5]: Agriculture: 11.9, Industry: 31.1, Services: 57 (2012 estimate)] and it provides employment to more than half of total employed people [Employment (% of total employment)[6] 2011: Agriculture: 33.0, Industry: 14.9, Services: 52.2].

As far as R&D is concerned, Philippines spend not much on R&D [Philippines's expenditure on R&D in 2009 (% of GDP, PPP)[7] was 0.12] and number of researchers per million of its population was also not encouraging. [Researchers in R&D (per million people)[8] in Philippines were 78.5 in 2007.]

Philippines stand within top 100 countries in both Knowledge Economy Index and Global Innovation Index [Knowledge Economy Index (KEI) 2012 Ranking[9] of Philippines was 92 and its Global Innovation Index 2012 Ranking[10] was 95].

16.2 Biotechnology in Philippines

Philippines started its biotechnology programmes in 1980 with the establishment of the National Institute of Molecular Biology and Biotechnology (BIOTECH) at the University of the Philippines at Los Baños (UPLB).[11] In 1987, the Philippine Council for Advanced Science and Technology Research and Development (PCASTRD) was created under the Department of Science and Technology (DOST) with an aim to develop, integrate and coordinate the advanced S&T sector including biotechnology. DOST also took up some projects related to genetic modification sometime between 1985 to 1989.[12]

In 1990, National Committee on Biosafety of the Philippines (NCBP) was created under Executive Order No. 430,a maiden venture among developing countries of Asia apart from Japan. In 1995, three other biotechnology institutes were established within the University of the Philippines System to focus on three sectors – industrial biotechnology, health biotechnology and marine biotechnology.[13] The biotechnology institute in UP Los Baños (UPLB) was involved in agricultural, forestry, industrial, and environmental biotechnology. In UPLB itself there are other institutes that are involved in biotechnology in one way or other. For example the Institute of Plant Breeding, Institute of Biological Sciences, Institute of Animal Sciences, Institute of Food Science and Technology, and the College of Forestry and Natural Resources. Other institutes and centers such as the Philippine Rice Research Institute, Philippine Coconut Authority, Cotton Research and Development Institute, Bureau of Plant Industry, the Bureau of Animal Industry, and the Industrial Technology and Development Institute are also involved in biotechnology R&D. Thus there are many institutes that are actively involved in biotechnology. In 2001 the national policy statement on modern biotechnology was made by the then President Gloria Macapagal-Arroyo which unambiguously articled the government's support to biotechnology. The policy stated

> "*We shall ensure that all technologies that we promote, including modern biotechnology, will provide farmers and fisherfolks the opportunity to increase their over-all productivity and income; enhance the welfare of consumers; promote efficiency, competitiveness, and improved quality standards of local industries – all within the paramount objective of attaining safely and sustainable development, including its human, social and environmental aspects*."[14]

Since then through various executive orders, administrative orders and proclamations the biotechnology and biosafety policies have been implemented. Besides this every year the last week of November is celebrated as 'National Biotechnology Week'. Further support had been affirmed by the Act, Bioindustry Development Act of 2010 which envisaged setting up Biotechnology R&D Centre and Biotechnology Guarantee Fund for attracting venture capital to biotechnology.[15]

The Act encourages scientists to establish start ups by giving five years leave of absence to scientists in public sector research laboratories to commercialize their inventions.

Thus the favorable policies have ensured steady growth of biotechnology, particularly agricultural biotechnology. It is evident from data on approvals and field trials that agricultural biotechnology is not limited to few crops. Moreover Philippines is promoting biopesticides and bioinsecticides also.

16.3 Human Resources and Capacity Building

Based on a survey conducted by PCASTRD agency in 1998 covering about 10 institutions across the country, there were 346 M.Sc. Degree holders and 301 Ph.D. holders in biological sciences.[16] Another survey was also conducted by an agency of the DOST covering 7 research institutes, where it was found that 105 experts were involved in modern biotechnology and about 212 in conventional biotechnology.[17] . In the recent years the human resources capacity has been enhanced as many institutes have been set up for specialization in biotechnology.

The following table (Table 16.1) gives the list of top performing institutes in Philippines in the field of biotechnology.

16.4 Industry and Biotechnology Employment

Number of biotechnology firms in Philippines was only 25 in 2006, out of which 13 were dedicated biotechnology firms.[18]

Biotechnology Firms by Applications in Philippines in 2006 was as follows:[19]

- Health: 4
- Agriculture: 19
- Food and Beverages: 6
- Environment: 1
- Industrial Processing: 9
- Bioinformatics: 2
- Natural Resources: 6

Table 16.1: Top Ranking Institutions in Philippines

Top Ranking Institutions based on Publications in 'Biotechnology and Applied Microbiology' in the period 2001-2012
International Rice Research Institute
University of Philippines
University of Philippines Los Banos
South Asian Fisheries Development Centre
University of Philippines Diliman

Source: Thomson Reuters' Web of Science Database, 2013.

As far as biotechnology employment in biotechnology firms is concerned, there were only 196 biotech employees in 2006.[20]

16.5 Publications and Patents

Publications in Research Area 'Biotechnology and Applied Microbiology' in the period 2001-2012 were 224 (Figure 16.1). No patents were granted.

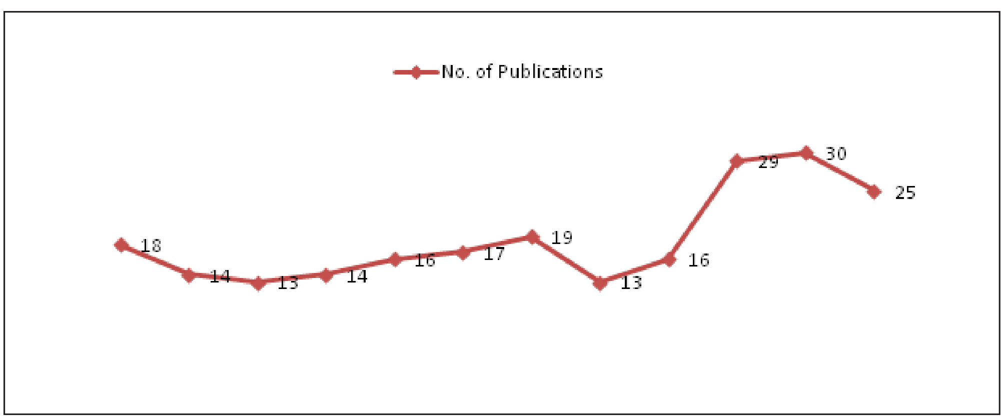
16.6 Biotechnology Regulatory Framework and Biosafety

The first guidelines were patterned after those used in the United States, Australia, and Japan in the early 1980s.[21] In October 15, 1990 ,The National Committee on Biosafety of the Philippines (NCBP) was created through Executive Order No. 430. In 2002, the Department of Agriculture issued Administrative Order No. 8 which formed the basis for the commercial release of GM crops. And in March 17, 2006, Executive Order 514 was issued to further strengthen the NCBP and establish the National Biosafety Framework.[22]. The three agencies that are responsible for biotechnology regulation are:

1) The National Committee on Biosafety of the Philippines (NCBP) under the Department of Science and Technology (DOST) with the aid of the Departments of Agriculture (DA), Environment (DENR) and the Health (DOH);
2) The Department of Agriculture (DA) via the Bureau of Plant Industry's (BPI) Biotech Core Team (BCT); and
3) Independent Scientific and Technical Review Panel (STRP).

Their roles and mandates are specified in the executive and administrative orders issued from time to time. Thus the biotechnology regulation in Philippines is well developed although there are

Figure 16.1: Publications in Research Area 'Biotechnology and Applied Microbiology'



Note: **Patents:** NIL.

Source: Thomson Reuters' Web of Science Database, 2013.

criticisms that the regulation is in fact pro-biotechnology only. [23]

16.7 Summing Up

In Philippines, biotechnology, particularly agri-biotechnology has grown by leaps and bounds thanks to the policy environment and regulatory framework. It is likely to grow further as many field trials have been approved and the policy favors both domestic production and import of GM food, as food, feed and industrial purposes.

Endnotes

1 WDI, World Bank Data 2013.

2 International Monetary Fund, World Economic Outlook Database, April 2013.

3 International Monetary Fund, World Economic Outlook Database, April 2013.

4 International Monetary Fund, World Economic Outlook Database, April 2013.

5 CIA The World Factbook, May 2013.

6 WDI, World Bank Data, 2013.

7 UNESCO Science Report, 2010.

8 WDI, World Bank Data, 2013.

9 World Bank, Knowledge for Development, 2013.

10 WIPO and INSEAD, The Global Innovation Index 2012.

11 Cruz E. de la Reynaldo (2000). "Philippines: Challenges, Opportunities, and Constraints in Agricultural Biotechnology". Available at: http://library.cgiar.org/bitstream/handle/10947/5582/Delacruz.pdf?sequence=1?sequence=1

12 Enriquez, Novenario and G. Virginia (2007). "Biotechnology Statistics: Philippines". Paper presented at the Asian Biotechnology, Innovation and Development (ABIDI), January 25. RIS, New Delhi.

13 C. Halos, Saturnina, 'Agricultural Biotechnology in the Philippines'(year not mentioned).

14 The statement is available at http://www.bic.searca.org/info_kits/policies/policy_statement.htm

15 http://www.congress.gov.ph/download/basic_15/HB01810.pdf

16 Enriquez-Novenario, and G. Virginia (2007a). "Status of Biotechnology in the Philippines" in Sachin Chaturvedi and S. R. Rao (eds.) *Asian Biotechnology, Innovation and Development: Issues in Measurement and Collection of Statistics.* RIS, New Delhi.

17 ibid.

18 OECD, Biotechnology Statistics Database, December 2012.

19 OECD, Biotechnology Statistics Database, 2009.

20 OECD, Biotechnology Statistics Database, 2009.

21 C. Halos, Saturnina, 'Agricultural Biotechnology in the Philippines'(year not mentioned).

22 Enriquez, Novenario and G. Virginia (2007). "Biotechnology Statistics: Philippines." Paper presented at the Asian Biotechnology, Innovation and Development (ABIDI), January 25. RIS, New Delhi.

23 "Ties that Bind: Regulatory Capture in the Country's GMO Approval Process", *Greenpeace 2012.* Available at: http://www.greenpeace.org/seasia/ph/Global/seasia/report/2007/10/ties-that-bind-regulatory-cap.pdf

Chapter 17:
Singapore

17.1 General Introduction

Singapore is a high income level[1] country [GDP, Current Prices (USD in Billions): 276[2]; GDP, Purchasing Power Parity (USD in Billions): 326[3]; GDP (PPP) Share of World Total (%): 0.4[4]]. Its economy is pre-dominantly a Services sector driven one where Agriculture has minimal share [GDP Composition by Sector (%)[5]: Agriculture: 0, Industry: 26.8, Services: 73.2 (2012 estimate)]. Services sector is also the major employer [Employment (% of total employment)[6] 2009: Agriculture: 1.1, Industry: 21.8, Services: 77.1].

As far as R&D scenario is concerned, Singapore spends quite impressively on R&D [Singapore's Gross Expenditure on R&D in 2012 [GERD] (USD in billions, PPP)[7] was 8.8 and its expenditure on R&D in 2012 (per cent of GDP, PPP)[8] was 2.65]. Singapore has one of the highest number of researchers per million of its population in the world. [Researchers in R&D (per million people)[9] in Singapore were 6173 in 2009.]

All such broad indicators justifies Singapore's high ranking on both Knowledge Economy Index and Global Innovation Index [Knowledge Economy Index (KEI) 2012 Ranking[10] of Singapore was 23 and its Global Innovation Index 2012 Ranking[11] was 3].

17.2 Biotechnology in Singapore

Singapore has focused on biotechnology based on biomedical/life sciences and there is no worthwhile activity in agricultural biotechnology. Singapore is capitalizing on its position as regional hub in trade, finance and services etc to build up a biotechnology industry that is specialized. Singapore places enormous emphasis in attracting investment, infrastructure and capacity building in human resources. The various agencies work in tandem with a total systems approach backed by the political will of the state. In that sense, the city republic has embarked upon an unique biotechnology strategy that leverages on the capacities built earlier in electronics and information technology. The investments are massive and public research institutions in biotechnology are supported to a great extent.[12]

17.3 Industry Structure and Initiatives[13]

The biomedical research in Singapore is a coordinated endeavor focusing on finding cures/drugs for five target diseases (cancer, ageing/neurobiology, cardiovascular , liver and infectious diseases). Singapore has identified five platform technologies as key technologies in biotechnology that would spur biotechnology R&D in Singapore and place it firmly in the global R&D map. The five key technologies are – bioinformatics, bioengineering, experimental therapeutics, immunology, and structural biology (including genomics, proteomics). Under Translational and Clinical Research five flagship programmes were launched in 2007-2008, each valued at S$25 million. They are:

1) Singapore Gastric Cancer Consortium (Cancer);
2) Translational Research Innovations in Ocular Surgery (Eye Disease);
3) Vulnerability, Disease Progression and Treatment in Schizophrenia and Related Psychoses (Neuroscience);
4) Developmental pathways to metabolic diseases (Metabolic Diseases); and
5) Scientific exploration, translational research, operational evaluation of disease prevention and preventive measures through new treatment strategies against Dengue (STOP Dengue).

The establishment of a Bipolis hub in 2003 can be considered as a significant landmark in development of biotechnology and biomedical sciences in Singapore.[14] It is noteworthy that even during the current global economic downturn Singapore has been able to attract significant FDI in biotechnology R&D. For instance global biomedical companies invested more than US$ 500 million in Singapore in 2008. Singapore invests heavily in biomedical R&D with investments exceeding US$ 760 million in 2007. In 2006 Singapore invested S $ 5000 million in R&D which is 2.39 per cent of GDP. The quantum and scale of investment in R&D has gone up from the 0.26 per cent of GDP in 1981 and 1 per cent of GDP in 1991. In the period of 2011-2015 Singapore government has set aside about $3.7 billion to enhance the biomedical R&D facilities, promote research and transforming research outcomes to products and sciences.[15]

Singapore gives importance to private sector investment and joint R&D in public and private sectors. By ensuring that the existing university system is well funded in biomedical and life sciences Singapore is building up a strong R&D infrastructure. The private sector and public sector institutions complement each other. According to one estimate more than 50 global pharmaceutical, biotechnology and medical technology companies are active in Singapore and this includes companies like Bayer, Schering-Plough , GlaxoSmithKline (GSK). There are more than 50 manufacturing facilities, many of which have been accredited by FDA (USA) and European Medicines Agency. The value addition per employee and contribution to the GDP is significant.

About 30 public-sector research/medical institutions are active in Singapore. The combination of huge investments in R&D with synergy between public sector and private sector can be expected to give Singapore an unique advantage. Obviously Singapore is giving emphasis to sectors/areas where it can draw on existing strengths of the National Innovation System even as it aims to attract not only FDI but also a pool of scientists and technocrats from other parts of the world to buttress its strategy. The enormous investment in Biopolis is attracting scientists working in stem-cells to Singapore.[16] In the recent years Singapore is promoting public-private partnerships to translate research to tangible products and services and this involves public sector research universities also. For example Singapore has promoted Singapore Immunological Network which includes Nocartis, Swiss Tropical Health Institute and Scripps Research Institute to discover and validate a new drug for Malaria.[17] The National University of Singapore based NUS Initiative to Improve Health in Asia is another project to contribute to health policy research and health systems development.

Table 17.1 gives the list of top performing institutes in Singapore in the field of biotechnology.

A*STAR Investigatorship (A*I) award was launched in 2008, to attract bright young researchers from other parts of the world to pursue research in Singapore. Singapore is also paying attention to nurturing and encouraging homegrown talent and expertise through incentives like fellowships. For example in 2001 a scheme was launched with the objective of training 1000 local Phd graduates in the leading universities of the world by 2015.

In terms of human resources Singapore is in an enviable position as 26.3 per cent of research scientists in private sector and 48.5 per cent of research sector in public sector biomedical sciences hold PhD, as of 2006. In 2006 the private sector R&D expenditure in biomedical sciences, S$ 531 million was almost double of public sector investment which stood at S$ 277 million. Since Singapore has a long history of investment by foreign pharmaceutical and electronics industry and as has had a liberal policy that encouraged FDI in key sectors, the current policy should be seen as a continuation of the earlier policy regime. According to Paul Teng "Countries like Singapore and Korea have purposely targeted specific sectors, such as the Life Sciences, for exploitation. The goal has been to broaden the base of the current economies through future diversification beyond current strengths like manufacturing and ICT." [18]

Singapore is also planning to emerge as regional hub for clinical trials. In 2007 the number of approved clinical trials was 253. Lest should it be construed that Singapore is interested in only cutting edge and world-class research without any interest in developing innovations or products that can meet the demands of the global market.

17.4 Publications and Patents

Publications in Research Area 'Biotechnology and Applied Microbiology' in the period 2001-2012 were 1969 (Figure 17.1).

Figure 17.2 graph depicts Singapore's performance in biotechnology patenting in the period 2001-2012.

Patents Granted in 'Biotechnology' in USPTO in the Period 2001-2012 were 174.

Patents Granted in 'Biotechnology' in EPO in the Period 2001-2012 were 59.

Singapore's revealed technological advantage in biotechnologies doubled from 0.9 in 1998-2000 to 1.8 in 2008-10.[19]

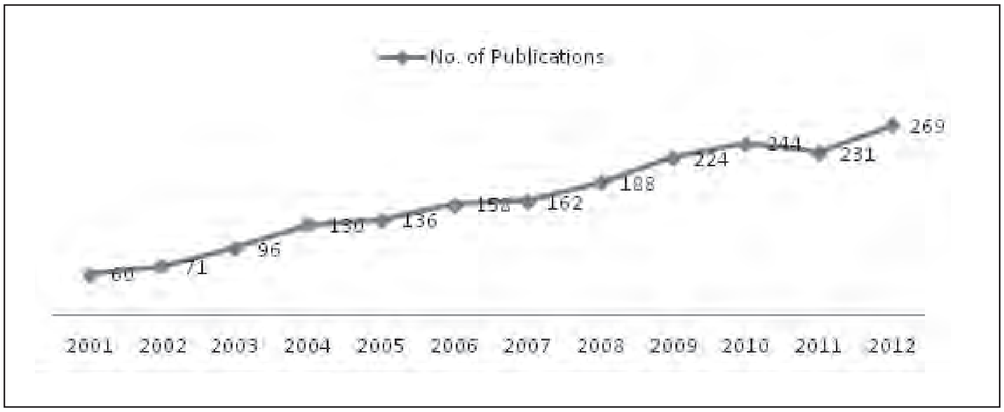
In terms of commercializing inventions and revenue generation through licensing, firms/research centers in Singapore have entered into deals with foreign firms. For example, S*Bio is likely to receive more than US$ 600 million in payment under two licensing schemes with Onyx and Tragara to develop oncology drugs. The spinning off of units based on innovation is another practice that is being followed by institutions in Singapore. Thus emphasis on IP rights coupled with commercialization/

Table 17.1: Top Ranking Institutions in Singapore

Top Ranking Institutions based on Publications in 'Biotechnology and Applied Microbiology' in the period 2001-2012
National University of Singapore
Nanyang Technology University
A*Star
Genome Institute Singapore
National Cancer Centre

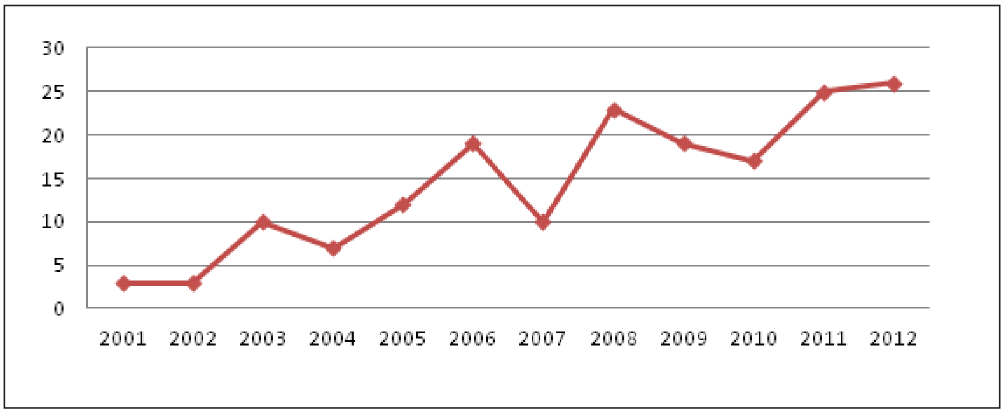
Source: Thomson Reuters' Web of Science Database, 2013.

Figure 17.1: Publications in Research Area 'Biotechnology and Applied Microbiology'



Source: Thomson Reuters' Web of Science Database, 2013.

Figure 17.2: Patents Granted in Biotechnology at USPTO



Source: Thomson Innovation Database, 2013

using innovations to generate revenue indicates that R&D is not viewed as an activity with no commercial objective. Although most of the research in basic science cannot be simply converted into viable products without further R&D the approach in Singapore is to encourage both basic science and applied R&D and focus on specific sectors and within sectors giving emphasis in selected technologies/platforms/problems. This helps in preventing the tendency to spread the resources too thin and attempting to do what all is possible. In other words the Singapore's agenda is a carefully developed agenda with well laid out objectives and investments to match with the objectives. In this regard it should be pointed out that Singapore has been pursuing the government directed economic strategy for long and this has resulted in development of a National Innovation System that has been built assiduously over the years with active participation from the government.

Singapore is not the only country in Asia that is vying for a share in the global biotech market, particularly in bio-medical technologies. Nor that is the only Asian country in which government is taking a pro-active approach in promoting biotechnology, investing heavily in basic sciences and R&D, in developing human resources and in adopting FDI friendly policies in select sectors. Thus Singapore has to compete with nations like Korea, China and India which have their own advantages with well developed innovation systems. Singapore has crafted a strategy that is much focused and well laid out in terms of targets. It has advantages like the active commitment from state and a bureaucracy that is committed to the plan.[20] Its other advantages include successful implementation of similar strategies in other sectors in the earlier decades.

17.5 Biosafety

The Genetic Modification Advisory Committee is the nodal body to oversee biosafety and develop biosafety guidelines. As there is no scope for cultivation in Singapore regulating agricultural biotechnology is confined to approving import of GMOs for food, feed or as ethanol. Thus Singapore has approved biotechnology crops in corn, canola, cotton, sugar beet, soy bean and alfalfa for different purposes.[21]

17.6 Summing Up

The strategy developed in Singapore cannot be duplicated in other countries, particularly in countries which lack human resources and the economic capacity to invest heavily in infrastructure and promotion of R&D. But some elements of that can be used in developing appropriate policies in other countries. For example the focus on selected sectors, with policies that would strengthen the existing capacity and policies that attract talented scientists from elsewhere.

Endnotes

1 WDI, World Bank Data 2013.

2 International Monetary Fund, World Economic Outlook Database, April 2013.

3 International Monetary Fund, World Economic Outlook Database, April 2013.

4 International Monetary Fund, World Economic Outlook Database, April 2013.

5 CIA, The World Factbook, May 2013.

6 WDI, World Bank Data, 2013.

7 Global R&D Funding Forecast 2013, Battelle and RDMag.com, 2012.

8 Global R&D Funding Forecast 2013, Battelle and RDMag.com, 2012.

9 WDI, World Bank Data, 2013.

10 World Bank, Knowledge for Development, 2013.

11 WIPO and INSEAD, The Global Innovation Index 2012.

12 Chaturvedi, S. (2009). "Evolving a National System of Biotechnology Innovation Some Evidence from Singapore", RIS, New Delhi.

13 The information provided in this is culled from various sources including http://www.edb.gov.sg/edb/sg/en_uk/index/industry_sectors/pharmaceuticals__.html

14 Waldby, Catherine (2008). Singapore Biopolis: Bare Life in the City State. University of Sydney.

15 "Overview of Singapore Pharmaceutical and Biotechnology Industry", Singapore Biotech Guide 2011-2012 .

16 Salter, B., Melinda Cooper, and Amanda Dickins (2006). "China and the Global Stem Cell Bioeconomy: An Emerging Political Strategy?" Global Biopolitics Research Group, University of East Anglia Working Paper No. 13.

17 "Overview of Singapore Pharmaceutical and Biotechnology Industry", Singapore Biotech Guide 2011-2012.

18 Paul S. Teng (2008). Bioscience Entrepreneurship in Asia : Creating Value with Biology. Singapore: World Scientific Publishing.

19 OECD, Biotechnology Statistics Database, December 2012.

20 http://www.saworldview.com/article/beefing-up-biotech-with-biopolis

21 Singapore-Agricultural Biotechnology Annual – US Foreign Agricultural Service report dated 25 July 2012.

Chapter 18:
Sri Lanka

18.1 General Introduction

Sri Lanka is a lower middle income level[1] country in South Asia [GDP, Current Prices (USD in Billions): 59.4[2]; GDP, Purchasing Power Parity (USD in Billions): 126[3]; GDP (PPP) Share of World Total (%): 0.15[4]]. Services sector plays a major role in its GDP [GDP Composition by Sector (%)[5]: Agriculture: 12, Industry: 30.1, Services: 57.9 (2012 estimate)] and also is a major employment provider [Employment (% of total employment)[6] 2010: Agriculture: 32.7, Industry: 24.2, Services: 40.4].

In research, Sri Lanka had just below 100 researchers per million of its population, which is not a satisfactory number as far as human capital is concerned. [Researchers in R&D (per million people)[7] in Sri Lanka were 96.3 in 2008.] Its spending on R&D is also very less [Expenditure on R&D in 2008 (per cent of GDP, PPP)[8] was 0.1]. These get reflected in its low ranking in both Knowledge Economy Index and Global Innovation Index [Sri Lanka's Knowledge Economy Index (KEI) 2012 Ranking[9] was 101 and its Global Innovation Index 2012 Ranking[10] was 94].

18.2 Biotechnology in Sri Lanka

In Sri Lanka agriculture and plantation crops contribute significantly to the nations GDP and export earnings, respectively. In this island country, biotechnology is yet to take firm roots and is in nascent stages. The scope for biotechnology is at present more or less confined to agricultural sector. As in many developing countries and LDCs biotechnology in Sri Lanka is largely driven by government and most of the research is done by public sector.

18.3 Initiatives, Industry Structure and Initiatives [11]

Agriculture contributes to 25 per cent of exports and livelihood for 65 per cent of the population. The four sub sectors that are critical for food security and exports are food crops, plantation crops, livestock and fisheries. Like many other developing countries in AP Sri Lanka also faces major challenges in increasing productivity in agriculture in the context of increasing population, declining soil fertility, low productivity and climate change.

The government has formulated National Agricultural Biotechnology R&D Programme and Investment Plan with the following objectives:

- Creating enabling policy environment and functional regulatory frameworks in support of biotechnology R&D

- Strengthen institutions and support services to increase relevance and efficiency of biotechnology R&D for agricultural development
- Enhance technology and Information Access through Regional and International collaboration and Networking
- Biotechnology R&D Applications for Food Security and Rural livelihoods
- Biotechnology Transfer, Commercialization and Delivery System
- Building Communication and Information Systems for Public Awareness and Stakeholder Participation
- Human Resources Development and Incentive Programmes

This is to be implemented in phases. Right now various policies and laws are in draft/consultation stage and it is expected that within the next few years they will be implemented. A National Biotechnology Policy is being finalized while policies for biosafety, IP protection in seed sector are being discussed. To incentivize scientists research allowance as 25 per cent of salary has been proposed. Centers of Excellence in biotechnology have been proposed to be established. Greater synergy among funding agencies and bringing in changes in the National Agricultural Research System (NARS) are envisaged. The research focus on using biotechnology across sectors and Sri Lanka is using different categories of technologies ranging from tissue culture to genetic modification as part of R&D in agriculture. For example some of the research projects are:

- Development rice varieties for abiotic stresses: submergence, salinity, drought escape/tolerance and iron toxicity;
- Molecular & phenotypic characterization of rice germplasm for drought-control of rice sheath blight by improving plant resistance through a biotechnological Approach; and
- In vitro clone propagation of pepper and Technology innovation for large scale in vitro multiplication of cardamom, cinnamon, black pepper, ginger and turmeric.

Another promising development is the use of nanotechnology in agriculture through nanobiotechnology. Sri Lanka has given importance to nanotechnology and it is utilizing the expertise of scientists of Sri Lankan origin in this.

The private sector in biotechnology is yet to take off in a big way. Biotechnology has been identified as an important area for development in Sri Lanka. Funding comes from international agencies (ADB, SIDA) and national funding agencies (National Science Foundation – NSF, Council for Agricultural Research Policy – CARP,

Table 18.1: Top Ranking Institutions in Sri Lanka

Top Ranking Institutions based on Publications in 'Biotechnology and Applied Microbiology' in the period 2001-2012
University of Colombo
University of Peradeniya
Coconut Research Institute
University of Jaffna
University of Kelaniya

Source: Thomson Reuters' Web of Science Database, 2013.

and National Research Council – NRC). NSF and CARP are funding universities and research institutes. The funding for biotechnology by NSF was started in 1992 only. But the biotechnology is underfunded in Sri Lanka. In 2003 CARP allotted 3 per cent of the budget distribution to biotechnology.

The number of researchers in biotechnology sector in Sri Lanka is estimated to be 264 as of 2005. But it lacks the critical mass in human resources to engage in productive R&D in biotechnology[12]. Agricultural biotechnology, Medical biotechnology and Animal biotechnology are the three sectors that get funded. Research in medical biotechnology is done at , inter alia, at University of Colombo, Institute of Biotechnology, Molecular Biology and Biotechnology, University of Kelaniya and University of Sri Jeyawaraenapura. Although some technologies like molecular diagnosis of dengue, PCR for TB have been developed by them, they are not commercialized. The only exception is technology for rapid detection of Salmonella in coconut has been transferred to Genetech Molecular Diagnostics. Genetech is perhaps the only private sector in medical biotechnology.

Table 18.1 gives the list of top performing institutes in Sri Lanka in the field of biotechnology.

The key role of biotechnology in increasing productivity in agriculture has been recognized. Biotechnology has been identified as a thrust area by the government. A National Committee on Biotechnology has been established. The need for a National R&D priorities and strengthening human, institutional and policy capacity has been accepted. With FAO's assistance a project has been established (FAO/TCP/SRL3101).

The plan is expected, inter alia, prepare investment plan for 2009-2015, determine National Biotechnology R&D priorities, Assess the present status of biotechnology, and develop plans for human resources development. Surveys were conducted and Workshops were held to determine national R&D priority. Based on these seven sub-programmes were included in the draft R&D programme for biotechnology.

Sri Lanka opened up its economy in 1979 and this stimulated investments in export promotion zones, particularly in textiles and garment production. But the phasing out of MFA restricted the expansion of this industry. Only 28 per cent of its GDP is from industry. Textiles and plantation crops constitute a major portion of the exports. The local pharmaceutical industry is limited to generic producers who lack R&D capacity.

The Gross Expenditure in R&D (GERD) is less than 1 per cent of GDP. This is much less than some countries in Asia. Sri Lanka has not been a favorite destination for FDI in high technology. The lack of trained professionals in R&D, underdevelopment of science and technology in higher education and the lack of indigenous capacity to develop technology are some of the factors that inhibit development of biotechnology. Moreover the lack of a strong and wide industrial sector limits the scope for private sector R&D which prefers imported technology. There is no venture capital activity worth the name.

The regional co-operation with SARC countries in biotechnology is virtually non-existent.

The FAO funded project referred to above can help in formulating the policy but funding and execution are challenging tasks. Mere funding for biotechnology is not sufficient unless forward and backward linkages are established. The need for long term plan for S&T is obvious.

18.4 Publications and Patents

In Sri Lanka publications in the field of biotechnology are insignificant and no patents were granted in this field.

18.5 Biosafety

Sri Lanka has signed and ratified the Cartagena Biosafety Protocol. The National Biosafety Framework for Sri Lanka (NBFSL) was developed and as a part of that Biotechnology regulatory system was developed.[13] But it is yet to be implemented.

GM labeling regulation was published in 2007 and under that non-GMO certification for soybeans and corn imports was required.[14] There is no central authority to regulate or oversee biotechnology regulation or use of biotechnology products. To overcome this lacuna, NBFSL recommended the formation of a national competent authority, to be known as the National Council for Biosafety (NCB).[15]

At present there are many Acts and rules that regulate various aspects of plant protection and environment.[16] But there is no comprehensive framework to integrate and regulate them in the broader context of biosafety. Another issue that has been highlighted is the absence of risk assessment and management of risk in various institutes where biotechnology research is undertaken.[17] As there are no GM plants under commercialization or development, the only route for GM products entering the market is through imports. But with a comprehensive biosafety law and policy being drafted and discussed, Sri Lanka is expected to take a step forward soon in biosafety.

18.6 Summing Up

Sri Lanka's biotechnology sector is in nascent stage and is expected to grow rapidly thanks to the new initiatives. But this should be seen in the larger context of absence of a functioning National Innovation System and under-funding for S&T in Sri Lanka.[18]

However with increase in allocation, steps to revitalize the NARS and initiatives in capacity building some of these can be over come in the near future. Thus biotechnology, particularly agribiotechnology is poised for a leap in Sri Lanka.

Endnotes

1 WDI, World Bank Data 2013.

2 International Monetary Fund, World Economic Outlook Database, April 2013.

3 International Monetary Fund, World Economic Outlook Database, April 2013.

4 International Monetary Fund, World Economic Outlook Database, April 2013.

5 CIA The World Factbook, May 2013 .

6 WDI, World Bank Data, 2013.

7 WDI, World Bank Data, 2013.

8 World Bank Data, 2013.

9 World Bank, Knowledge for Development, 2013.

10 WIPO and INSEAD, The Global Innovation Index 2012.

11 The information in this section is largely based on the following presentations and information available in the web: Presentation at the 5th Asian Biotechnology Development Conference held at Kandy in December 2010; Presentation by Dr. Padmini C.G. at Kathmandu Conference February 2009 available at www.ris.org.in; Presentatation by Dr. G.A.U. Jayasekera "Biotechnology Capacity in Sri Lanka", ABIDI Conference 2007.

12 See the analysis by Dr. V.V.Krishna and Usha Krishna in World Science Report 2005 (UNESCO) Pp 255-257 on Status of S&T in Sri Lanka and references cited there in.

13 www.biosafety.lk/pub/policy/policy.doc

14 Sri Lanka Biotechnology Annual Report 2008 and GAIN-USDA, GAIN Report Number: CE8005.

15 www.biosafety.lk

16 See http://www.unescobkk.org/rushsap/environmental-ethics-resources/biosafety-regulations-in-asia-pa/biosafety-sri-lanka/ for a list.

17 Deepthi Wickramasinghe (2007). "Biosafety and Biosecurity in Research Environment in Sri Lanka: Issues and Challenges." http://ironside.sandia.gov/AsiaConference/DeepthiWickramasinghe.pdf

18 Science Technology and Innovation in Sri Lanka – UNCTAD Panel 2007. http://www.unctad.org/sections/dite_dir/docs/dite_pcbb_stdev0075_en.pdf.

Chapter 19:
Thailand

19.1 General Introduction

Thailand is a upper middle income level[1] country in East Asia and Pacific region [GDP, Current Prices (USD in Billions): 365[2]; GDP, Purchasing Power Parity (USD in Billions): 651[3]; GDP (PPP) Share of World Total (%): 0.78[4]]. Services sector has a dominant role in its GDP [GDP Composition by Sector (%)[5]: Agriculture: 8.6, Industry: 39, Services: 52.4 (2011 estimate)] and is also a major employment sector [Employment (% of total employment)[6] 2011: Agriculture: 38.7, Industry: 20.7, Services: 40.7].

As far as R&D scenario in Thailand is concerned, it had above average number of researchers per million of its population [Researchers in R&D (per million people)[7] were 315 in 2007 in Thailand] and its ranking in both Knowledge Economy Index and Global Innovation Index is satisfactory. [Thailand's Knowledge Economy Index (KEI) 2012 Ranking[8] was 66 and its Global Innovation Index 2012 Ranking[9] was 57.]

19.2 Biotechnology in Thailand

Thailand is one of the few developing countries that have well articulated National Biotechnology Policy with specific goals.[10] Agriculture contributes 9 per cent of GDP while manufacturing and services contribute 36 per cent and 55 per cent, respectively. Thailand is the worlds 14th largest agricultural and food exporter.[11] Rice, rubber and cassava are the top three cropos grown in Thailand. Thailand has a significant generics industry in the pharmaceutical sector. Building on its capabilities, Thailand has ambitious plans to expand its reach in biotechnology into Nanobiotechnology, Bioinformatics. Human resources development is also given emphasis in the plans for biotechnology.

19.3 Industry Structure[12]

Of the new companies majority of them are in medical/health, constituting 65 per cent, while agricultural biotech firms constitute 27 per cent and other sectors 8 per cent. In R&D investment 70 per cent of the companies are in agri-biotechnology and the rest are in medical/health. The industry in Thailand is largely an industry that is driven by governments plans and policies. Thailand made a start in agricultural biotechnology in 1983 with founding of National Center for Genetic Engineering and Agricultural Biotechnology (BIOTECH) in 1983. There were many trials and experiments on Genetically Modified Plants in the 1980s and 1990s including imported transgenic plants. But commercialization was delayed due to resistance from civil society and lack of regulatory framework on biosafety.[13] Between 1992 and 2000 more than thirty studies on using agricultural biotechnology in various crops were authorized but none of them reached the stage of commercialization or approval for planting. The lack of clear policy framework on trials and commercialization was a stumbling block.[14]

Export of shrimps was a major foreign exchange earner in 1990s with about US$ 1.5 billion annually and employing 1.3 lakhs people. But the shrimp industry was affected by White Spot Syndrome Virus whose origin was in China. Testing for this virus in batches in shrimps that were to be exported could prevent their rejection later if their presence was detected. Thailand used DNA technology to screen stocking fry so that WSSV positive batches could be rejected before they were slated for export. When the outbreak of WSSV in South America in late 1990s and first decade of 2000s led to the reduction of exports of shrimps to the USA from countries in South America, exports from Thailand increased as by then Thailand had successfully implemented a prevention and testing programme based on the indigenously developed DNA probe technology. The investment in development of the DNA proble yielded substantial returns on investment. The shrimp fry used to stock the shrimp ponds was identified as the potential source of the virus. The timely detection of the source and development of a DNA prove saved the industry from facing rejections in huge quantities and helped in exporting more to the USA. [15]

Thailand used agricultural biotechnology in biomarker selection and in plant transformation technology to produce transgenics with specific traits and varieties that are resistant to papaya ringspot virus and chilli vein-banding mottle virus. Transgenic rice research for salt and drought tolerance was undertaken with support from Rockefeller Foundation. Thus by the end of 1990s, Thailand proved its capacity to undertake R&D in biotechnology successfully. But this did not result in large scale commercialization of GM crops as the biosafety regulations were not fully developed by then and there was resistance from civil society.

The USA-EU dispute in WTO on trade in GMOs had its impact on commercialization of biotechnology in Thailand as exports of GMOs and GMO based food products to EU faced uncertainty. But Thailand went ahead with its biotechnology plans and saw the potential of using biotechnology in many sectors despite concerns about biosafety and bioethical issues. Thailand is a partner in the International Rice Genome Sequencing project.

In December 2003 the ambitious National Biotechnology Policy Framework for 2004-2009 was unveiled. According to the policy biotechnology will be an important tool in country's overall economic and social development. Emphasis was on new technologies and the value addition was highlighted as one of the objectives. The policy framework envisaged six goals to be achieved by 2009. The policy envisaged that at least 100 companies of modern biotechnology would evolve and annual investment of US$ 125 million will be made in biotechnology.[16] In agriculture the policy envisages that "biotechnology is to support Thailand to become the kitchen of the world by maintaining and enhancing its competitiveness in agriculture and food industries which will increase in export value up to 1.2 trillion Baht (3 times the 2002 export value), and improve the export value of processed agricultural products from 12th in the world ranking, up to the top 5 by the year 2009."

Increasing production of all major crops, boosting seed exports, and export of high value added from agricultural commodities was envisaged. An important aspect of the strategy and in general application of biotechnology in agriculture is to increase the value addition through technology and to use technology in such a way that economic benefits could be derived or value addition takes place. This is illustrated in Figure 19.1.[17]

The Board of Investment acts like a catalyst by offering various incentives including no tax incentives. In some activities there is no restriction on foreign equity. In 2007 maximum privileged promotion package was announced for biotechnology. Qualified projects receive 8 year tax holiday. Besides these locating the project in a S&T park would entitle additional 50 per cent income tax holiday for five years after expiry of tax holiday for projects in four areas. It is estimated that more than 20 foreign biotechnology companies have invested in Thailand.

According to a recent news report: "At the end of February 2009, there were more than 80 newly founded biotech companies in Thailand. Thirty one companies have been awarded investment incentives by the Board of Investment, resulting in an estimated investment of more than Bt1.3 billion."[18]

Thailand is a country that benefits from medical tourism. The private hospitals generated US$ 1 billion in 2003 from medical tourism.[19] Thailand wants to grow as a major country in bio-service sectors also. Companies have invested in stem-cell technologies, medical diagnostics, drug development, etc. Similarly companies have invested in industrial biotechnology and also in environmental biotechnology. But Thailand's advantage may not be in medical biotechnology as in terms of human resources, there are more scientists working in agricultural biotechnology than in medical biotechnology.[20]

Although biotechnology industry in Thailand is thus largely driven by policies of the government its success cannot be taken as granted because Thailand has to compete with countries like Korea in the region. Its pharmaceutical industry is well known more for the generics than for its capacity in new drug R&D.

19.4 Human Resources

Every year the eight universities award 800-900 bachelor's degrees in biotechnology, 300-400 masters degrees and 40 PhDs in biotechnology. The government

Figure 19.1 Innovation Value Chain

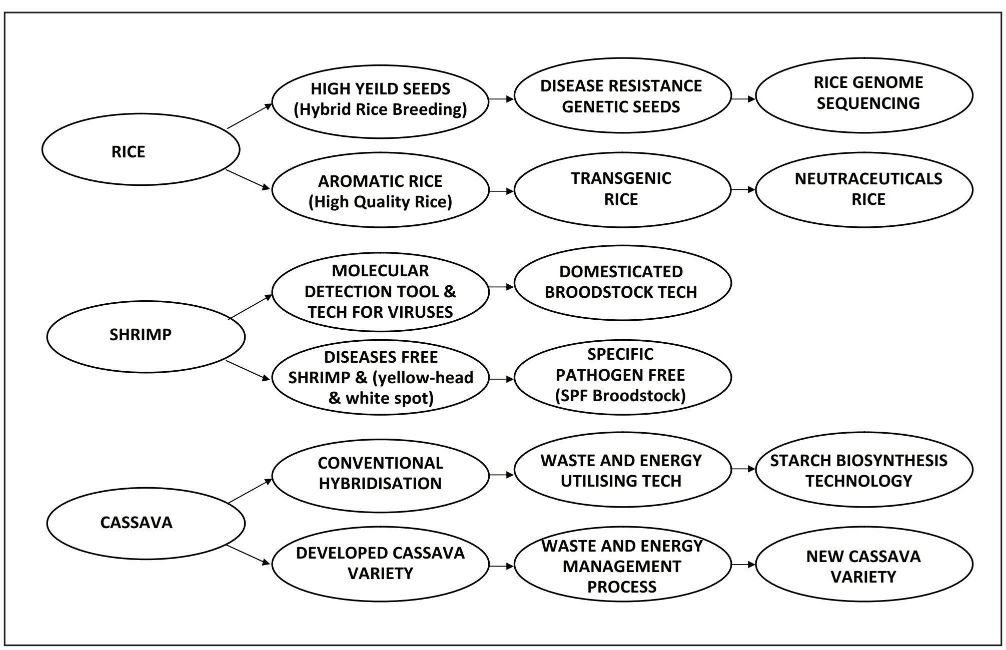


Table 19.1: Top Ranking Institutions in Thailand

Top Ranking Institutions based on Publications in 'Biotechnology and Applied Microbiology' in the period 2001-2012
Mahidol University
Chulalongkorn University
Kasetsart University
Prince Songkla University
Chiang Mai University
Khon Kaen University
King Mongkuts University of Technology Thonburi
National Science and Technology Development Agency
Asian Institute of Technology
Suranaree University of Technology

Source: Thomson Reuters' Web of Science Database, 2013.

encourages movement of trained/skilled personnel in biotechnology into Thailand. As a part of the long-term strategy to develop human resources within the country the plan envisages "No less than 5,000 personnel engaged as professional biotechnology researchers in the public and private sectors. No less than 500 personnel engaged in biotechnology management.

No less than 10,000 students at the level of bachelor, master and doctoral degree in fields related to biotechnology".

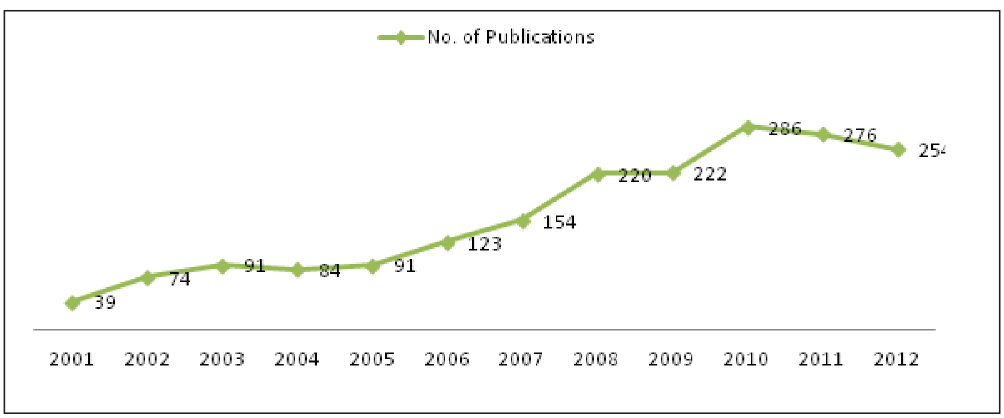
Table 19.1 gives the list of top performing institutes in Thailand in the field of biotechnology.

19.5 Patents and Publications

Publications in Research Area 'Biotechnology and Applied Microbiology' in the Period 2001-2012 were 1914 (Figure 19.2).

Thailand had enacted laws on Intellectual Property Rights and the Biotechnology Strategy envisages recognition and protection of these rights. Still Thailand is also considered as a country where piracy is rampant

Figure 19.2: Publications in Research Area 'Biotechnology and Applied Microbiology'



Notes : Patents Granted in 'Biotechnology' in USPTO in the Period 2001-2012: 8.
Patents Granted in 'Biotechnology' in EPO in the Period 2001-2012: 3.

Source:Thomson Reuters' Web of Science Database, 2013.

Box 19.1 : Specialise Thy Neighbours

Many Asian economies need specially tailored programmes for human resource development in science and technology. There are some major initiatives which need to be further strengthened.

The National Center for Genetic Engineering and Biotechnology (BIOTEC) of Thailand has launched a programme at the state-of-the-art infrastructure at the Thailand Science Park, for Human Resource Development Programme in Biotechnology for Cambodia, Laos, Myanmar and Vietnam (CLMV). This programme specifically addresses the underlying causes of the shortage of skilled manpower in the field of biotechnology in CLMV, which are lack of facilities, equipment, technical know-how, limited research and development in biotechnology and inappropriate training facilities and equipment. The programme offers short-term training courses to young researchers from CLMV to work/train in BIOTEC laboratories. The training courses consist of teaching of basic and advanced techniques, designing and conducting a mini research project and site visit to factories or project sites. The trainees are provided with living and research/training expenses and are assigned a one-on-one BIOTEC researcher to give the training and guidance. BIOTEC developed a pilot programme on HRD for CLMV in 2001 with its own funding. In 2002, the Board of the ASEAN Foundation approved BIOTEC's proposal and agreed to provide the funding of USD 92,070 to co-support this Programme, with BIOTEC providing a matching fund equivalent to USD 73,480. Under this ASEAN Foundation – BIOTEC collaboration, a total of 20 fellowships were granted since 2004. From 2007, the Programme offered training opportunities to young scientists from the Asia Pacific region, while maintaining funding priority for CLMV. The number of applications grew from 40 in 2003 to 74 in 2008.

Source: BIOTEC Annual Report 2008.

and its use of compulsory licensing has been controversial. Thailand's IPR regime may be a hindrance to biotechnology companies which may prefer countries with better enforcement of IPRS. Although some suggestions in this regard have been made,[21] it is doubtful whether Thailand will opt for such measures.

19.6 Biosafety

Thailand has signed and ratified Cartagena Protocol. Its national biosafety regulations are yet to be enacted. Thailand in the meanwhile has implemented biosafety regulations through rules. The absence of a holistic framework is a major barrier in commercialization of biotechnology. Field trials now have to be approved by the cabinet on a case-by-case basis. As of 2012 Thailand Biosafety Law is in final draft awaiting to be concluded and promulgated. Thailand has not formally approved any GM vegetables or horticultural crops. However in May 2012 EU Rapid Alert System for Food and Feed (RASFF) reported that samples of papaya that originated from Thailand had genetically modified materials. Similar materials were detected in a shipment of vegetables and papaya to Switzerland.[22] Thailand has been a beneficiary of various capacity building programmes and projects supported by UNEP, Rockefeller Foundation, USAID and other agencies.

19.7 Summing Up

Thailand has embarked upon an ambitious plan with specific goals and strategies and the policy does not neglect one sector in favor of another. The linking of biotechnology with specific economic, social and health objectives is a step in the right direction. The government is investing heavily in biotechnology and these investments should help it to sustain the biotechnology in the long term.

Endnotes

1 WDI, World Bank Data 2013.

2 International Monetary Fund, World Economic Outlook Database, April 2013.

3 International Monetary Fund, World Economic Outlook Database, April 2013.

4 International Monetary Fund, World Economic Outlook Database, April 2013.

5 CIA The World Factbook, May 2013.

6 WDI, World Bank Data, 2013.

7 WDI, World Bank Data, 2013.

8 World Bank, Knowledge for Development, 2013.

9 WIPO and INSEAD, The Global Innovation Index 2012.

10 The key elements of the strategy can be found in http://www.business-in-asia.net/biotech_policy.html.

11 Nares Damrongchai (2004). "Biotechnology for Thailand's Socio-economic development". Presentation at IInd Conference on Biotechnology for Asian Development.

12 The information in this section is based on, inter alia, Overview of Biotechnology in Thailand presentation by Pichet Ikor at the Fourth Asian Conference on Biotechnology and Development 2009, Kathmandu.

13 *Thailand: Biotechnology Agricultural Biotechnology.* USDA Foreign Agriculture Service GAIN Report Number TH6077 .

14 "The Study of Agricultural Biotechnology Benefits in Thailand". Biotechnology Alliance Association – 2007

15 Morakot Tanticharoen, Rudd Valyasevi, Jade Donavanik, and Thippayawan Thanapaisal (2004). "Recent Major Developments Of Science and Technology In Thailand: Biotechnology." *www.Business-in-asia.com*

16 Thailand's National Biotechnology Policy Framework 2004-2009, National Center for Genetic Engineering and Biotechnology.

17 Pun-Arj Chariratana (2006). "Evolution of Agro-Biotechnology Innovation System in Thailand". Globelics Conference Presentation.

18 http://www.nationmultimedia.com/worldhotnews/30102666/Biotechnology:-Achieving-our-national-goals

19 Thailand Biotech Guide 2006/2007.

20 supra 9.

21 Michael P. Ryan, Eric Garduño (2004). "An Intellectual Property System in Thailand for Bio-Innovation and Commercialization: A National Strategy for Business, Government, and the Technology Community". Thailand consistently figures in the list of countries where IPR regime and enforcement are found inadequate by USTR.

22 Thailand Agricultural Biotechnology Annual – US Foreign Agricultural Service GAIN Report TH 2069 dated 16 July 2012.

Chapter 20:
Vietnam

20.1 General Introduction

Vietnam is a lower middle income level country[1] in East Asia and Pacific region [GDP, Current Prices (USD in Billions): 138[2]; GDP, Purchasing Power Parity (USD in Billions): 320[3]; GDP (PPP) Share of World Total (%): 0.38[4]]. It is basically a Industry-driven economy [GDP Composition by Sector (%)[5]: Agriculture: 21.5, Industry: 40.7, Services: 37.7 (2012 estimate)] whereas Agriculture is the major sector of employment [Employment (% of total employment)[6] 2011: Agriculture: 48.4, Industry: 21.3, Services: 30.3].

Vietnam's expenditure on R&D is not impressive [Vietnam's expenditure on R&D in 2009 was 0.19 (per cent of GDP, PPP)[7]] and its ranking on both Knowledge Economy Index and Global Innovation Index is also on lower side. [Vietnam's Knowledge Economy Index (KEI) 2012 Ranking[8] was 104 and its Global Innovation Index 2012 Ranking[9] was 76.]

20.2 Biotechnology in Vietnam

The government decree No. 18/CP in 1994 stated that first priority for scientific research is given to biotechnology during 1995-2010. For this 'Capacity Development Programme in Biotechnology' is initiated and implemented by the Ministry of Science, Technology and Environment (MOSTE). A National Commission on Biotechnology was formed in 1997.

The main institute for biotechnological research is the Institute of Biotechnology (IBT) at the National Center of Natural Science and Technology, followed by two research institutions belonging to the Ministry of Agriculture and Rural Development (MARD), namely the Institute of Agricultural Genetics (IAG) and Institute of Agricultural Sciences (IAS). In the universities, new courses specializing in genetic engineering and biotechnology began to be offered. Establishment of genetic engineering research centers within the universities has also been started.

20.3 Specific Initiatives

Agriculture's contribution to GDP is 25 per cent but 70 per cent of the households are involved in it. Over the years Vietnam has moved from a net importer of food to world's third largest rice exporter and is also an important exporter of coffee, rubber, pepper, and cashew. In 2011, the agricultural exports were valued 25 billion US dollars[10]. Agricultural biotechnology can enhance the exports besides increasing the productivity of agriculture. Investment for R&D in biotechnology comes exclusively from government sources. However, the level of investment remains far below the average in the region. The network of key laboratories is considered as the heart of biotech R&D in Vietnam. Five key laboratories, namely "Laboratory for Gene Technology", "Laboratory for Enzyme and Protein Technology", "Research center for Vaccines and Pharmaceutical products", "Laboratory for Animal Cell Technology", and "Laboratory for Plant Cell technology" have been established with an investment of US$ 3-5 million for each. Investment project for the Laboratory of Microbial Technology was approved in 2011. There are 2 national institutes, 16 ministerial institutes involved in biotechnology research.

Even with limited funding, facilities, and biotechnology-experienced scientists, Vietnam has recognised the important role of biotechnology. But so far no significant results have been obtained. The absence of private sector in biotechnology is an important drawback. Since government has limited resources, private sector funding could give a boost to biotechnology. But Vietnam has not fully opened up its economy and agricultural research and biotechnology remain to be the domain of the government while FDI in biotechnology is permitted.

20.4 Human Resources

Universities have established biotechnological courses for biology and agriculture students. With current technical infrastructure and laboratory facilities, biotech training at universities is mainly based on theoretical courses and students have little access to the practical and laboratory work. In recent years, there had been more than 500 scientists involved in R&D biotechnology. However, at present, there are not enough capable scientists with adequate exposure to advanced biotechnology. In addition, they lack of opportunities for interaction with national and international research scientists and organizations. Till 2007, Vietnam had trained only 1500 workers/engineers, 400 masters and 90 PhD in biotechnology.[11]

Table 20.1 gives the list of top performing institutes in Vietnam in the field of biotechnology.

In terms of fields of application and number of persons involved in biotechnology, the variation among various institutions is indicated in Table 20.2. Biotechnology is a priority activity in some institutions only. Thus, Vietnam has a long way to go in terms of utilization of human resources in biotechnology and application of biotechnology in different sectors, particularly in agricultural biotechnology.

Table 20.1: Top Ranking Institutions in Vietnam

Top Ranking Institutions based on Publications in 'Biotechnology and Applied Microbiology' in the period 2001-2012
Vietnam Academy of Science and Technology
Can Tho University
Hanoi University of Technology
Hue University
National Institute of Hygiene and Epidemiology
Vietnam National University
Hanoi National University of Education
Hanoi University of Science and Technology
Hue University of Agricultural Forestry
Nong Lam University

Source: Thomson Reuters' Web of Science Database, 2013.

Moreover, research is still scattered and there is no mechanism to ensure that research is not duplicated elsewhere. The agricultural R&D system in Vietnam is not yet mature enough to apply biotechnology and deliver results.

20.5 Patents and Publications

Vietnam's IP regime is TRIPS compliant and the standards of patent protection are at par with global norms[13].

Publications in Research Area 'Biotechnology and Applied Microbiology' in the period 2001-2012 were 242 (Figure 20.1), but no patents were granted in this field.

20.6 Biosafety

Vietnam is in the process of establishing biosafety norms including labeling of GM food products.

20.7 Summing Up

Biotechnology in Vietnam is in nascent stages. Vietnam is giving importance to biodiversity conservation and use. Since the agricultural innovation system is weak it cannot be expected to use biotechnology in a big way in R&D or in commercialization.

The policy framework in Vietnam (when seen in the overall context of

Table 20.2 Institutes and Number of Staff working in Biotechnology[12]

Research Institutions involved in Biotechnology R&D	Field of Application	No. of Staff Involved/Total	%
Institute of Biotechnology (NCST)	Animals, plants, microorganisms and basic genetic techniques	200/236	85
Vietnam Agricultural Science Institute (MARD)	Fundamental, R&D and technique transfer	17/212	8
Institute of Agricultural Genetics (MARD)	R&D on crop breeding and breeding science	53/120	44
Cuu Long Delta Rice Research Institute (MARD)	Rice breeding, hybrid rice varieties	15/125	12
Institute of Microbiology and Biotechnology- Vietnam National University (MOET)*	Basic research and education	36/40	90
Key Laboratory for Enzyme and Protein Technology, Vietnam National University (MOET)*	Biomedical	21/22	95
Biotechnology Department, University of Agriculture and Forestry (MOET)	Basic research and education	16/?	-
Biotechnology R&D Institute, Can Tho University (MOET)	Agricultural biotechnology, improved plant varieties and animal breeds.	10/16	62
Food Industries Research Institute (MOIT)*	Microbial genetics and fermentation	30/99	30
School of Biotechnology and Food Technology (MOET)*	Microbial genetics and fermentation	33/75	44
Institute of Vaccine and Medical Biologicals (MOH)**	Vaccine Biomedical	17/410	4
The Company for Vaccine and Biological Production No.1 (MOH)**	Vaccine Biomedical	38/246	15
Biotechnology Center of Ho Chi Minh City (Ho Chi Minh City)*	Agricultural, medical and environmental biotechnology	60/94	64

Notes: *As 2012 (direct interview); **from company website.

Figure 20.1: Publications in Research Area 'Biotechnology and Applied Microbiology'

Source: Thomson Reuters' Web of Science Database, 2013.

Vietnam's economic policy and trade policy) will need changes if Vietnam wants to use biotechnology in a big way. More investments in agricultural R&D and in human resources development and capacity building are necessary if Vietnam wants to reap the benefits of biotechnology revolution.

Endnotes

1 WDI, World Bank Data 2013.

2 International Monetary Fund, World Economic Outlook Database, April 2013.

3 International Monetary Fund, World Economic Outlook Database, April 2013.

4 International Monetary Fund, World Economic Outlook Database, April 2013.

5 CIA The World Factbook, May 2013.

6 WDI, World Bank Data, 2013.

7 UNESCO Science Report, 2010.

8 World Bank, Knowledge for Development, 2013.

9 WIPO and INSEAD, The Global Innovation Index 2012.

10 Ministry of Agriculture and Rural Development (MARD) at http://www.agroviet.gov.vn/Lists/appsp01_statistic/Attachments/49/Baocao_12_2011_f.pdf

11 Banh Tien Long. National conference "Human resource capacity building for high tech area according to society needs". Binhduong 11/4/2009.

12 Ngo Luc Cuong (2004). "Assessments of Needs in Biotechnology Applications in Least Developed Countries: Case Study in Vietnam". *UNU-IAS Working Paper 122*.

13 Nguyen Nguyet Dzung (2007). "Vietnam Patent Law: Substantive Law Provisions and Existing Uncertainties", *Kent Journal of Intellectual Property,* Vol.6, No.2.

References

Abergel, Elisabeth A. 2010. "Climate-ready Crops and Bio-capitalism: Towards a New Food Regime?" *International Journal of Sociology of Agriculture and Food*, 18 (3): pp. 260-274.

ADB. 2009. *Asian Development Outlook 2009: Rebalancing Asia's Growth*. Asian Development Bank. Manila.

ADB. 2013. *Asian Development Outlook 2013*. Asian Development Bank. Manila.

Ademola, A. Adenle, Sulayman K. Sowe, Govindan Parayil, and Obijiofor Aginam. 2012. "Analysis of Open Source Biotechnology in Developing Countries: An Emerging Framework for Sustainable Agriculture". *Technology in Society*, 34 (3): pp. 256-269.

Aerni, P. 2006. "Mobilizing Science and Technology for Development: The Case of the Cassava Biotechnology Network (CBN)". *AgBioForum,* 9(1): 1-14.

AG. 2009. "Australian Biotechnology Sector Fact Sheet". Department of Innovation, Industry, Science and Research, Australian Government.

Australian Government. 2012. *Australia in the Asian Century.*

Agrawala, S. C. Bordier, V. Schreitter, and V. Karplus. 2012. *Adaptation and Innovation: An Analysis of Crop Biotechnology Patent Data*. ENV/WKP. OECD, Paris.

Alston, J. M., P. G. Pardey, and M. J. Taylor (eds). 2001. *Agricultural Science Policy: Changing Global Agendas.* Baltimore: Johns Hopkins University Press.

Anwar, Naseem, David J. Spielman and Steven Were Omamo. 2010. "Private-Sector Investment in R&D: A Review of Policy Options to Promote its Growth in Developing-Country Agriculture". *Agribusiness*, 26 (1): pp. 143-173.

Asian Development Bank and International Food Policy Research Institute. 2009. *Building Climate Resilience in the Agriculture Sector in Asia and the Pacific*. Asian Development Bank, Philippines.

Australian Institute of Commercialization. 2011. *Enabling Technologies Roadmap Study for the Department of Innovation, Industry, Science & Research.*

Bainbridge, William Sims, and Mihail C. Roco (eds.). 2006. "Managing Nano-Bio-Info-Cogno Innovations: Converging Technologies in Society". Springer.

Bharadwaj, A., and Glasner, P. 2009. Local Cells, Global Science. The Rise of Embryonic Stem Cell Research in India. London: Routledge.

Biospectrum Bureau. 2009. "Malaysia to Promote Biotechnology", February 11. shttp://www.biospectrumasia.com/content/160109MYS8315.asp.

BiotechCorp. 2008. *Strengthening Value Creation*, BiotechCorp Annual Report. Malaysian Biotechnology Corporation.

Biotechnology Australia. 2007. At www.biotechnology.gov.au Last accessed on July 13, 2009.

Blakeney Michael. 2011. *Trends in Intellectual Property Rights relating to Genetic Resources for Food and Agriculture*. Background Study Paper No. 58. Commission on Genetic Resources for Food and Agriculture. FAO. Rome.

Brian Salter, Melinda Cooper, Amanda Dickins. 2006. "China and the Global Stem Cell Bioeconomy: An Emerging Political Strategy?" Global Biopolitics Research Group, University of East Anglia Working Paper No 13.

Brian Salter and Alex Faulkner. 2011. "State strategies of governance in biomedical innovation: aligning conceptual approaches for understanding 'Rising Powers' in the global context". *Globalization and Health*, 7 (3).

Brooks Sally and Michael Loevinsohn. 2011. "Shaping Agricultural Innovation Systems Responsive to Food Insecurity and Climate Change". *Natural Resources Forum*, 35: pp. 185-200.

Budget. 2008. http://science.kukuchew.com/2007/09/07/malaysia-2008-budget-biotechnology-sector/

Business Line. 2009. "Malaysia Looking Collaboration in Biotech". Last accessed on http://www.thehindubusinessline.com/2009/02/12/stories/2009021250961700.htm

Catherine Waldby. 2008. "Singapore Biopolis: Bare Life in the City State". University of Sydney.

Channa, Ty. 2006. "Crop Improvement and Biotechnology in Cambodia". Training and Information Center, Cambodian Agricultural Research and Development Institute (CARDI), Phnom Penh, Cambodia. Mimeo.

Channa, Ty, Phiv Chin Theng and Huy Veng. 2004. Crop Improvement and Biotechnology in Cambodia. Paper presented at the 4th ASEAN-ILSI Training Workshop on Safety and Risk Assessment f Agriculture-related GMOs, 31 August- 2 Septmeber 2004, Jakarta, Indonesia.

Chatterjee, Bipul, and Manabar Khadga (eds). 2011. *Climate Change and Food Security in South Asia*. CUTS, Jaipur.

Chaturvedi, Sachin. 2007. "Environmental Concerns and Biotechnology in South Asia". *South Asia Journal*, Islamabad, Volume 18, Issue 4, December.

Chaturvedi, Sachin. 2006. "Dynamics of Biotechnology Research and Industry in India: Statistics, perspectives and Key Policy Issues". STI Working Papers 2005/06, Directorate for Science, Technology and Industry, OECD.

Chaturvedi, Sachin. 2005. "Evolving a National System of Biotechnology Innovation: Some Evidence from Singapore". *Science, Technology and Society*, Vol. 10:1. New Delhi: Sage Publication.

Chaturvedi, Sachin. 2002. "Status of Biotechnology in Singapore". RIS Occasional Paper No. 65, RIS, New Delhi.

Chaturvedi, Sachin and S. R. Rao (eds.). 2005. *Biotechnology and Development: Challenges and Opportunities for Asia*. New Delhi: Academic Foundation.

Chaturvedi, Sachin and S. R. Rao. 2006. "Biotechnology and Innovation Related Policy Indicators in Asia: An Introduction". *Asian Biotechnology, Innovation and Development: Issues in Measurement and Collection of Statistics*. New Delhi: RIS.

Chiesa, V and Chiaroni, D. 2004. *Industrial Clusters in Biotechnology - Driving Forces, Development Processes and Management Practices*. London: Imperial College Press.

Chikelu Mba, Elcio P Guimaraes and Kakoli Ghosh. 2012. "Re-orienting Crop Improvement for the Changing Climatic Conditions of the 21st Century". *Agriculture and Food Security*, 1(7). http://www.agricultureandfoodsecurity.com/content/1/1/7

Choudhury, Naiyyum and M. Serajul Islam. 2005. "Biotechnology in Bangladesh" in Sachin Chaturvedi and S. R. Rao (eds.) *Biotechnology and Development: Challenges and Opportunities for Asia*. ISEAS, Singapore, RIS and Academic Foundation, New Delhi.

Christoph Then andRuth Tippe. 2012. "European Patent Office at Crossroads Report – Patents on Plants and Animals Granted in 2011" http://www.evb.ch/cm_data/npos_patente_report_march_2012_en.pdf

CII. 2007. Study of Growth and Potential of the Biotechnology Industry in Industry in India. Confederation of Indian Industries, New Delhi.

Clark, N., A. Frost, I. Maudlin and A. Ward. 2012. *Biotechnology and Agricultural Development in Low Income Countries: Case Materials from the Research into Use*. Program Innogen Working Paper 101. ESCRC Genomics Network.

Concept Public Relations India Pvt. Ltd. (February 10, 2009). 'Current Global Economic Climate Calls for Strategic Collaborations', in 'Malaysia To Enhance Partnerships With Indian Biotechnology And Life Sciences Companies'.

Cooke, Philip, Carla De Laurentis, Franz Tödtling, Michaela Trippl. 2007. *Regional Knowledge Economies: Markets, Clusters and Innovation.* London: Edward Elgar.

Cruz, Reynaldo De la. 2000. "Philippines: Challenges, Opportunities, and Constraints in Agricultural Biotechnology and the Poor". Proceedings of an International Conference on Biotechnology, Washington DC, 21- 22 October 1999. Edited by G. J. Persley and M. M. Lantin. Washington DC.

Damrongchai, Nares. 2004. "Biotechnology for Thailand's Socio-economic Development". Presentation made at the Second Conference on Biotechnology for Asian Development, New Delhi.

Daniel Lee Kleinman, Abby J. Kinchy and Robyn Autry. 2009. "Local Variation or Global Convergence in Agricultural Biotechnology Policy: A Comparative Analysis." *Science and Public Policy,* 36 (5).

Das, Anath Bandhu. 2013. "Bioprospecting and Genetic Engineering of Mangrove Genes to Enhance Salinity Tolerance in Crop Plants" in S.M. Jain and S. Dutta Gupta (eds), *Biotechnology of Neglected and Underutilized Crops*. Springer. Heidelberg.

DBT 2009. Indian Biosafety Rules and Regulations at www.dbtbiosafety.nic.in accessed on July 14, 2009. Department of Biotechnology, Government of India.

DBT. 2007. *Annual Report, 2007-08.* Department of Biotechnology, Ministry of Science and Technology, Government of India, New Delhi.

D'Costa, A.P. and Parayil, G. 2009. "China, India, and the New Asian Innovation Dynamics: An Introduction," in G. Parayil and A.P. D'Costa (eds.) *China, India, and the New Asian Innovation Dynamics.* New York: Palgrave.

Dhakal, D., and N. Joshi. 2007. Research and Development of Agricultural Biotechnology in Nepal: A review", in S. Chaturvedi and S.R. Rao (eds), *Asian Biotechnology, Innovation and Development: Issues in Measurement and Collection of Statistics*. New Delhi: RIS.

Dommelen, Ad van. 2001. Hazard Identification of Agricultural Biotechnology Finding Relevant Questions Utrecht: International Books.

Dutfield, Graham. 2008. *Global Intellectual Property Law: Commentary and Materials.* London: Edward Elgar.

Dulce E. de Oliveira and Marc Van Montaguin. 2011. *Plants for the Future- Challenges for Agricultural Research*. OECD. Paris.

Enriquez-Novenario, Virginia G. 2007. "Biotechnology Statistics: Philippines." Paper presented at the Asian Biotechnology, Innovation and Development (ABIDI) Conference, January 25, 2007, RIS, New Delhi.

Enriquez-Novenario, Virginia G. 2007a. "Status of Biotechnology in the Philippines" in Sachin Chaturvedi and S. R. Rao (eds.) *Asian Biotechnology, Innovation and Development: Issues in Measurement and Collection of Statistics*, RIS, New Delhi.

Enriquez-Novenario, Virginia G. 2009. "Biotechnology in the Philippines". Paper presented at the 4th Asian Conference on Biotechnology and Development, February 12-13, 2009, Kathmandu, Nepal.

EPO. 2008. EPO Worldwide Statistical Patent Databases, September.

Ernst, D., T. Ganiatsos, and L. Mytelka. 1998. *Technological Capabilities and Export Success in Asia*. London: Routledge.

Ernst and Young. 2008 . *Beyond Borders: Global Biotechnology Report 2008.* Ernst and Young.

FAO. 2011. *Biotechnologies for Agricultural Development.* FAO. Rome.Financial Times. 2013. fDI Markets. June.

GAIN. 2006. *Cambodia Grain and Feed Grain Industry in Cambodia.* Global Agriculture Information Network, USDA Foreign Agricultural Service, Washington DC.

Gangulli, P., Rita Khanna and Ben Prikril. 2009. *Technology Transfer in Biotechnology*, WILEY-VCH Verlag GmBH & Co KGaA, Weinheim.

Gary P. Pisano. 2006. Science Business. *Harvard Business Review*.

Gary, Richard. 2012. "Intellectual Property Rights and the Role of Public and Levy Funded Research: Some lessons from International Experience" in OECD *Improving Agricultural Knowledge and Innovation Systems.* OECD. Paris.

GNBB. 2007. Position Paper on National Biotechnology Policy adopted at the Conference on Promotion of Biotechnology: National and International Perspectives, Dhaka, April 6-8, 2007, Global Network of Bangladeshi Biotechnologists, Dhaka.

Govindan, Parayil. 2003. "Mapping Technological Trajectories of the Green Revolution and the Gene Revolution from Modernization to Globalisation". *Research Policy* 32, (2003), pp.971-990.

Grossman, G. and E. Helpman. 1991. *Innovation and Growth in the Global Economy*. Cambridge: MIT Press.

Guo, Jerry. 2008. "Nepal Counts on Science to Turn Struggling Country Around". *Science*, 320 (5882), 1411, 13 June.

Gupta, Shalini. 2007. "Indian Biotechnology Industry: An Overview" in Sachin Chaturvedi and S. R. Rao (eds.) *Asian Biotechnology, Innovation and Development: Issues in Measurement and Collection of Statistics.* RIS, New Delhi.

Haider, Mohammed Solaiman. 2008. "Developments of Biosafety Regulatory Regime in Bangladesh". South Asia Biosafety Programme (SABP) Newsletter, 4 (12), December, New Delhi.

Halos, Saturnina C. 2005. "Agricultural Biotechnology in the Philippines". Cambodia (KH), Legislative Profile.

Halford, Nigel G. (ed.). 2006. *Plant Biotechnology: Current and Future Applications of Genetically Modified Crops*. Chichester, England, Hoboken, NJ: J. Wiley.

Hobday, Mike. 1995. *Innovation in East Asia*. Aldershot: Edward Elgar. http://international.biotec.or.th/hrd.asp

Hodges, Matt. 2009. *Characterization of the Functional Components required for Apomixis* in Maize Apomixis Consortium. CGIAR. Washington.

Hong Phua Kai. 2007. "Biotechnology in Singapore" in S. Chaturvedi and S.R. Rao (eds), *Asian Biotechnology, Innovation and Development: Issues in Measurement and Collection of Statistics,* Research and Information System for Developing Countries (RIS), New Delhi.

Huang, J. and Qinfang Wang. 2003. "Biotechnology Policy and Regulation in China". Institute of Development Studies Working Paper No. 195, Biotechnology Policy Series No. 4, August.

Hübel Andreas , Thilo Schmelcher and Ulrich Storz. 2012. *Biopatent Law: Patent Strategies and Patent Management.* Springer. Heidelberg.

IAASTD. 2009. *Agriculture at a Crossroads: East and South Asia and the Pacific*, Vol. II. International Assessment of Agricultural Knowledge, Science and Technology for Development, World Bank, Washington D. C.

IRRI. 1984. *Report of Inter-Center Seminar on IARCs and Biotechnology.* April, Los Banos, Philippines.

IBIS World. 2009. *Biotechnology in Australia: Australian Industry Report.* Melbourne, Australia.

Iqbal, M. and M. Ahmad. 2005. Science and technology based agriculture vision of Pakistan and prospects of growth. Proc. PSDE 20th AGM. 10-12 January 2005, Islamabad.

IMF. 2009. *World Economic Outlook (WEO): Crisis and Recovery.* International Monetary Fund, April.

IMF. 2013. *Regional Economic Outlook: Asia and Pacific.* International Monetary Fund, April.

Islam, A. S. 2007. Future of Biotechnology in Bangladesh, Bangladesh Association for Plant Tissue Culture and Biotechnology. Dhaka.

Itkor, Piche. 2009. "Overview of Biotechnology in Thailand". Presentation made at the Fourth Asian Conference on Biotechnology and Development 12-13 February 2009, Kathmandu.

Jasanoff, Sheila. 2005. "Biotechnology and Empire: Global Power of Seeds and Science." Available at: www.hks.harvard.edu/sdn/articles/files/Jasanoff-Empire.pdf

Jawahir L. Karihaloo and Oswin Perera. 2010. APAARI Issue Paper: Harnessing biotechnologies for food security in the Asia-Pacific region. Paper produced for FAO international technical conference on Agricultural Biotechnologies in Developing Countries (ABDC-10), held in Guadalajara, Mexico 1-4 March 2010.

JBA. 2009. Japan Bioindustry Letters. Japan Bioindustry Authority, 25 (4), March.

JETRO. 2007. *Attracting Sectors: Biotechnology.* Japan External Trade Organisation.

JmcNaughton, Rowena. 2007. Local Vegetables to Boost Cambodian Diets, Partners in Research for Development Summer 2005-06, ACIAR.

Kapur, Arvind. 2011. "IPR Laws to Protect Innovation, Not to Restrict Crop Breeding." *Journal of Intellectual Property Rights,* 16: pp. 17-123.

Khatri, Yougesh and Houng Lee. 2003. "Information Technology and Productivity Growth in Asia". IMF Working Papers 03/15, International Monetary Fund.

KIET. 2008. *Annual Biotechnology Industry Survey*. Korea Institute for Industrial Economics and Trade.

KIET 2005. Statistics on the 2004 Korean Bio Industry, Korea Institute for Industrial Economics and Trade, MOCIE, December.

Kilugudi, Jayaraman. 2012. "GM Phobia spreads in South Asia". *Nature Biotechnology, 10* (11): pp. 1017-1019.

Kimberly, Ann Elliott. 2010. "Pulling Agricultural Innovation and the Market Together". CGD Working Paper 215. Center for Global Development. Washington DC.

Kuala Lumpur. 2009. Royal Danish Embassy, Trade Council of Denmark, 2 March, www.ambkualalumpur.um.dk/.../TheBiotechnologyIndustry/

Lal, Rattan, Mannava V.K. Sivakumar, S.M.A. Faiz, A.H.M. Mustafizur Rahman, and Khandakar R. Islam (eds). 2010. *Climate Change and Food Security in South Asia.* Springer. Heilderberg.

Lim, Dongsoon. 2009. "Biotechnology Industry, Statistics and Policies in Korea" . *Asian Biotechnology and Development Review*, 11 (2), March, New Delhi.

Ling, April Wong Yuen and Deris, Irdawani. Biotechnology in Malaysia, www.symbiosiso.com/apr02_biotech.htm nline.

Lipton, M. 2007. "Plant Breeding and Poverty". *Journal of Development Studies,* 43 (1):31-62.

Macer, Darryl R.J., and Minakshi Bhardwaj. 2005. '"How Well Does Japan Meet Its Challenges and Responsibilities in Biotechnology and Development for Asia?" in Sachin Chaturvedi and S. R. Rao (eds.) *Biotechnology and Development: Challenges and Opportunities for Asia*.

Mahoney, Richard, Keun Lee and Mikyung Yun. 2005. "Intellectual Property, Drug Regulation, and Building Product Innovation Capability in Biotechnology: The Case of Hepatitis B Vaccine in Korea." Innovation Strategy Today: bioDevelopments International Institute Inc.

Margarita, Escaler, Paul P.S. Teng and Andre D. Powell. 2012. "Challenges of Harmonization of Agricultural Biotechnology Regulatory Systems across APEC Economies". *Biosafety,* 1(3): pp 1-7.

Mark A. Pollack, and Gregory C. Shaffer. 2009. *When Cooperation Fails The International Law and Politics of Genetically Modified Foods.* Oxford: Oxford University Press.

Meric S. Gertler and Tara Vinodrai. 2009. "Life Sciences and Regional Innovation: One Path or Many?" *European Planning Studies*, 17: 2 (Febraury 2009): 235-261.

MFSC. 2006. National Biosafety Framework: Nepal. Ministry of Forests and Soil Conservation, Kathmandu

Mitsumori, Yaeko. 2005. The Biotechnology Industry in Japan- An Update on Policies and Programs, British Embassy, Tokyo.

Minna, Allarakhia, D. Marc Kilgour, and David Fuller. 2010. "Modelling the Incentive to Participate in Open Source Biopharmaceutical Innovation". *R&D Management,* 40 (1): pp. 50-66.

MoEF. 2009. Indian Biosafety Clearing House established by Ministry of Environment and Forest, Government of India. Last accessed at www.indbch.nic.in on July 14, 2009.

MoF. 2009. Economic Survey. Ministry of Finance, Government of India, New Delhi.

MOP. 1999. Cambodian Human Development Report. Ministry of Planning, Phnom Penh, Cambodia.

MOST. 2007. *China Science and Technology Statistics Data Book*. Ministry of Science and Technology of the People´s Republic of China, Beijing.

MOST. 2006. *China Science and Technology Indicators, The Yellow Book on Science and Technology*, Vol. 8, Ministry of Science and Technology of the People´s Republic of China, Beijing.

NARC. 2002. Vision for 20 Years Agricultural Research for Sustainable Livelihood Improvement, Nepal Agricultural Research Council, February, Kathmandu.

National Academy of Sciences. 2002. *Environmental Effect of Transgenic Crops: The Scope and Adequacy of Regulation.*

Neal, D. Fortin. 2009. *Food Regulation: Law, Science, Policy and Practice*. John Wiley & Sons, Inc.

New Zealand Trade and Enterprise. 2009. "Market Profile for Biotechnology in the Australian Market". January.

Ngo Luc Cuong. 2004. "Assessments of Needs in Biotechnology Applications in Least Developed Countries: Case Study in Vietnam". UNU-IAS Working Paper 122.

Nguyen, Nguyet Dzung. 2007. "Vietnam Patent Law: Substantive Law Provisions and Existing Uncertainties". *Kent Journal of Intellectual Property*, Vol 6. No. 2 , Chicago.

Nguyen, Tuong Van. 2000. "Agricultural Biotechnology in Vietnam." Available at: www.bic.searca.org/seminar_proceedings/bangkok.../nguyen.pdf

Niosi, Jorge E., Peter Hanel and Susan Reid. 2012. "The International Diffusion of Biotechnology: The Arrival of Developing Countries". *Journal of Evolutionary Economics*, 22: pp. 767-783.

Nuffield Council on Bioethics. 2003. The Use of Genetically Modified Crops in Developing Countries.

Obidimma C Ezezika, Nadira Saleh, and Abdallah S Daar. 2012. "Trait Stacking for Biotech Crops: An Essential Consideration for Agbiotech Development Projects for Building Trust". *Agriculture and Food Security*. 1 (5).

OECD. 2005. *Compendium of Patent Statistics*. January.

OECD. 2006. *Biotechnology Statistics.* OECD, Paris.

OECD. 2009. *Biotechnology Statistics*. OECD, Paris.

OECD. 2009. Patent and REGPAT Databases, OECD, Paris, January.

Otero, Gerardo. 2008. *Food for the Few: Neoliberal Globalism and Biotechnology in Latin America.* University of Texas Press.

Pack, Howard, and Larry E. Westphal. 1986. "Industrial Strategy and Technological Change: Theory versus Reality". *Journal of Development Economics,* 22: 87-128.

Padmashree, Gehl Sampath. 2007. "Intellectual Property and Innovation in Least Developed Countries: Pharmaceuticals, Agro-Processing and Textiles and RMG in Bangladesh" United Nations University - MERIT, 19/07/07 (Background Paper No. 9).

Pardey, P. G., J. M. Alston, and R. R. Piggott (eds.). 2006. "Agricultural R&D in the Developing World: Too Little, Too Late?", Washington, DC: International Food Policy Research Institute.

Paul, J. H. Schoemaker, and Joyce A. Schoemaker. 2009. *Chips, Clones*, and *Living Beyond 100 How Far Will the Biosciences Take Us?*' London: FT Press.

Paul, S. Teng. 2008. "Biotech Enterprises in Asia". *Bioscience Entrepreneurship in Asia: Creating Value with Biology.* P-33. Singapore: World Scientific Publishing.

Piesse, J., and C. Thirtle. 2010. "Agricultural R&D, Technology and Productivity". *Philosophical Transactions of the Royal Society Biological Sciences*, 365: pp. 3035-3047.

Pollack, Mark A. and Gregory C. Shaffer. 2009. *When Cooperation Fails: The International Law and Politics of Genetically Modified Foods.* New York: Oxford University Press.

Preeg, Ernest H. 2005. *The Emerging Chinese Advanced Technology Superstate*. Hudson Institute.

Robert W. Herdt. 2012. "People, Institutions, and Technology: A Personal View of the Role of Foundations in International Agricultural Research and Development 1960-2010". *Food Policy*, 37: pp. 179-190.

Roco, Mihail C. and William Sims Bainbridge. 2006. Nanotechnology: Societal Implications - Maximising Benefits for Humanity. Report of the National Nanotechnology Initiative Workshop, December 3-5, 2003, Arlington, VA.

Reichmann, J., and K. Maskus (eds.). 2005. *Public Goods and Technology Transfers under a Globalised International Property Regime.* Cambridge University Press.

Sakiko Fukuda-Parr (ed). 2007. *The Gene Revolution GM Crops and Unequal Development*. London: Earthscan.

Samejima, Masahiro. 2008. Japan as a Patent Market, Intellectual Asset Management. August/ September.

Sasson, A. 1988. *Biotechnologies and Development.* Paris: UNESCO.

Scott, Steffanie, Peter Vandergeest, and Mary Young. 2009. "Certification Standards and the Governance of Green Foods in Southeast Asia in Corporate Power" in Jennifer Clapp and Doris Fuchs (eds) *Global Agrifood Governance.* The MIT Press.

Shan, James. 2008. "From Herbs to High Tech: Growth of China's Pharmaceutical Sector will have Global Impact". *Business Forum China*, November-December, Issue 6, Beijing.

Siaw, Timothy. 2007. "Malaysia Realizes Biotechnology Potential". *Supplement Life Science IP Focus,* 2007, 5th Edition, Malaysia, May.

Silberglitt, Richard, Philip S. Antón, David R. Howell, Anny Wong with Natalie Gassman, Brian A. Jackson, Eric Landree, Shari Lawrence Pfleeger, Elaine M. Newton, and Felicia Wu. 2006. *The Global Technology Revolutions 2020*. Santa Monica, CA RAND Corporation.

Smeltzer, Sandra. 2008. "Biotechnology, the Environment, and Alternative Media in Malaysia". Media and Communications Publications Paper 5. http://ir.lib.uwo.ca/commpub/5

Spielman, D.J., F. Hartwich, and K. von Grebmer. 2007. "Sharing Science, Building Bridges, and Enhancing Impact: Public-Private partnerships in the CGIAR". Discussion Paper No. 708. International Food Policy Research Institute. Washington DC.

Stenberg, Lennart. 2007. Policies for Life Sciences and Biotechnology in Japan. VINNOVA's Strategy Development Division, University of Tokyo, Stockholm and Tokyo, November.

Thomson Reuters. 2013. Web of Science Database.

Thomson Reuters. 2013. Thomson Innovation Database.

Thorburn, Lyndal and Hopper, Kelvin. 2007. "Bioindustry Review of Australia". *Australasian Biotechnology,* Volume 17, Number 1, March.

Thorsteinsdóttir, H. (ed). 2011. *Building Bridges: A Study on South-South Collaboration in Health Biotechnology*. Academic Foundation. New Delhi.

UNCTAD. 2007. The Least Developed Countries Report, Knowledge, Technological Learning and Innovation for Development.

UNESCAP. 2009. *Economic and Social Survey of Asia and the Pacific 2009: Addressing Triple Threats to Development*. United Nations Economic and Social Commission for Asia and the Pacific.

UNESCAP. 2013. *Economic and Social Survey of Asia and the Pacific 2013*. United Nations Economic and Social Commission for Asia and the Pacific.

UNESCO. 2010. *UNESCO Science Report.* United Nations Educational, Scientific and Cultural Organization.

UNESCO. 2012. UNESCO Institute of Statistics, October. United Nations Educational, Scientific and Cultural Organization.

Varshney, Rajeev K., Kailash C. Bansal, Pramod K. Aggarwal, Swapan K. Datta and Peter Q. Craufurd. 2011. "Agricultural Biotechnology for Crop Improvement in a Variable Climate: Hope or Hype". *Trends in Plant Science,* 16 (7): pp. 363-371.

Vietnam Biotechnology. 2005. Global Agriculture Information Network (GAIN) Report number VM5050, Date- 08/11/2005

Vroom, W. 2009. *Reflexive Biotechnology Development*. Wageningen: Wageningen Academic Publishers.

Wheelwright, Scott M. 2007. "Biotechnology in Malaysia". *BioProcess International*.

WIPO. 2009. WIPO Statistical Database, World Intellectual Property Organization April.

Wong, Joseph. 2005. "Re-making the developmental state in Taiwan: the challenges of biotechnology". *International Political Science Review*. 26. pp. 169-191.

Wong, Joseph. 2011. *Betting on Biotech Innovation and the Limits of Asia's Developmental State*. Ithaca: Cornell University Press.

World Bank. 2013a. *East Asia and Pacific Economic Update, April*.

World Bank. 2013b. *South Asia Economic Focus*, Spring.

Xielin, Liu and Jinhui An. 2007. "Biotechnology Statistics: Publicly Funded Biotechnology R&D Programs in China". Paper presented at the Asian Biotechnology, Innovation and Development Initiative (ABIDI), 25 January 2007 at New Delhi.

Zhe, Li. 2009. "Definitions, R&D Activities and Industrialization of Biotechnology in China". Paper presented at the Fourth Asian Conference on Biotechnology and Development, 12 February 2009 at Kathmandu, Nepal.

Zika, E. *et al.* 2007 and EC. 2007. In both the references to USA indicated that EU considers USA as a benchmark to measure the state of biotechnology in Europe. In 2007 a mid-term review was made. Mid-term review *http://ec.europa.eu/biotechnology/docs/com_2007_175_en.pdf*

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