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**Biotechnology in South Asia:**
**Issues of Technological Capability and Development***

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## 1. Introduction

After many decades of relative anonymity, technology and especially technological change and its links to economic growth have become centre stage in the debate on development. Much of the recent analysis has concentrated on technological innovation and technology gaps between industrialized countries. The effect has been that a considerable amount of research on these issues has also found its way to developing and industrializing countries. The phenomenal success first of Japan and more recently of South Korea and the other Asian NICs has been largely attributed to technology and the ability of the economy to adapt to technological change. In turn other industrializing countries, especially those with a certain degree of technical skills and financial resources are looking more closely at this model of development in order to reduce the widening technological and economic gaps between the industrialized world and themselves. Of all the reasons that are attributed to the success of the Japanese and South Korean models of development, the one that appears to be receiving the closest scrutiny in most developing countries is that of strategic targeting. The debate however raises a number of other questions relating to technological capability and the ability of the economy to adapt itself to accepting and adopting a new technology in an efficient manner.

The paper presented here looks at some of the recent discussions in the context of biotechnology research and development in industrializing countries. Industrializing countries in this context are developing countries which are characterized by a certain level of technological capability, skills and a knowledge base which is able to adapt new science based technologies to the local environment. Biotechnology is an interesting case to look at because it can be adopted by countries having a wide range of technological skills ranging from relatively simple activities such as plant breeding to the highly sophisticated genetic engineering research which is only within the reach of the more scientifically advanced nations. Based on a survey carried out recently of six south Asian countries, the paper attempts to examine issues of technological capability and the likelihood of these countries developing a successful biotechnology industry based on their technological capabilities. What is meant exactly by technological capability and strategic targeting is outlined during the course of the paper.

## 2. Technology and Economic Development

Through the years economists have debated the many possible causes for why different countries experience different rates of economic growth with respect to each other and why economic gaps develop between countries. A number of different frameworks have been used to explain production structures and economic growth rates in different countries, including differences in initial labour and capital endowments, changing skills among the population, and the theory of technology gaps between nations. This final analysis, that of technology gaps has found a lot of appeal in recent years. The development of the product cycle theory by Posner (1961), where technical change occurred as a result of innovation in industrialized countries, and imitation in developing countries has now been formalized in economic theory. Differences in growth rates between countries are no longer considered as given but instead are attributed to technology "gaps". Most importantly, they no longer assume that production patterns based on national endowments remain static but instead, technology can be used to enhance or change these national endowments *over time*. Thus while initially a country begins from a position of comparative advantage in labour intensive products, there is no reason why it should remain in that position. Instead it may be possible for the country to use new technologies to enhance its basic comparative advantage or indeed in the more extreme case to change that comparative advantage.

The model of economic growth developed first by Japan and then followed successfully by South Korea and the other Asian NICs has given rise to a new branch of economic analysis, first put forward formally by Brander and Spencer (1983) and later given empirical support in a book edited by Krugman (1988) on the new economics. The identification of "strategic sectors" in the economy, for example automobiles in the case of Japan after the war allowed the government along with industry to develop an infrastructure which would support and develop this industry. However the key here was an infrastructure which was flexible enough to adapt to changing needs and changing technologies (see Freeman 1987 for an excellent analysis of technological development in modern Japan).

Soete (1991 a,b) describes three types of strategic targeting. The first type is the most obvious, where certain sectors are considered to be strategic such as military technologies but also other areas considered to be important to the economic development of a country or a region. The microelectronics support programme of industrialized countries are included in this category; agricultural technologies in developing countries may also qualify. Nevertheless, even within this relatively narrow definition, the problem of identifying strategic and non-strategic sectors arises. The second category of strategic targeting is in trade policy. The "new trade" theory points to the existence of increasing returns in some products which are traded internationally. Here changing technologies make it possible for countries to reap economic rents from dynamic increasing returns. The final sector and probably the broadest, relates more to industrial policy. The example used here is that of the automobile industry with its forward and backward linkages, pervading all aspects of socio-economic activities in a country. Here of course the danger is that such a definition can be used by governments to justify protection on a very large scale, some of it perhaps unjustified.

In the following section we examine the impact of a new technology, namely biotechnology, on industrializing countries in southern Asia. The survey based on a recent visit to six countries in south and south-east Asia, looks at developments in research, policies geared toward promoting biotechnology and the general research and development environment, including issues such as intellectual property rights and education which are relevant to the development of biotechnology. Through the survey we not only hope to provide a brief glimpse of the development and diffusion of a new technology in these countries, but also attempt to address some of the issues discussed above, relating to strategic targeting and technological capability.

## 3. Biotechnology in South Asia: A Survey

### 3.1. India [3]

In India biotechnology research and development has been promoted within the framework of the more general policy on science and technology. That the government perceived biotechnology as important for fulfilling India's national development goals was evident when the Department of Biotechnology was formed in 1986 as a separate department within the Ministry of Science and Technology. The main reason for forming the department was the perceived need to coordinate biotechnology research already ongoing for some years in the country. It was felt that while the scientific capability to develop biotechnology based products existed, the research needed to be guided in a particular direction which would enable it to fulfil national needs. For this a central body was needed which could firstly ensure cooperation between researchers located in far flung areas of the country as well as act as an institution through which the Government of India could allocate funding for specific research projects or areas. The Department's major responsibilities include:

1. to evolve integrated plans and programmes
2. to identify specific research and development programmes and biotechnology related manufacturing
3. to identify and establish infrastructural support at the national level

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[3] Much of this section is based upon discussions with officials at the Department of Biotechnology, the Annual Report of the Department of Biotechnology and various other researchers in the public and private sectors

4. to import new, recombinant DNA based biotechnological processes, products and technology
5. to evolve biosafety guidelines for laboratory research and production applications
6. to initiate scientific and technical research priorities
7. to initiate programmes of manpower development in biotechnology and
8. to establish the international centre for genetic engineering and biotechnology (ICGEB)

As is evident from this agenda, its priorities lie in research and training. This is done mainly by collaborative work with universities and research institutions who provide the infrastructure and the research and training while the Department provides the funding. In addition, there are advisory boards composed of both scientists within the country and foreigners. The latter category includes non-resident Indians who are represented in relatively large numbers. On a more specific level each project is supervised by a group consisting of members of the scientific community as well as personnel from the Department of biotechnology.

In agriculture, the emphasis lies on developing new, superior varieties of four crops, rice, brassica, chickpea and wheat; biological control of pests and diseases in crops such as sugarcane, cotton, pulses, oilseeds and vegetables; and biomass production for reforestation programmes through tissue culture; also special emphasis is being placed on sericulture biotechnology which is an important means of livelihood in the rural areas. India's rural needs have resulted in research in biofertilizers and have given way to a larger programme on environmental biotechnology. Six projects have been launched in the areas of bioconversion, fossil fuels, and for improving the quality of water.

Another area where india has made considerable progress is in aquaculture and marine biotechnology. Programmes include intensive carp culture using biotechnology, increasing the production of prawn and developing transgenic fish.

In medical biotechnology, emphasis is placed on recombinant DNA technology, development of diagnostic kits, drug delivery systems, DNA probes, vaccines for cholera, biosensors, prenatal diagnostics and genetic disorders. Diagnostic kits for a number of ailments such as amoebiasis, typhoid, tuberculosis, leprosy and hepatitis B are under advanced stages of commercialization. Two diagnostic kits, one for the detection of bancroftian filariasis and the other for pregnancy detection has been developed through private sector companies.

Although most of the researchers involved in biotechnology research are working in public sector research laboratories, private sector contributions in this field are rising. Beginning with the production and marketing of new seeds and varieties, companies are now moving into more sophisticated techniques such as tissue culture and genetic mapping. In the medical area, an increasing number of companies are working on vaccines and diagnostic kits for which India provides a large market. A number of these companies are working with the Department of Biotechnology in their projects. One such company is A.V. Thomas and Co. which has provided much of the basic research and the tissue culture of resistant varieties for the cardamom project recently initiated by the Department of Biotecnnology. Supervision of the field trials is also being carried out by A.V. Thomas. A number of other private entrepreneurs have developed markets abroad. The two areas in which such private export oriented companies dominate are agriculture, especially tissue culture and cloning and pharmaceuticals. The Swedish multinational Astra has set up a research institute in South India which does research in the pharmaceutical field. An outcome of this investment has been the formation of another private company, Genei Limited which produces and exports indigenously designed recombinant DNA research tools and is presently exporting about six products to laboratories in the USA. Much of the technology used was originally acquired from the Astra Research Centre, although increasingly know how is coming from private indigenous firms; local buyers are largely Indian universities and research centres including the prestigious Indian Institute of Sciences. In addition, in recognition of the importance of private sector involvement in research, the Department of Biotechnology has helped to set up a Biotechnology Venture Company with participation from financial

institutions and industry in 1990.
An important function of the Department of Biotechnology as mentioned earlier, is that of information dissemination and training. While India has a relatively reasonable pool of skilled labour, the interdisciplinary and hi-tech training that biotechnology research requires is weak or lacking. The Department has helped nineteen universities nationally to set up postgraduate teaching programmes in biotechnology. A few short term training courses (two to four weeks each) on new biotechnology techniques, as well as fellowships to study abroad are offered each year. To improve cooperation with other nations a visiting programme for foreign scientists and a few other financial support programmes at different levels of the educational system have been organized by the Department of Biotechnology.

The national infrastructure houses the Biotechnology Information System, a computer system which links nine information centres at universities and research institutes in the country; national facilities for animal tissue and cell culture; microbial type culture collection (MTCC), Blue Green Algal Collection (BGA), collection on plant tissue culture, biochemical engineering research and process development, oligonucleotide synthesis and enzymes and biochemicals, as well as four genetic engineering laboratories nationwide.

International research and development cooperation has also been listed as a priority and ongoing programmes include projects with Germany, Switzerland, the United States and the Soviet Union. Bilateral programmes with the UK, Sweden, Vietnam, Poland, the Netherlands, China, Cuba, Brazil among others are currently being finalized.

Despite these efforts, India is facing a number of urgent new problems which it must respond to. Firstly the problem of biological diversity has been sharply highlighted in recent years and the upcoming United Nations Conference on Environment and Development (UNCED) has placed pressure on countries, especially those from developing areas to respond to the threat of the loss of biological diversity from these countries. While the UNCED meeting will influence international responses to conserving biological diversity, on a national level India has drawn up a detailed programme for the establishment of a facility for the conservation of germplasm to protect biological diversity.

Another issue which India must tackle is that of intellectual property rights. For a few years now, India has been placed on the US' "Special 301" list. This is basically a list of those countries who violate US patent laws. The US would like these countries to change their internal patent laws, bringing them more in line with US patent laws, so as to prevent present violations. In an attempt to persuade major violators to change their legislation, the US Trade Representative, Ms Carla Hills travelled to a number of countries in south Asia including India in the winter of 1991. India has so far resisted making these changes but for a number of reasons will probably have to comply in the coming years. US threats to impose trade barriers on Indian exports for one is a strong enough reason at the moment when the country has just emerged from its worse balance of payments crisis. India will also have to change its laws if it is to successfully attract foreign investment, and already the new liberalization policy is being implemented. In biotechnology, the controversial "new seed policy" which allows duty free import of seed including new varieties on the condition that the mother plant be eventually deposited in India, has already been in force for a few years. India is not yet a member of UPOV but may indeed join if it alters its patent laws. There appears to be strong resistance on the part of the Indian scientific community to join UPOV or allow the patenting of biotechnological products, and the next few years will indeed bring about many interesting changes.

Internally, the diffusion of biotechnology faces a number of obstacles, mainly in the form of the infrastructure and market restrictions which have existed in India for so many years. Although biotechnology has developed in a relatively free environment, and a number of small and big private companies have also taken advantage of this environment to invest in this technology, cooperation between public and private sectors is still regarded with some suspicion.

In an interesting development, a number of biotechnology firms are being encouraged to produce their products for the external market. A large amount of trade now takes place with the Netherlands, which buys the tissue culture plantlets produced in India. The firms which are at the forefront of this trade are doing so successfully and appear to be competitive internationally. Thus there seems to be a shift away from across the board infant industry protection, although this is selectively practiced. In the medical sector for example, such firms are rare unless they are foreign holdings in which case the research patent is held with the foreign company. Nevertheless, these developments are encouraging, both for the scientific community which has easier access to biochemicals and enzymes needed from abroad, as well as for cooperation between private and public sector enterprises.

Biotechnology research and development in India is therefore still highly pre-competitive, and funded mostly by the government. However, there is a distinct change in government policies regarding the development of this technology and in the environment for private investors. Private sector involvement both in research and development is considerable, especially in agriculture and health, two areas where the size of the internal market is considerable. In agriculture, a number of specialized and relatively new firms have established themselves in the external market as well. For basic and industrial research, import of a number of materials such as enzymes and laboratory equipment can be imported relatively easily. Foreign multinationals have established research institutes in India, some of them consisting largely of local researchers, reflecting the relatively skilled pool of labour in India. In terms of strength therefore, India's investment in basic scientific research has proved an asset in the long run.

In terms of weaknesses, the fledgeling technology faces an economy which is still dominated by cumbersome controls and weak linkages between the elaborate network of public research institutes and the private sector. There is some evidence to show that the public sector most notably the Department of Biotechnology, is collaborating with private sector firms in developing technological capability, but the atmosphere remains largely one of mistrust.

### 3.2. Thailand [4]

Thailand first actively recognized the importance of biotechnology for its agricultural and industrial research in 1983 when the National Centre for Genetic Engineering and Biotechnology (NCGEB) was formed. The Centre obtains its authority directly from the Ministry of Science, Technology and Energy and is in charge of coordinating biotechnology research and development across the country.

The national biotechnology research network supported by the NCGEB consists largely of universities and research institutes across the country. At present the NCGEB funds research projects at Chiang Mai University, Chulalongkorn University, Kasetsart University, Khon Kaen University, King Mongkut's Institute of Technology, Thonburi (KMITT), Maejo Institute of Agricultural Technology, Mahidol University, Prince of Songkhla University, Srinakarinwirot University, Prasanmit Campus and the Thailand Institute of Scientific and Technological Research (TISTR).

In industrial applications of biotechnology, the research projects can be divided into two priority areas: one dealing with waste matter and pollution and the second for commercial production of a number of industrial inputs used by Thailand, formerly imported from abroad. In the first area the NCGEB has finalized projects in bioleaching, biogas production as well as pollution combatting biotechnology. The research is currently supervised by Dr Morokot Tanticharoen at KMITT and includes a biogas pilot plant which will shortly be ready for commercialization and scaling up. A successful example of University-

[4] This section is largely based on discussions in Thailand with the Director of the National Centre for Genetic Engineering and Biotechnology (NCGEB), the NCGEB Activities Report 1989-1990, researchers at Mahidol University, KMITT and AIT in Bangkok.

industry linkage is Spirulina. This bacteria which is used for wastewater treatment was initially a research project at KMITT funded by the NCGEB. In Thailand it has now been commercialized by a private sector company and is applied to the problem of starch pollution. Industrial biotechnology is relatively new and remains geared to developing some of the basic products and processes that Thailand lacks. Thus another research project at KMITT is aiming to develop a production process for bakers yeast for commercial purposes ---a common input in a number of industrial processes but still not commercially produced in Thailand.

Pharmaceutical research priorities are geared to local problems. Two ongoing research projects are looking at the development of mosquito larvicide at TISTR and the production of 6-Aminopenicillanic acid (6-APA) using genetic engineering at Mahidol University.

Despite the considerable amount of ongoing research in industrial biotechnology, Thailand is still largely agricultural and this, believes Dr Amaret Bhumiratana of Mahidol University, is where the country's greatest potential lies. The country is relatively advanced in tissue culture and cloning technology and has built up a huge market, primarily in Western Europe in the export of orchids. A number of new projects which are still in the research stage are looking at a wide variety of areas ranging from improvement of dairy cattle through to genetically engineered growth hormones as well as research in embryo transfer technology to tissue culture in horticulture and important agricultural exports such as rattan. In addition to this, the NCGEB has initiated several projects investigating tissue culture for oil palm propagation comparing its performance to oil palm seedlings derived from hybrid seeds, identification of disease resistance genes in rice and tissue culture of drought resistant strains of rice. In addition to these simpler technologies agricultural research is now aiming at genetic engineering. The research is mainly examining rice where a DNA probe is to be identified which will enable protein improvement in rice through direct gene transfer as well as RFLP mapping in rice.

In the area of public health biotechnology, research has concentrated on Thai health priorities and includes field trials of bacteria which are used for mosquito control at Mahidol University, research on viral insecticide at Kasetsart University, and genetic engineering in immunodiagnostics.

To conduct this research, a number of specialized laboratories have been identified across the nation and strengthened through funding provided by the NCGEB. These can be listed as follows:

1. Plant genetic engineering unit, Kasetsart University
2. Microbial genetic engineering unit, Mahidol University
3. Marine biotechnology laboratory, Chulalongkorn University
4. Biochemical engineering and pilot plant research and development unit, KMITT
5. Microbiological Service Unit, TISTR.

Despite a considerable amount of funding for research for the government, Thailand still faces a number of problems in increasing its competitiveness world wide in biotechnology. The two major problems which were identified lie in the area of capabilities and linkages between research and commercial sectors.

Thailand faces a shortage of skilled personnel in biotechnology. Dr Yuthavong, Director of the NCGEB pointed out that the number of graduates each year who are able to do biotechnology research number about 200. A major objective of the NCGEB is to provide research grants to doctoral and master level students to improve basic research capabilities in the country. Three priority areas have been identified for students studying abroad, biotechnology being one of them. The long term objective is to develop MSc and PhD programmes in Thailand which can compete with similar programmes abroad. A number of universities have begun offering MSc and also PhD programmes in biotechnology.

With respect to research and development, Thailand is no exception to the major problem facing other developing countries, that of weak links between public research and private enterprises. Like in most other developing countries, research in biotechnology is funded largely by public organisations like the NCGEB and conducted by research institutes which do not have the facilities required for large scale commercialization. As a result the NCGEB has been trying to encourage private companies to invest in the research carried out by research institutes. There is some evidence to show increasing interest in biotechnology---the cases mentioned above of orchids and spirulina where the research initially began at public research laboratories but is now being produced by private industry on a large scale. In addition, projects are currently underway initiated by Thai industry, for example the case of soya sauce where researchers at public laboratories have been asked to do research on quality control and improvement, and fish paste - the Thai substitute for salt -where industry has approached research institutes for help on reducing time and improving efficiency of the fermentation process.

Thailand is presently under pressure like a number of other developing countries to change its patent laws. But this may soon change - as Thailand cannot afford trade retaliation from its main trading partners. Many researchers believe that although Thailand's present research will not be affected in a major way, it is likely that changing its patent laws may cost Thailand more in the long run as it moves to upgrade technology and its research capabilities. Thailand is therefore trying to do two things at the same time:

1. Build up capabilities in basic scientific research and
2. Develop an industry in biotechnology.

With its past tendency to rely on foreign technology imports, this may be more difficult for Thailand than for other countries in the region. However, its liberal investment laws and flourishing market may help Thailand to collaborate with and obtain foreign non-proprietary technology from foreign companies. In the long run however, improving the skills of its labour force appear to be the key to developing biotechnology.

### 3.3. The Philippines [5]

The Philippines unlike India and Thailand does not have an official policy on biotechnology. Nevertheless, the government has been actively engaged in promoting biotechnology research and development through various channels. As with most developing countries, this research appears to be largely "pre-competitive" or dominated by public sector research institutions and universities.

Within the public sector, research is largely concentrated in the network established by the University of the Philippines, and research institutes established by the government. The work of these institutes includes its own research programmes as well as active participation in government policy making in the form of recommending projects for funding. These institutes also participate in the technical panels that meet to recommend new policy areas in biotechnology. The University of the Philippines network includes a number of other colleges and universities with independent programmes in biotechnology. Many of them are primarily geared toward basic research and training in the natural sciences and any specific programmes on biotechnology usually take second place.

The priorities however remain geared to the needs of the larger community. In agriculture and industry, biotechnology is being used for the production of biofuels, microbial enzymes including amylase, cellulase and protease, organic acids, bioinsecticides, microbial-based fertilizers, microbial polysaccharides and plant tissue culture.

With respect to health biotechnology these are the priority areas which have been identified and where research is presently ongoing: drug research which is focusing on medicinal plants under what has been

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[5] This section largely based on discussions at UP Los Baños, IRRI, UP Manila, and a recent report by Dr W.G. Padolina (1991).

identified as the "herbal medicine programme". The Philippine pharmaceutical industry is heavily dependent on the import of most of its drugs. Having to import brand names and to make royalty payments for licensed products has largely rendered most drugs out of the reach of the majority rural poor. Research on medicinal plants as an alternative but also in addition to conventional drugs has been ongoing at the Institute of Biological Sciences (IBS) at the University of the Philippines campus at Los Baños. They have developed extension and outreach programmes for rural areas and currently one of these programmes has been funded by the government of the Philippines. In addition to this, several publications on Philippine medicinal plants have been circulated from IBS.

Similarly, in order to cope with local diseases and health problems, research in vaccines and diagnostics is currently examining schistosomiasis and malaria; biochemical characterization and disease patterns associated with microsporidia as well as the development of diagnostics to identify human and animal diseases prevalent in the Philippines.

Although work in biotechnology remains largely within the realm of the not-so-advanced technologies, some research has also been done using "new techniques" namely, the use of cell fusion in improving cellulose degradation, increasing alcohol yield, improving production of animal vaccines and the production of monoclonal antibodies for diagnosis of plant viruses [6].

Despite the research efforts, two major problems remain which are impeding the growth of the biotechnology programme:
1. Lack of skilled personnel
2. Inadequate coordination of research and development activities in the country.
According to a recent report by Dr W.G. Padolina, Chairman of the Sectoral Technical Panel on Biotechnology to the Government of the Philippines, there were in 1990 only 58 PhDs and 151 MS' distributed across 20 institutions involved in biotechnology research and development. There needs to be a considerable increase according to this report, in R&D personnel if the Philippines is to progress along with other ASEAN nations.

The need for better coordination of research and development and an efficient pooling of resources to tackle the internal problems of the Philippines has led to new government policies. Five priority areas in biotechnology have been identified: agriculture, aquaculture, health, industry and environment. Within these broad priority areas, six projects have been identified for implementation between 1991 and 1996. These are:
1. Penicillin production
2. Diagnostics and vaccines
    - -human diagnostics and vaccines
    - -plant diagnostics
    - animal diagnostics and vaccines
3. Coconut tissue culture
4. Coconut tailored fats
5. Urban Wastes
6. Reforestation

Coordination and implementation of these programmes is done mainly within the University of the Philippines network, with the University of the Philippines at Los Baños being a major contributor. UP Los Baños supports an infrastructure whereby both universities and institutes work together. Faculty and researchers are exchanged across institutes as and when required. In addition, providing support to the teaching system at the University are a number of autonomous institutes, such as the Institute of Plant

[6] Padolina (1991)

Breeding and the National Institutes of Biotechnology and Applied Microbiology (BIOTECH) which contribute research skills and equipment to the system.

The Institute of Plant Breeding formed in 1975 aims to strengthen plant breeding research to develop new and improved crop varieties for Philippine agriculture. Since then, the Institute has established in Cellular and Molecular Plant Biology (CMPB) programme whose research goals include: 1. Development and application of in vitro technology, 2. Recombinant DNA technology for specific gene transfer, cloning, use of RFLPs and isozyme markers and 3. other non-conventional techniques involving somaclonal variations, in vitro selection and indeed mutation by chemicals and irradiation. The Institute has developed and released more than 50 superior varieties of about 19 crops including corn, wheat, sorghum, cassava and sweet potato among others.

BIOTECH with its 13 laboratories and a pilot plant has a mandate to develop technology for goals and services which are cheaper alternatives to conventional products, safer for the environment and use local materials. Thus far BIOTECH has had a number of successes in commercialization of its products including the production of a superior yeast strain which is presently being used by two companies for increasing alcohol production; at the same time the development of thermophilic and mesophilic anaerobic fermentators produces biogas from distillery slops and reduces pollution and a process using local isolates decolorizes the distillery wastes; and the successful commercialization of inoculants for use as fertilizers in reforestation projects.

The presence of the International Rice Research Institute (IRRI) is also a tremendous resource in the Los Baños region. Although not specifically part of the network at UP, IRRI with its team of highly skilled researchers and enormous capital resources, gives an added technological capability to the region. Its work on conservation and development of new rice varieties has benefitted the Philippines and other rice growing countries enormously both directly through transfer of new varieties to the field as well as through training programmes for young researchers.

The benefits of such a system whereby institutes are obliged to use the skills offered by the University or at other research institutes are quite plain---ensuring greater collaboration as well as allowing a more efficient utilization of the skilled labour force which many have pointed out is rather scarce in the Philippines. The disadvantages of the system have been an inequitable division of resources between the specialized research institutes and the University and while students and teaching staff have access to the resources of the research institutes, a number of departments at the University have experienced a considerable loss in their resources as their research activities have been taken over by the Institutes. However, despite this it appears that the advantages are greater than the disadvantages and close cooperation between institutes and scholars may tip the scales even further in favour of the advantages in the long run.

Like most other countries in the region, the Philippines is presently debating a change in its patent laws. Biotechnology products are presently not included in the country's patent legislation and there are strong feelings expressed on both sides, pro and con when the subject is mentioned.

Interestingly enough, of all the countries surveyed, regional cooperation, not only within ASEAN but also with other Asian countries, appears to be high on the list of priorities with respect to biotechnology. This may be because of all the countries, the Philippines still does not have a coherent policy on biotechnology and the need to cooperate with other researchers may be greater.

### 3.4. Republic of China on Taiwan [7]

Taiwan in comparison with the countries discussed previously, is more advanced in biotechnology research and development. Taiwan's national policy on biotechnology was established in 1982 when biotechnology was declared one of eight programmes strategic to the country. Today the government has built a strong infrastructure of public sector research and development which supports the private sector. In fact in contrast to many other countries promoting biotechnology research, Taiwan's emphasis is on promotion with comparative disregard to regulation of new biotechnologies.[8]

The structure of biotechnology research in Taiwan consists of three levels. The basic research is conducted to some extent at the universities, but largely at the Academia Sinica, an institute of scientific excellence, devoted solely to academic research. The Academia Sinica originally established in Mainland China, was re-established in Taiwan after the formation of the Government of the Republic of China in exile. Divided up into separate institutes, each doing research in the different branches of science, the Academia is not involved in any application of its research output. Four of the institutes are specifically relating their work to biotechnology. The Institute of Botany is presently working on tissue culture of a number of crops including bamboo, passion fruit and papaya. Rice, an important staple crop in Taiwan, is being genetically mapped. At the Institute of Zoology, a national classification of insects has just been completed and published. The Institute is also working on aquaculture and studying the impact of growth hormones on varieties of fish. The Institutes of Molecular Biology and Biomedical Sciences are also involved in basic research, although the Institute of Biomedical Sciences is also funding clinical research at a number of hospitals in Taiwan. The emphasis is on vaccines for diseases such as hepatitis B and on diagnostic kits, a number of which are being marketed by Taiwanese industry.

The second level within the Taiwanese biotechnology research and development structure is the autonomous Government created and largely funded research institute, the Development Centre for Biotechnology. Established in 1984, its purpose is specifically to promote and upgrade biotechnology industry in Taiwan. This it proposes to do by linking up vertically the institutes who do basic scientific research such as the Academia Sinica and downstream biotechnology industry. For this it also has a pilot plant facility to develop technologies, enabling their transfer to larger scale industrial production. Horizontally, the Centre buys, adapts and develops new biotechnologies, facilitating their transfer to local industry. Its main research divisions include molecular biology, microbiology, cell biology and immunology, biochemistry, applied chemistry and agricultural biotechnology. The process development section includes facilities for scale up, fermentation, process scale up, recovery, separation and purification technology, large scale cell culture technology, conceptual process design and economic evaluation and pilot and production plant engineering. The current projects which have reached this stage of development are a genetically engineered hepatitis B vaccine, monoclonal antibodies, process scale purification, bioinsecticide process scale up, mammalian cell and hybridoma scale up production and contracted production of biotechnological products. Examples of successful transfer of technology for larger scale production include aspartame and a number of antibodies.

In addition, there is a division for industry and technology information whose objectives are to provide updated information to industry and market surveys for biotechnology research and development projects in the private and public sectors. At present this division provides services which include product and market analysis, strategic analysis for product development and also maintains a database containing product and market information.

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[7] The section on biotechnology in Taiwan is based on meetings with researchers at institutes at the Academia Sinica, and various people at the Development Centre for Biotechnology

[8] US OTA (1991), p 240

In agricultural biotechnology, the focus lies on microbial pesticides, fungicides, biofertilizers, transgenic technology, artificial seed technology, animal vaccines as well as antibodies for crop protection. The head of the agriculture division however voiced dissatisfaction with the general structure of biotechnology research in the country. According to him, there is no linkage with academic institutions such as the Academia Sinica who in turn do not show much interest in the application of their research for the country. Similarly, the Development Centre for Biotechnology has not been very successful at bridging this gap between research and application or at developing products which can be then marketed. Industry in turn has not shown as much interest as initially hoped in the products developed by the Centre. Indeed, the gap caused by this resulted in the formation of two new companies by the Centre to market products developed in recent years: one for diagnostic kits and the other for fungicide development.

On the international level, the Centre collaborates on a regular basis with a number of industrialized countries especially the USA and Germany and is also a member of the Asian Productivity Organization which consists, as the name suggests, largely of Southeast Asian countries. Biotechnology information is largely exchanged through periodic meetings consisting mainly of scientific but also policy and management representatives. The Centre is also represented at other meetings in the region such as the Third Pacific Rim Conference on Biotechnology scheduled for August 1992.

The Bioindustry Development Association (BIDEA) is a non-profit organization founded in 1989 and aims to promote cooperation between industrial sectors, government and academia in the field of biotechnology. Its members include over twenty organizations and companies and almost two hundred individual members in Taiwan. Its goals include the promotion of industrialization in biotechnology, as well as the diffusion of biotechnology in the economy. This it does by holding symposia and conferences, through international cooperation and information dissemination and lastly, by contributing to the development of human resources in biotechnology. It also publishes a quarterly journal entitled "Bioindustry". A venture capital funding system for funding new startup companies in biotechnology has also been started. Government banks launched these financing schemes and special income tax benefits are available. The result has been the formation of 13 venture capital companies in biotechnology since 1986.[9]

With regard to supporting infrastructure such as an intellectual property rights law, the Taiwanese government whose recent changes in the national patent system will bring it more in line with that of the US, is encouraging researchers as well as private firms to file for patents. The government goes as far as to pay for the costs of filing a patent and researchers who would previously not have bothered to file, as a result are now becoming more interested in obtaining a patent for their biotechnology products.

Taiwan is thus moving biotechnology into industry. The initial research phase of pre-competitive, government supported research appears to be on the decline now and there is more emphasis on industrialization. Although industry has been relatively slow at recognizing this, Taiwan appears to have left other developing countries in Asia behind and moved into the era of venture capital and full scale commercialization of biotechnology.

### 3.5. Republic of Korea [10]

The Korean programme in biotechnology and its achievements are by far the most notable of all the countries surveyed. Biotechnology was selected along with two other new technologies as the most important areas to be targeted for national R&D programmes by the Korean government. Consequently,

[9] US OTA (1991), p 240.

[10] This section is based on meetings with officials at KOGERA, the Genetic Engineering Research Centre, Seoul National University and Lucky Research Centre.

in 1984, the National Assembly passed a bill promoting Genetic Engineering. The Genetic Engineering Centre was established in 1985, the foremost research laboratory for genetic engineering and biotechnology in the Republic of Korea. The Centre is divided into research and development divisions and a technology service and is meant to perform a role similar to that of the Biotechnology Development Centre in Taiwan discussed briefly above.

The Genetic Engineering Research Centre has four major divisions: Division of Biochemistry, Molecular and Cell Biology, Division of Microbiology, Division of Bioresources and Process Technology and the Division of Technology Development and Services. Each division has a number of research laboratories. The Division of technology development and services offers a gene bank, a bio pilot plant, biopotency evaluation, insect resources, plant development evaluation and regulation. The Centre is also involved in a human genome research programme. It is funded largely by the Korean Ministry of Science and Technology (MOST) and its main functions include the building up of national research and development infrastructure and leading the way in biotechnology, which it does through development and dissemination of new biotechnologies and products; through training and by contributing to the national policymaking structure; and functioning as a centre of excellence to promote cooperation between research and industry. The latter function is fulfilled through research and development assistance programmes including access to the gene bank, biopotency evaluation and biomaterials, and by supporting bioindustries through the transfer of biotechnologies.

The training component of Korean biotechnology consists mainly of the universities. Seoul National University is the largest national university, and its divisions of biology, molecular biology, chemistry and medicine are mostly involved in teaching although some basic research is also being carried out. A new institute for Molecular Biology and Genetics at Seoul National University plans to have a total research staff of 200. Its objectives include basic research in the life sciences, development of Genetic Engineering technologies, graduate education in genetic engineering as well as cooperative research with other research institutes. The basic research divisions include three laboratories: molecular genetics, cell biology and biochemistry. Applied research is carried out by the Virus and Molecular Oncology laboratory, the Microbial Engineering laboratory and the Plant Molecular Biology laboratory. Additional infrastructure includes a radioisotope room, a cell culture room, a cell and gene storage room and an animal breeding room.

South Korean industry has a strong tradition in "old" biotechnology. The food industry has now moved ahead from old fermentation technologies into specialty chemicals such as amino acids and enzymes. However, the most lucrative market in the new biotechnology is that of pharmaceuticals and drugs. Many of the large conglomerates that dominate the economy have branched into pharmaceuticals and have consequently made a commitment to biotechnological research. One such company is Lucky Ltd. of the Lucky Goldstar Group which has started a Research and Development Centre whose research activities include biotechnology. Among their success stories, human gamma interferon for the treatment of cancer and rheumatoid arthritis has now been commercialized. Protein engineering research started in the mid-1980s. Actively pursued with X-ray crystallography and molecular modelling methods, they are closely related to rapidly growing recombinant DNA techniques. In order to keep abreast of new developments in the field of molecular biology, Lucky has also started the Lucky Biotech Corporation near San Francisco in the United States which collaborates with US and other foreign genetic engineering companies. Its research activities include gene cloning and the development of vectors and hosts. In an attempt to harness some of the potential of private sector research in biotechnology, the government devotes much of its biotechnology funding to the Korean Genetic Engineering Research Association (KOGERA). Established in 1982, its main purpose is to promote research and development, especially with respect to genetic engineering and industrialization in the field of biotechnology. This it does by increasing cooperation between companies and public sector research, by actively participating in the drive to improve investment and researcher skills as well as increased participation in policy impact studies. KOGERA at the moment has 18 member companies, principally involved in pharmaceuticals, chemicals, food and textiles. Its research and development activities include national research and development projects initiated by MOST, Bioenergy projects initiated by the Ministry of Energy and Resources (MOER) as well as cooperative projects between corporate members of KOGERA. In the national arena, thus far about 40 projects have been completed including the development of phenylalanine, hepatitis B vaccine as well as hepatitis diagnostic kits.

KOGERA's training and information dissemination activities include domestic and foreign training courses, organization of seminars and workshops, surveys of biotechnology as well as a number of publications including journals---"Genetic Engineering" (Quarterly) and "Technology Information" (Bimonthly), weekly newsletters and training manuals.

South Korea's patent law was changed in 1987 to include protection for chemical and pharmaceutical products and micro-organisms and now extends coverage for upto 15 years.[11]

Despite these efforts however, there are some problems facing the biotechnology research community in Korea. The problem common to all the countries surveyed thus far, namely a lack of cooperation between public and private sectors, is not unusual in Korea either. The reason according to researchers at the Lucky laboratory, is that the priorities and goals of public and private sector are very different. The fact that most companies who are branching out into biotechnology are either pharmaceutical companies or are buying up pharmaceutical companies like Lucky Ltd., is no coincidence. This is where the short to medium term profits lie. Government priorities however are only partially geared towards the same profit making goals, thereby creating a conflict. Companies are therefore reluctant to join national research and development projects and when they do join, the projects are mostly those perceived to be beneficial to the company as well, such as those mentioned above.

Lucky researchers also point out that while public sector investment in biotechnology is rising, this does not appear to be the case with private companies, a large number of whom feel that the dividends of investing in biotechnology have been slow to emerge. The recent changing of the patent laws to bring them in line with US legislation on biotechnology has also led to wariness among biotechnology companies, many of whom now have to compete directly with US companies.

### 3.6. Peoples Republic of China [12]

In the late 1970s, the Chinese government began developing a programme which would introduce hi-tech into the country. In 1985, biotechnology policy formulation was begun. Two programmes specifically dealing with biotechnology were launched: the "torch" programme whose goal is the commercialization and industrialization of biotechnology, and the "spark" programme which aims to bring biotechnology to the majority of the Chinese population which remains rural. Today there are three priority areas in biotechnology, agriculture, medicines and pharmaceuticals and protein engineering for industrial use.

In agriculture, there are at the moment about 50 projects, most of them involving genetic engineering. The main areas of research are the following: rice biotechnology where there is close cooperation with the International Rice Research Institute (IRRI) through the Rockefeller foundation which is supporting rice research both at IRRI and in China, disease resistance, nitrogen fixation, animal genetic engineering especially in pigs and fish, and finally fundamental research in agricultural biotechnology.

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[11] US OTA (1991), p 238.

[12] Section on China largely based on discussions with officials of the National Research Centre for Science and Technology Development, and the China National Centre for Biotechnology Development.

In pharmaceuticals, genetic engineering is being used in the production of vaccines such as the hepatitis B vaccine and drugs to fulfil the needs of the large population. Here the Ministry of Public Health has been actively involved. The Shanghai Institute of Biological Products (SIBP) is one such institute. Supported by the Ministry of Public Health it is one of the state owned large enterprises responsible for development, research and production of prophylactics, blood products, antitoxins and clinical diagnostics reagents. A number of drugs and vaccines have been produced and successfully commercialized. With economic liberalization in China, the World Bank has just granted a loan for the production, full-scale commercialization and dissemination of a new measles vaccine. A Dutch company is being employed to establish this production unit.

Since 1985, China's policy formulation has consisted of the following highlights:

1. Adapt new technologies to transform old, "traditional" industries.
2. Establish key technologies which the country lacks or is weak in, including purification and reactor technologies.
3. Strengthening of fundamental research in the sciences
4. Strengthening of the national infrastructure supporting biotechnology research. This includes setting up a gene bank, developing tool enzymes and relevant capital equipment as well as improving animal breeding
5. Cooperation with other countries including the USA, the European Community and the OECD. In addition, China has ongoing projects with developing countries, notably Thailand and India.

Overall funding and coordination of biotechnology research in China is carried out by the China National Centre for Biotechnology Development (CNCBD). All funding for biotechnology is first transferred by the Government to the CNCBD. Following advice from its reviewing panels which include scientists as well as government officials and policy analysts, the CNCBD allocates its funds to deserving and priority projects across the country. At the present moment there are about 100 research institutes across the country which are involved in biotechnology research projects funded by CNCBD. The CNCBD only funds the research part of R&D. However, once a product has been developed and needs to be commercialized, China too is facing the problem of having to persuade industry to finance the scale up and marketing of the product. Industry is generally reluctant to invest in research and development and it is left to the government to develop special incentives to improve this relationship between basic research and industrial development. This is especially so in agriculture where research results are available only after a longer period of research. In the same way as with other countries surveyed thus far, but to a lesser degree, Chinese industry prefers to invest in pharmaceuticals and industrial biotechnology. Direct government investment in research and development in agricultural biotechnology is therefore essential especially for a predominantly rural country such as China.

The National Research Centre for Science and Technology Development (NRCSTD) which acts under the State Science and Technology Commission (SSTC) is involved in policy research on technology in general. Their research on technology assessment, forecasts and evaluations of biotechnology impacts often form the basis for science and technology policy in China.

The most serious problem however which is likely to face China in the coming years is the issue of intellectual property rights. The Director of the CNCBD predicts a change in the Chinese patent system to accommodate biotechnology within a few years. China plans to join the World Intellectual Property Organization (WIPO) as well as the General Agreement on Tariffs and Trade (GATT), both international organizations which are discussing changes in international intellectual property rights regimes. China will most likely have to change its patent laws to some degree, and by joining WIPO, recognize patents granted by a number of other countries. It remains to be seen what impact this will have on the local capability and products that the country has developed in biotechnology. Academics seem to be divided, some arguing that because China's biotechnology programme is geared largely to fulfilling rural needs, processes and products used for this are old and no longer have patents in the west; others argue that in future, China is likely to be competing with the international community and therefore the change, although inevitable, will have considerable future impact on Chinese industry, and agriculture. In the area of pharmaceuticals especially, the west is likely to face the greatest resistance from China on the patent issue.

## 4. Biotechnology and Technological Capability: Some Conclusions

The countries surveyed have very different levels of skills in basic scientific research, different market structures and different priorities in their research. Yet we can identify a number of important similarities in biotechnology research and development between these countries. Firstly biotechnology research in all these countries began largely as pre-competitive research, ie., government initiated policies based on national priorities and needs. This is not to deny the significant role played by the private sector in many of these countries, however in general it appears that major funding for biotechnology initially came from the government and was then followed by private sector R&D at various levels.

Of the countries surveyed, China, India, Thailand and the Philippines have a greater proportion of government involvement in research and development than South Korea and Taiwan. Research priorities are also more closely linked between countries within the two groups. Thus because companies in South Korea and Taiwan find themselves competing in foreign markets primarily in the OECD countries, their research priorities lie in similar fields, notably the pharmaceutical industry where the potential for profits are highest. In contrast, agricultural research where economic rents associated with new innovations are relatively lower, appear to be largely in the sphere of public sector research. In the first group of countries, agricultural research tends to be dominant. However an increasing amount of pharmaceutical and medical research is also being seen.

Thus it is clear that scientifically there is an enormous potential for the development of biotechnology research. Technological capability has been described by Lall (1989) as having three main components, technical, entrepreneurial and managerial skills which would provide the environment for effective development and diffusion of new technologies. Thus it is not just the scientific and technical skills which are important to the development of biotechnology but indeed the economic and scientific infrastructure which ensure not only high quality research, but also that the linkages between research and development, between research and industry are strengthened. A strong background in basic research is indeed a first step but thus far a major obstacle faced by industrializing countries is getting research to produce tangible results.

As this survey has demonstrated to some extent, a number of these countries have both explicitly and implicitly acknowledged the importance of these three components of technological capability in their national policies on biotechnology. The ability of policy changes to bring about changes in practice is another question altogether. Nevertheless, the interesting feature of the development of biotechnology in these countries is the attempt to incorporate some elements of what we can call here the "South Korean" or "Japanese models" of technological development. Thus while much of the research is still initiated and funded by the government, so called pre-competitive research, the importance of industrial involvement both at the research as well as the development stages is being encouraged and also importantly, there is a recognition of the need for an economic environment which is conducive to research and investment in biotechnology.

It is therefore evident that biotechnology hailed as an important new technology has been recognized by all these countries and is at various stages of development. The question remains therefore whether it is possible for the diffusion of this technology given the infrastructure in these countries. We would argue yes given many of the changes in infrastructure that are being made in order to incorporate biotechnology into the national economy. The rates of these changes will determine the success or failure of the diffusion of biotechnology and other new technologies to come. The real challenge for industrializing and developing countries therefore lies in ensuring an infrastructure and an environment which allows close cooperation between public and private research and development as well as investment in new technologies. For this simultaneous effort needs to be made at two levels if biotechnology is to succeed. Firstly, the development of a basic technological infrastructure and an environment conducive to investment in new technologies which is absent in a large number of countries who nevertheless are pursuing the development of this technology. Some steps have been taken in this direction although much still needs to be done. Secondly, the connection between academic research and industry is still very tenuous and needs to be actively encouraged.

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