The Development of Thailand's Technological Capability in Industry

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ABSTRACT

The capability of biotechnology-based industries for technology acquisition, operation, adaptation and innovation was assessed from a survey of 36 companies in 8 industry groups. Most companies had good operative and adaptive capability, but poor innovative capability, while the acquisitive capability depended on the type of company. Companies with research and development (R&D) activities had significantly greater acquisitive, operative and adaptive capabilities than those without R&D, but all companies had very low innovative capability. Joint venture and foreign companies had significantly higher operative capability than local companies. Technologically-aggressive Thai companies tended to have active technology acquisition strategies, while joint venture and foreign companies relied on parent companies for technology acquisition. Large companies tended to have higher overall capability than small companies. Industries using upstream technologies had higher acquisitive and innovative capabilities than those using downstream technologies. The overall capabilities of the various industry groups in descending order were : aquaculture, animal feeds, seed, dairy, ornamental plants, organic acids, alcohol and health and related industries. Market niches for small industries were found in aquaculture, animal feed, seed, ornamental plant and some health (e.g., diagnostics) industries. Many new technologies could be rapidly absorbed by these industries. Strategies for upgrading their technological capabilities include improvement of financing (availability and accessibility), improvement of incentives for technological development, promotion of R & D in industrially relevant topics in public institutions (which have most of the R & D resources), promotion of linkage between public institutions and industries, facilitation of access to new technologies, creation of technology and creation of a capable manpower supply.

DEVELOPMENT OF THAILAND'S TECHNOLOGICAL CAPABILITY IN BIOTECHNOLOGY - BASED INDUSTRIES

EXECUTIVE SUMMARY

1. Introduction

The purpose of this study was to examine the current indigenous technological capability of Thai firms in the biotechnology-based industries, to trace the development of this capability, to determine whether there were any weaknesses and if so to recommond how these weaknesses might be addressed in such a way as to improve the future development of this industrial sector in Thailand.

There is a sharp distinction between biotechnology-based industries in developed countries and those in developing countries, including Thailand. The former are derived mainly from technological advances which made possible the manufacture of new high value-added products such as drugs from genetic engineering. Many small biotechnology companies set up for commercialization of such new advances were later integrated with large established companies in pharmaceutical, agro-chemical industries, etc., and market niches are being founded for new products through these established firms. By contrast, the so-called biotechnology-based industries in the developing countries have no local technology push and are still little aware of the advantages offered by new biotechnology. Very few companies are producing new biotechnology products on a commercial scale. Nevertheless, many developing countries, including Thailand, are strengthening their capabilities in new biotechnology by government support for research and development R&D and buildup of trained personnel. **However, unlike Singapore and South Korea, Thailand still lacks measures which will encourage the biotechnology-based or other industries to spend more effort on** technological development and on build up of technological capability. National policies are needed to help industries achieve this desirable goal. The policies should, furthermore, adequately promote technology in small industries which constitute a very important part of the biotechnology-based industries, and which might otherwise be bypassed by new technological advances.

The policies and strategies for strengthening critical capabilities required to development the biotechnology-based industries in Thailand, evolved from a survey of the present capabilities of selected producing firms and infrastructure agents. The major weaknesses and strengths of these agents were assessed and the survey analysis provided the basis for policy recommendations.

2. The Environment

Industrial and macroeconomic policies comprise implicit policies which can indirectly affect technology and skill enhancement in the industrial sector. In addition to this are the explicit policies for technological development. In Thailand,the main features of present implicit policies are investment promotion, industrial protection, industrial export promotion, and promotion of small and medium industries. A critical assessment of these policies shows that they are still generally inadequate, ambiguous and ineffective with respect to enhancement of technological capability. The explicit technological development policies also need to be substantially improved, even though Thailand has paid considerably more attention to science and technology during the past decade. Examples are the explicit measures provided in the Fifth and Sixth National Plans. The present main components of science and technology policies include manpower development, R&D strengthening, promotion of technology transfer, technology development by the private sector and technologyuse by the private sector. The main problem with these policies is the lack of effective mechanisms for implementation.

Like other industries, the biotechnology-based industries are affected by industrial, macroeconomic and technology policies.

In contrast to other areas of science and technology in Thailand, the supportive infrastructure for biotechnology, althoug presently limited, is relatively strong and has a gathering momentum. The current total manpower output of bachelor degree programs related to biotechnology is about 2000 per year, with about 40 specifically in biotechnology. The output of master degree graduates is about 450 in biotechnolology-related areas, including about 10 specifically in biotechnology. The capacity for doctoral degree education is presently very limited with programs only in the biosciences. The present combined R&D manpower strength in 20 major Thaiinstitutions is slightly less than 500. The present research strengths are in biomedical and agricultural sciences, while such areas as bioprocess engineering are still relatively weak.

Technical services available from public sector agents include information services, analytical/quality control services, and problem solving/development services. Two major agencies forsupport of biotechnology are the National Center for Genetic Engineering and Biotechnology and the Science and Technology Development Board. The former also provides additional support through provision of information and training, formation of links between universities and industries, and formation of international links.

3. Profile of the Present Technological Capability of the Thai Biotechnology-Based Industries

A total of 8 industries comprising 40 firms were chosen for a survey. The eight industries were the alcohol, aquaculture, dairy, feed,flowers (ornamental plants), health-related, organic acid, and seed industries. They could be roughly divided into two groups : those using upstream technology (aquaculture, dairy, flowers and seeds) and those using downstream technology (alcohol, feeds, health-related and organic acids). The industries and firms were chosen to provide broad representatives for the whole biotechnology industrial sector, based on the assumption that common problems revealed from the studies would be sector-wide problems. **The survey led to assessment of four major types of technological capability : acquisitive, operative, adaptive and innovative capabilities.** The criteria for assessing these various capabilities were defined. In general, the firms were found to have moderate ratings in acquisitive, operative and adaptive capabilities, but low to very low innovative capability. **The various industries were ranked in the following descending order of overall technological capability : aquaculture, feed, seed, dairy, flowers, organic acid, alcohol and health-related industries. In general, firms in the upstream technology industries tended to have higher capabilities than those in the downstream technology industries.** This trend for ligher capability in the upstream group was especially marked for acquisitive and innovative capabilities. An explanation for this trend is that upstream technologies are relatively unsophisticated when compared to downstream technologies, so that Thai firms employing upstream technologies developed world frontier or near world frontier capability levels relatively easily.

The capability ratings were further compared among firms grouped according to various other firm characteristics including : size (large vs. small), type of investment (Thai vs. joint venture/foreign), market orientation (export, import-substitute, or both), promotional status (with or without Board of Investment promotional privileges), existence of training programs, and existence of R&D activities. **The most striking result was that firms with R&D activities had significantly higher acquisitive, operative and adaptive capabilitiesthan those without R&D activities.** This result implied that the R&D personnel in firms with R&D activities were generally more aware of technological advances, had better access to new technology and consequently gave their firms higher capabilities in acquisition, operation and adaptation. **These higher capabilities were achieved in spite of the fact that the R&D activities did not lead to major innovations (i.e., the innovative capability ratings were low).**

The alcohol and health-related industries had low capability ratings, especially in innovative capability. This was somewhat surprising when one considers that Thai universities have good expertise in these areas and that these industries are amongst the leaders in biotechnological advances in industrialized countries. With the alcohol industries in Thailand, we consider the primary cause for the lag to be overprotection. With the health-related industries the situation is more complex. A part of the reason for the poor rating is probably that these industries are mostly concerned with relatively simple formulation work. With the joint venture and foreign firms, the R&D activities and facilities are mostly foreign-based, so that their indigenous capability is low.

4. Behavior and Attitude of the Firms Toward Technology

Further inquiries into the behavior and attitude of the surveyed firms toward technology led to further insights concerning the real and perceived benefits of technology in their performance. **Slightly more than half of the firms stated that they obtained their technology wholly or mostly from local sources.** These were mostly firms in such upstream industries as the aquaculture and ornamental plant industries. The majority of firms engaged in downstream industries such as the organic acid, alcohol or pharmaceutical industries obtained their technology from foreign sources. This pattern fit well with the conclusion that the firms in upstream industries tended to have higher capability ratings because they employed less sophisticated technology. However, it **raises an**

important question as to how they can gain benefit from new advances in biotechnology generated abroad.

Analysis of the factors affecting technology choices by these firms revealed that Thai biotechnology-based industries are not technology driven. On the whole, technological advantages were given less importance than product market potential and raw material availability. Interestingly, small and medium-sized firms tended to give more importance to technological advantage as a factor affecting technology choice than large firms. Specifically, firms in the flower and ornamental plant industries gave equal importance to technological advantage, to product market potential and to raw material availability. Firms with export market orientation, and firms with promotional privileges also gave relatively more importance to technological advantage.

Evolution in operative capability. The majority described some of firms which had been in operation for more than five years. This involved changes in raw materials, processes and products, and was often accompanied by enhanced adaptive capability. Changes included significant modifications in addition to small continuous changes. **However, major innovative changes were rarely seen even in the firms which have significant R&D activities.** This finding reflected the fact that the major role of R&D as perceived by the small and medium Thai firms was for adaptation of raw materials, and as perceived by large Thai, joint venture and foreign firms was for production efficiency improvement. **The main reasons cited for lack of innovative capability in the firms were inadequate skilled manpower, insufficient equipment and low R&D capability in general. These canbe traced further to insufficient funds and lack of technology policies at the firm level.**

Our study on the practice of the firms in human capital formation led to the conclusion that there was a high mobility in large firms with multi-product business operations, but low mobility in small and medium-sized firms with a single product or only a few products. A limited career path for technologists accounted partly for the observed high mobility. Another factor was the scarcity of technologists in fields with large demand. The degree of technologists' mobility in turn affected technology acquisition and operation. Technological capability in general also depended on managerial capability, entrepreneurial attitude and business strategy. For example, large Thai firms strategically attached more importance to development of technological capability than small and medium-sized firms.

5. Bridging the Present Capability Gaps and Building Future Capability

The existence of capability gaps can be viewed from many perspectives. The fact that technological capabilities in all categories, especially the innovative capability, are lower than those of the world frontier indicates that present gaps exist which should be bridged. A more difficult task lies in the attempt to assess the needed capabilities for the future, taking into account the advances in biotechnology in industrialized countries.

The gaps in acquisitive capability may be largely attributed to substantial deficiencies in infrastructural agents, to the existence of barriers to technology transfer and to deficiencies in technical manpower for industry. With respect to infrastructural agents, our survey has revealed a serious deficiency and even a trend to deterioration in information services that is in need of urgent rectification. The problem is particularly serious for small and medium-sized industries which depend on government support in this area. Linkage between public institutions including state universities and the industries still needs to be substantially improved, although many universities are now offering technical and

R&D services to the industries. Another glaring deficiency is the lack of consulting firms giving assistance to industries for acquisition of new technology. Finally, there is a need for the presence of foreign technologists who can bring in new technology which is increasing rapidly in the biotechnology area. This requires balanced measures which will encourage the influx of needed foreign experts with new technology, while making sure that the technology will be transferred to Thais.

In addition to briding the present capability gaps, we need to be concerned also with building up capability in future industries and future technologies. While these cannot be clearly predicted, it can be anticipated that they will be influenced by current advances in more industrialized countires, by foreseen resource and environmental problems and by factors which will give Thailand a competitive edge in the export market. **Examples of potential future products are biopesticides, biofertilizers, new starch-derived products, food flavours and colours, diagnostics, antibiotics, vaccines and biosensors. Examples of future technologies, which presently exist only in university R&D laboratories but which will increase in industrial importance, include genetic engineering, nueleic acid probe, monoclonal antibody, enzyme immobilization, protein engineering and biospecific downstream processing technologies.**

6. Major Strategies for Gaining Needed Future Capabilities for the Industries

Strategies are needed both for the industries and for the technologies. **The most important strategies concern promotion of technological efforts by the firms**, which include those aimed at achieving innovative capability and the capability to absorb new technologies generated abroad. **Closely related and also of highest importance are strategies for targeted manpower training and for**

creation of financial and tax incentives for the firms to undergo the needed technological efforts. Strategies of moderate importance, aimed at strengthening technology, include selective strengthening of key institutions (universities, research institutes, funding agencies, information agencies), strengthening of laws and regulations for promotion of science and technology in general and for biotechnology-specific issues in particular. These include the patenting system, regulations on biosafety and regulations on utilization and conservation of genetic resources. Industrial strategies of moderate importance include promotion of export of biotechnology-based products, promotion of local manfacture of products for domestic markets, promotion of subcontracting production and of procurement measures.

7. Conclusion and Policy Recommendations

The biotechnology-based industries in Thailand owe their present strength more to raw material availability than to technological advantage. Their technological capability is still low by international standards, but has potential for future strengthening. This is necessary in view of increasing participation of Thailand in highly competitive international markets. The lack of innovative capability is a weakness that must be rectified if Thailand is to be a successful competitor in international biotechnology-based industries in the future. The small and medium-sized industries need special attention in view of their importance in the economy and their dependence on government support measures. The Thai biotechnology-based industries have otherwise no overall serious defects which will seriously hamper their future development if these identified problems are successfully tackled.

Based on the conclusion of our study and those of other studies, major policy recommendations are given for variours government and private sector agents in order to achieve the goal of strengthening technological capability in Thai biotechnology-based industries.

1. INTRODUCTION

1.1 Scope, Structure and State of Development of Biotechnology-Based Industries

1.1.1 The Global Scene and Trends: Biotechnology in Industrial Countries

Biotechnology-based industries manufacture a very wide range of products using a very wide range of processes. As defined by the US Office of Technology Assessment (1984), biotechnology includes any technique that uses living organisms (or parts of organisms) to make or modify products, to improve plants or animals, or to develop microorganisms for specific uses. In this broad sense, biotechnology has existed since the dawn of civilization and forms the basis of much of our present agriculture, our agro-industries, our health-based industries and other industries. Fermented foods and alcoholic beverages are examples of products of traditional biotechnology. The present prominence of biotechnology on the global scene, however, is largely due to recent major advances in biosciences and bioengineering, which have opened the way to new products and processes with a high commercial impact. The new biotechnology involves our ability to manipulate living organisms at the cellular and molecular levels. For example, genetic engineering techniques make possible the production of high value-added pharmaceuticals in much greater quantities than was previously possible. These new biotechnology products are only beginning to enter the world market, but a strong impact is forecast for the future. Table 1.1 shows a forecast (Smithson, 1988) for selected pharmaceuticals, chemicals and agricultural products in the next decade. The total world market

Table 1.1

ESTIMATED OF IMPACT OF NEW BIOTECHNOLOGY ON SELECTED MARKETS

	World Market[a] $ X 10^6		New Biotechnology's Impact[b], %
	1995	2000	
PHARMACEUTICALS			
Anticancer	9,500	15,500	30-40
Anti-infective	22,000	30,750	30
Cardiovascular	45,000	70,600	40
Central nervous system	16,900	23,100	40
CHEMICALS			
Amino acids	750	900	50+
Industrial enzymes	550	700	30
AGRICULTURAL PRODUCTS			
Insecticides/herbicides	21,200	31,000	50
Plants and seeds	19,000	26,750	75
Fertilizers	34,000	45,000	20

[a] Manufactured value in current dollars.

[b] Percentage of new products introduced between 1986 and 2000 that will involve new biotechnology.

Source: SRI International (Smithson, 1988) for biotechnology products in the year 2000 will be approximately US $ 250 billion, and large fractions (20 - 75 %) of these products will come from new biotechnology.

The world biotechnology industry is evolving rapidly from the stage of technology segmentation, that is, segmentation according to types of technology, toward a segmentation on the basis of more traditional markets (Riley and Taylor, 1986). At least three waves of commercialization may be expected over the rest of this century. At present, the leading edge of biotechnology is mostly in the pharmaceutical and health-related industries, since the new technologies were initially derived mainly from biomedical sciences. The first wave which has occupied most of this decade, includes markets in diagnostics, pharmaceuticals and laboratory research. The next wave is projected to arrive in the early nineties as processes using new biotechnology become more fully developed. This will include markets in agriculture, environmental control and specialty chemicals. The wave arriving in the late nineties will see biotechnology integrated into products in commodity markets such as minerals, chemicals and paper pulp. The turn of the century should also see integration of biotechnology and electronics, resulting in the development of biochips, and of biotechnology and material science, resulting in a variety of new biocompatible materials.

The international competition in biotechnology markets is highly complex. In general, biotechnology-based products take longer to reach the market than other technology-based products owing to two main factors, long research and development time and complex regulatory procedures in testing and marketing of products due to safety and environmental concerns. The unique funding needs in biotechnology industries have been met by various strategies including venture capital and private offerings prior to public offering. Strategic alliances are often made between small biotechnology companies and large industrial companies, which thereby gain access to the new technical expertise in return for their investment. The revenue strategies for biotechnology companies include not only product sales, but also technology licensing, contract research, and sale of research products still awaiting further development, that is, sale of results from intermediate steps in the technology development process. Consequently, the commercialization of pharmaceuticals derived from new biotechnology has sometimes benefited large pharmaceutical companies which market the final products more than the biotechnology companies which developed them to some intermediate stages (Taunton-Rigby, 1988).

Analysis of international competitiveness in biotechnology (US Office of Technology Assessment, 1984) has shown the importance of various factors, all of which can be influenced by policy decisions. The factors are listed in Table 1.2 in order of importance. Of these, the most important are financing and tax incentives for firms, government funding of basic and applied research and personnel availability and training.

The relative strengths in biotechnology in major industrial countries can be assessed from various information sources. Data compiled by Nomura Research Institute (Klausner, 1987) showed higher competitive strength of biotechnology in the USA than in Japan in terms of number of pure biotechnology companies (200 in USA vs. 2-3 in Japan), number of publicly traded firms involved with biotechnology (21,519 vs 1,992), biotechnology employment and new research results. The USA is far more developed than Europe and Japan in funding investments through venture capital and public equity markets. On the other hand, European and Japanese governments are relatively more supportive of biotechnology than the US government. While the US government support is mostly in the form of research and development grants and tax credits, the Japanese and European governments also provide additional support in areas like technology transfer, risk capital and industrial grants and loans.

Taking pharmaceutical and other chemical industries as manufacturing industries closely linked with biotechnology, data from

Table 1.2

FACTORS POTENTIALLY IMPORTANT TO INTERNATIONAL COMPETITIVENESS IN BIOTECHNOLOGY

Most important factors:

- Financing and tax incentives for firms
- Government funding of basic and applied research
- Personnel availability and training

Factors of moderate importance:

- Health, safety and environmental regulation
- Intellectual property law
- University-industry relationships

Least important factors:

- Antitrust law
- International technology transfer, investment and trade
- Government targeting policies in biotechnology
- Public perception

Source: US Office of Technology Assessment (1984) a survey by the Japanese Economic Planning Agency (Itoh, 1986) indicated that about half of the Japanese respondents rated the technology level and technological development capability of Japanese enterprises lower than their US counterparts in 1980. However, the Japanese position has steadily improved and will shortly be on par with its US competitor. A similar conclusion can also be made regarding competition between Japanese and European enterprises, with the latter starting from a weaker position than the USA. Other studies from US and Japanese sources (US Office of Technology Assessment, 1984; Lewis, 1984; Oxender et al. 1985; Itoh, 1986) have given profiles of competitive position in various technology areas. In brief, the USA has an overall competitive edge in commercialization of new biotechnology, while Japan is its most serious competitor. The USA has a clear lead in genetic engineering (recombinant DNA) technology, while Japan holds a lead in fermentation and traditional bioprocess engineering. European countries, while generally lagging behind the USA and Japan in commercialization of new, biotechnology, are nevertheless strong competitors in specific products, including some pharmaceuticals, specialty chemicals and animal agriculture products. The competitive positions of major industrial countries in selected areas of biotechnology are summarized in Table 1.3

A list of firms specializing in new biotechnology products and processes, and major industrial companies which are utilizing biotechnology significantly are given in Table 1.4

1.1.2 Biotechnology in Developing and Newly Industrialized Countries

The rising prominence of biotechnology in major industrial pcountries in the last decade was also accompanied by increasing awareness of its importance in developing and newly industrialized countries, which hoped to solve various problems in development through

Table 1.3

COMPETITIVE POSITIONS OF MAJOR INDUSTRIAL COUNTRIES IN COMMERCIAL BIOTECHNOLOGY .

Technology	Assessment
Recombinant DNA (genetic engineering)	The USA leads Japan and Europe, which are on par with one another. However, Japan has a high potential in microbe utilization and downstream techniques.
Fermentation and bioprocess engineering	Japan is ahead of the USA, but on par with Europe in fermentation. Japan is the world leader in bioprocess engineering.
Animal cell culture and hybridoma technology	The USA is the leader, while Japan is on par with Europe. Japan is likely to be a significant competitor in large scale culture.
Plant biotechnology	The USA and Europe are ahead of Japan, although Japan has great potential in large scale plant cell culture and bioprocessing.
Biosensors and bioelectronics	Japan has a high potential in techniques compatible with current semiconductor fabrication, but it is weak in immunotechniques.
Protein engineering	The USA and Europe are ahead of Japan, which has only a small pool of personnel.

SOURCES: US Office of Technology Assessment (1984), Oxender et al. Evaluation Program (1985), Itoh (1986).

Table 1.4

SOME COMPANIES IN MAJOR INDUSTRIAL COUNTRIES COMMERCIALIZING BIOTECHNOLOGY

Country	Company	Fields of focus[a]
A. Established Companies.[b]		
USA	American Cyanamid	Ph
USA	Corning Glass Works	SCF
USA	Dow Chemical	Ph, PA, CCE, SCF, AA, Env
USA	Eastman Kodak	Ph, Env
USA	Eli Lilly	Ph, PA
USA	Exxon	CCE, Env, CCF
USA	General Electric	El, Env, Ph, SCF
USA	Monsanto	PA, AA
USA	Pfizer	Ph, PA, CCE, AA, SCF, Env
USA	SmithKlineBeckman	Ph, AA
UK	Glaxo	Ph, AA, SCF
UK	Imperial Chemical Industries	CCE, SCF, Ph, PA
UK	Unilever	SCF, AA, PA
W. Germany	BASF	SCF, Ph
W. Germany	Hoechst	Ph, SCF
W. Germany	Schering	Ph, SCF
France	Elf Aquitaine	Ph, SCF, PA, AA, Env
France	Rhone-Poulenc	Ph, SCF, PA, AA
Netherlands	Gist Brocades	SCF, Ph, CCE
Switzerland	Ciba-Geigy	Ph, PA, SCF
Sweden	Pharmacia	Rs
Japan	Ajinomoto	SCF, Ph
Japan	Kikkoman	SCF, PA
Japan	Mitsui Group	CCE, SCF, Ph
Japan	Sumitomo Chemical	Ph, SCF, PA, Env
Japan	Suntory	SCF, Ph

Country	Company	Fields of focus[a]
B. New Biotechnology Firms[c]		
USA	Amgen	Ph, PA, AA, SCF
USA	Centocor	Ph
USA	Cetus	Ph, AA, CCE
USA	Genentech	Ph, AA, CCE
USA	Genetics Institute	Ph, PA, SCF, Env
UK	Agricultural Genetics	PA, AA
UK	Celltech	Ph
France	Transgene	Ph, AA,
Switzerland/USA	Biogen	Ph, AA, CCE, Env

[a] Ph : Pharmaceuticals. PA : Plant Agriculture. AA : Animal Agriculture. SCF : Specialty Chemicals and Food. CCE : Commodity Chemicals and Energy. Env : Environmental. Rs : Research Supplies. El : Electronics.

[b] Multi-product companies in traditional industrial sectors, many of which are transnational corporations.

[c] New biotechnology firms (NBF) are entrepreneurial ventures started mostly since 1976 to commercialize biotechnology

SOURCES: US Office of Technology Assessment (1984), Hammer (1986/1987), Daly (1985), Arthur D. Little (1988).

this technology. The latter have focused particular attention on utilization of this technology to improve their budding industries. For them, the range of biotechnologies encompasses both "appropriate technology" to improve the livelihood of the general populace, (e.g., biofertilizer production and shrimp farming) and "high technology" to improve major industrial sectors. Some prospects for utilization of biotechnology in developing and newly industrialized countries are listed in Table 1.5

Since developing countries, and even most newly industrialized countries, still have a relatively weak biotechnology infrastructure, there is still little or no commercialization of new biotechnology comparable with that in the major industrial countries. By contrast, biotechnology in these countries, as applied to industry is still mostly conventional or traditional. Very few companies in only a few countries are producing new biotechnology products on a commercial scale. Examples are listed in Table 1.6. These are typically joint ventures with partners in industrialized countries. Nevertheless, biotechnology is being applied increasingly and with a growing degree of sophistication in many of these countries. Plant tissue culture is an example of an industrial technology used intensively and with high commercial success in many of these countries.

Although major advances in new biotechnology still await significant utilization in developing and newly industrialized countries, their attractive potential has persuaded many of these countries to strengthen their capability in this area. The measures in most countries are in the form of government support for research and development and for buildup of trained personnel, although such countries as Singapore and South Korea also have financing schemes and tax incentives for industry. Some countries have set up national centres to support or carry out research and development, to facilitate technology transfer, and to provide information to industry. Table 1.7 gives a list of national centres in biotechnology

Table 1.5

SOME PROSPECTS FOR UTILIZATION OF BIOTECHNOLOGY IN DEVELOPING AND NEWLY INDUSTRIALIZED COUNTRIES

Agriculture

Plant biotechnology

Improvement and propagation of tropical fruit trees, forest plants, palms, legumes, tubers, rice, ornamental plants.

Microbial fertilizers

Improvement and production of rhizobia, mycorrhiza, compost inocula.

Animal biotechnology/Embryo technology

Animal stock improvement. Embryo manipulation and transfer in livestock

Aquatic biotechnology

Aquaculture of shrimps, fishes, seaweed. Production of marine products.

Industry

Fermentation technology

Production of feed components (eg. citric acid, amino acids), single-cell protein, industrial chemicals.

Enzyme technology

Production and utilisation of starch degrading enzymes, peroxidases, proteases. Enzyme and cell immobilization for production of antibiotics, sweeteners, etc.

Energy and environment

Energy

Production of alcohol, biogas and other biofuels.

Environment

Utilisation of agroindustrial waste, utilisation of agricultural excess products.

Health

Vaccines and diagnostics

Development of diagnostics from monoclonal antibodies and nucleic acid probes. Development of vaccines from recombinant DNA.

Drugs and pesticides

Development of drugs from plants and marine sources. Development of improved microbial larvicides.

Table 1.6

SOME COMPANIES IN DEVELOPING AND NEWLY INDUSTRIALIZED COUNTRIES USING NEW BIOTECHNOLOGY

Country	Company	Fields of focus
Malaysia	Sime Darby	Plant agriculture
Singapore	Singapore Biotechnology (Joint venture with Merck,USA)	Pharmaceuticals
Singapore	Plantek (Joint venture between NPI, USA; Kyowa Hakko Kogyo, Japan)	Plant agriculture
South Korea	First Sugar Manufacturing (Joint venture with Engentech, USA)	Pharmaceuticals
South Korea	Lucky Cooperation (Joint venture with Chiron, USA)	Pharmaceuticals
Taiwan	Hailsun Chemical	Specialty chemicals and food
Taiwan	San Fu Chemical	Specialty chemicals and food
Thailand	Bangkok Flowers Center Co., Ltd.	Plant agriculture

in some developing and newly industrialized countries.

A few efforts on the international scale have been made to use biotechnology as a major tool for advancement of developing countries. The UN Industrial Development Organization (UNIDO) has set up the International Centre for Genetic Engineering and Biotechnology (ICGEB) in Trieste, Italy and Delhi, India. Progress has, however, been slow and a significant impact has yet to be felt. More successful and longer running is the work of the Consultative Group on International Agricultural Research (CGIAR), which supports a number of organizations devoted to agricultural research, including agricultural biotechnology. These include the International Rice Research Institute (IRRI) in the Philippines, the International Maize and Wheat Improvement Center (CIMMYT) in Mexico and the International Laboratory for Research on Animal Diseases (ILRAD) in Kenya. Another successful example of international co-operation for a specific mission to which biotechnology is making a significant contribution is the UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases. This has focused efforts on development of drugs, vaccines, diagnostics and preventive measures for major tropical diseases of the world. These co-operative efforts are bringing the benefits of biotechnology to developing countries.

In addition to providing new opportunities, biotechnology is also posing new threats to developing and newly industrialized countries. New products, or old products produced in higher quantities and with better quality through biotechnology, are affecting the markets and competitiveness of these countries. For example, biotechnology-based sweeteners are adversely affecting sugar exports from these countries, and even posing a threat to indigenous sugar markets through their import or local production. Another example is the effect of increased palm oil production through use of superior plant strains. Yet another example is the production of tropical plants and plant products (flavours, drugs, etc.) in temperate countries through tissue and cell culture. The main

Table 1.7

NATIONAL CENTRES OF BIOTECHNOLOGY IN SOME DEVELOPING AND NEWLY INDUSTRIALIZED COUNTRIES

Country	Centre Name	Description
Philippines	National Institute of Biotechnology and Applied Microbiology (in University of the Philippines, Los Banos)	R&D in basic and applied research in alcohol and other fermentations
Singapore	Institute of Molecular and Cellular Biology	R&D in microbial physiology, immunology and plant cell biology, post-graduate training.
South Korea	Genetic Research Center (in Korea Advanced Institute of Science and Technology)	R&D in collaboration with university affiliated research institutes.
Taiwan	Development Center for Biotechnology	Private organization linking public research with industries, will act as business developer
Thailand	National Centre for Genetic Engineering and Biotechnology	Supports and co-ordinates R&D, supports manpower training, facilitates technology transfer and supplies information to industries.

implication for developing and newly industrialized countries is that it will become increasingly necessary for them to harness new biotechnology in order to maintain their competitiveness in traditional markets, and to find new markets to replace ones lost.

1.1.3 Technologies in the Biotechnology-Based Industries

Technologies in the biotechnology-based industries can be divided into several groups according to different criteria. For example, they can be grouped collectively based on scientific areas from which the technologies arose (e.g., recombinant DNA technology and hybridoma technology). They could also be classified according to the processes involved, (e.g., fermentation and embryo transfer technology). They could be grouped together according to products, (e.g., vaccine technology and enzyme technology). Because of different classification criteria, overlap between the various technologies is to be expected. Additional overlap is expected because many technologies stem from the same sources or use similar techniques. For the purpose of our study, we divided biotechnology-based industries according to various products, assigned technologies required for their production, and assigned different roles to these technologies. The key biotechnologies, designated as core technologies, were essential biological technologies for the manufacture of a particular product. Technologies of a secondary, supportive nature were designated as auxiliary technologies. Non-biological technologies of a production or support nature were designated as peripheral technologies. Using this approach, a matrix was constructed linking the products with technologies as shown in Table 1.8. The products were chosen on the basis of current economic significance to Thailand. This Table provides a basis for the conceptual framework of the study which will be dealt with in Section 1.4.

Table 1.8

TECHNOLOGIES REQUIRED FOR BIOTECHNOLOGY-BASED PRODUCTS

	GEN ENG	HYB FUS	FERM REAC	ENZ	TISS CUL/ FUS	MCRO	CHEM ANAL	CONT MEAS	POL CONT	CHEM ENG	MECH ELEC ENG	THAI INDUSTRIAL CODE
1. AGRICULTURE												
Seeds	A	-	A	-	C	-	A	A	-	P	P	1111
Seedlings	A	-	A	-	C	-	A	A	-	P	P	1111
Biofertiliser												
Rhizobia	A	-	C	-	C	C	A	A	P	P	P	35120
Composts	A	-	C	-	C	C	A	A	P	P	P	35120
Orn. plants/flowers	A	-	A	-	A	A	A	A	P	P	P	-
Aquaculture												
Shrimp	A	A	-	-	-	A	A	A	P	-	P	13020
Fish	A	A	-	-	-	A	A	A	P	-	P	13020
Artemia	A	A	-	-	-	A	A	A	P	-	P	13020
Algae	A	A	-	-	-	A	A	A	P	-	P	13020
Livestock /embryos	A	A	-	-	A	-	A	A	-	-	-	111
Biopesticides	A	-	C	-	A	C	A	A	P	P	P	35120
Mycorrhizae	-	-	C	-	A	C	A	A	P	P	P	1111
2. AGRO-INDUSTRY												
Dairy												
Milk	A	-	C	A	A	A	-	P	P	P	C	31121-2
Butter	-	-	-		-	A	-	P	P	P	A	31121
Grains												
Rice	-	-	-	-	-	A	A	-	P	-	P	31161
Corn	-	-	-	-	-	A	A	-	P	-	P	31162
Other	-	-	-	-	-	A	A	-	P	-	P	31169
Flour/starch												
Rice	-	-	-	-	-	A	A	-	P	-	P	31211
Corn	-	-	-	-	-	A	A	-	P	-	P	31163
Wheat	-	-	-	-	-	A	A	-	P	-	P	31163
Cassava	-	-	-	-	-	A	A	-	P	-	P	31164
Sugar												
Raw	A	-	C	C	A	A	A	-	P	P	P	31181-2
Refined	A	-	C	C	A	A	A	-	P	P	P	31181-2
An. feed/SCP												
Poultry	A	-	C	C	A	C	A	-	P	P	P	31220
Swine	A	-	C	C	A	C	A	-	P	P	P	31220
Ruminant	A	-	C	C	A	C	A	-	P	P	P	31220

	GEN ENG	HYB FUS	FERM REAC	ENZ	TISS CUL/ FUS	MICRO	CHEM ANAL	CONT MEAS	POL CONT	CHEM ENG	MECH ELEC ENG	THAI INDUSTRIAL CODE
Yarn												
Cotton	A	-	-	C	-	A	A	-	P	-	P	32112-3
Hemp	A	-	-	C	-	A	A	-	P	-	P	32119
Jute	A	-	-	C	-	A	A	-	P	-	P	32116
Silk	A	-	-	C	-	A	A	-	P	-	P	32111
Leather tanning	-	-	-	C	-	A	A	-	P	-	P	32310
Pulp and paper	-	-	-	-	-	A	A	-	P	P	P	34111
Biopolymers	A	-	-	C	A	A	A	-	P	P	P	00000
Rubber products												
Latex	A	-	-	C	A	A	A	-	P	P	P	35599
Rubber sheet	A	-	-	C	A	A	A	-	P	P	P	35591
Tobbaco products												
Leaves	A	-	-	-	A	A	A	-	P	-	P	31411-2
Cigarettes	A	-	-	-	A	A	A	-	P	-	P	31420
3. FOOD, BEVERAGES AND SPECIALTY CHEMICALS												
Bioprotectants												
Fruit/veg.	A	-	C	-	A	A	A	A	P	P	P	00000
Fish/seafood	A	-	C	-	A	A	A	A	P	P	P	00000
Meat	A	-	C	-	A	A	A	A	P	P	P	00000
Monosodium glutamate	A	-	C	C	A	C	A	A	P	P	P	31213
Lysine/methionine	A	-	C	C	A	C	A	A	P	P	P	31219
Citric acid	A	-	C	C	A	C	A	A	P	P	P	31219
Bean curd	A	-	-	-	-	A	A	-	P	-	P	31132
Fermented foods												
Cheese	A	-	C	C	A	C	A	A	P	P	P	31121
Cocoa	A	-	C	C	A	C	A	A	P	P	P	31190
Soy sauce	A	-	C	C	A	C	A	A	P	P	P	31132
Fish sauce	A	-	C	-	A	C	A	A	P	P	P	31142
Vinegar	A	-	C	A	A	C	A	A	P	P	P	31219
Yoghurt	A	-	C	A	A	C	A	A	P	P	P	31121-2
Yakult	A	-	C	A	A	C	A	A	P	P	P	31121-2
Enzymes	A	-	C	C	A	C	A	A	P	P	P	00000

	GEN ENG	HYB FUS	FERM REAC	ENZ	TISS CUL/ FUS	MICRO	CHEM ANAL	CONT MEAS	POL CONT	CHEM ENG	MECH ELEC ENG	THAI INDUSTRIAL CODE
Fructose syrup	A	-	C	C	A	A	A	A	P	P	P	31219
Alcoholic beverages												
Breweries	A	-	C	C	A	C	A	A	P	P	P	31330
Wineries	A	-	C	-	A	C	A	A	P	P	P	31320
Distilleries	A	-	C	C	A	C	A	A	P	P	P	31310
Glucose syrup and sorbitol	A	-	C	C	A	A	A	A	P	P	P	31219
Nucleic acid and other flavors	A	-	C	C	A	C	A	A	P	P	P	31219
Food coloring agents	A	-	C	A	A	C	A	A	P	P	P	31219
Preserved foods												
Fish and seafood	-	-	-	A	-	A	A	-	P	-	P	31141
Fruit and veg.	-	-	-	A	-	A	A	-	P	-	P	31131
Fruit juice	-	-	-	A	-	A	A	-	P	-	P	31131
Meat	-	-	-	A	-	A	A	-	P	-	P	31112
Frozen foods												
Ice cream	-	-	C	A	-	A	A	-	P	-	P	31123
Seafood	-	-	-	A	-	A	A	-	P	-	P	31149
Fruit and veg.	-	-	-	A	-	A	A	-	P	-	P	31139
Commodity chemicals												
Glycerol	A	-	C	-	A	C	A	A	P	P	P	35111/231
Ethyl alcohol	A	-	C	C	A	C	A	A	P	P	P	35111
Acetic acid	A	-	C	-	A	C	A	A	P	P	P	35111
Butanol	A	-	C	-	A	C	A	A	P	P	P	35111
Oils (an. and veg.)												
Coconut	A	-	C	A	A	A	A	-	P	P	P	31151
Palm	A	-	C	A	A	A	A	-	P	P	P	31151
Peanut	A	-	C	A	A	A	A	-	P	P	P	31151
Pork	A	-	C	A	-	A	A	-	P	P	P	31151
Rice	A	-	C	A	A	A	A	-	P	P	P	31151
Other	A	-	C	A	A	A	A	-	P	P	P	31151
Detergents	A	-	-	C	A	-	A	-	P	P	P	35231
Paints varnishes, etc.	-	-	-	-	-	A	A	-	P	P	P	35210

	GEN ENG	HYB FUS	FERM REAC	ENZ	TISS CUL/ FUS	MCRO	CHEM ANAL	CONT MEAS	POL CONT	CHEM ENG	MECH ELEC ENG	THAI INDUSTRIAL CODE
4. HEALTH AND HEALTH RELATED INDUSTRIES												
Antibiotics	A	-	C	A	A	C	A	A	P	P	P	35220
Vaccines	A	A	C	-	A	C	A	A	P	P	P	35220
Monoclonal antibodies and diagnostics	A	C	C	-	A	C	A	A	P	P	P	35220
Biopesticides	A	-	C	-	A	C	A	A	P	P	P	35120
Plant medicines	A	-	C	-	A	A	A	-	P	P	P	35220
Toiletries												
Toothpastes	-	-	-	-	-	A	A	-	P	P	P	35232
Soaps	-	-	-	-	-	A	A	-	P	P	P	35231
Perfumes	-	-	-	A	-	A	A	-	P	P	P	35232
Cosmetics	-	-	-	-	-	A	A	-	P	P	P	35232
Hormones and vitamins	A	-	C	-	A	C	A	A	P	P	P	00000
5. ENERGY, ENVIRONMENT AND OTHERS												
Methane production	A	-	C	A	A	C	A	A	P	P	P	35111
Hydrogen production	A	-	C	A	A	C	A	A	P	P	P	35111
Waste treatment and recycling	A	-	C	C	A	C	A	A	P	P	P	00000

KEY TO TECHNOLOGIES:

A = Auxilliary C = Core P = Peripheral

GEN ENG = Genetic engineering	HYB FUS = Hybridoma fusion
FERM REAC = Fermentation and reactor	ENZ = enzyme
TISS CUL/FUS = Tissue culture and cell fusion	MCRO = Microbial
CHEM ANAL = Chemical and biochemical analysis	CONT MEAS = Control and measurement
MECH ELEC ENG = Mechanical and electrical engineering	

Table 1.8 lists the products from the Thai industrial index which the researchers selected as requiring some biotechnology input. The technologies used or potentially useful for these industries are listed as core, auxilliary or peripheral depending upon whether the technology is a biologocal technology integral to the particular production process (core technology), a biological technology supportive to the production process (auxilliary technology) or a non biological technology necessary for the production process. This classification system is not intended to indicate the relative importance of the different technologies. Obviously, any production process is only as strong as its weakest link. Good biological technology supported by bad engineering would not lead to efficient production. Rather, the purpose of the table is to clarify the roles of the various biotechnologies in industry. For example, an examination of Genetic engineering technology will show that it is not a core technology for any industry. However, it is an auxilliary technology for many. A specific example will help to illustrate. The production of monosodium glutamate and lysine is carried out by a fermentation process. Therefore, fermentation and reactor technology are essential or core technologies for the industrial production process. Enzyme technology is also a core technology because of the enzymatic conversion of starch to glucose as an initial step in the preparation of the substrate for fermentation, and microbial technology is a core technology because microbes are used in the fermentation process. Genetic engineering and cell fusion technology, however, are not core technologies but rather auxilliary technologies for this industry, because they are used for basic microbial strain development work to improve the efficiency of the production process. Chemical and mechanical engineering are non biological technologies essential for the production process and they are thus given as peripheral technologies. This preliminary list was used to select products with a high biotechnology content which were important in the Thai economy.

The purpose of this classification was to focus on biotechnological aspects of industry, and not to rank these technologies in order of importance. Obviously, all of these technologies can influence product quality and cost, and any industrial process is only as strong as its weakest link.

1.2 Role of Biotechnology-Based Industries in the Thai Economy.

Biotechnology-based industry may be defined as any industry in which the conversion process acquires living organisms or biocatalysts to affect raw materials or intermediate inputs and convert them into final products or other intermediate products. In other words, biotechnology-based industries are those which use industrial processes or manufacture products by the application of biotechnologies. In this light, biotechnology-based industries encompass a wide range of products. Table 1.8 above presents a partial list of such biotechnology-based products.

The following paragraphs discuss the roles and performance of biotechnology-based industries in the Thai economy. The discussion will concentrate on production, growth prospects, export performance, and imports in the biotechnology-based industries. Limitations and opportunities that are associated with technological capability development in these industries will also be highlighted.

1.2.1 Production and Trends in Biotechnology-Based Industries

Traditionally, Thailand has an agriculturally based economy and the majority of gross domestic product, employment and export earning have been generated through the production of goods in economic sectors where biotechnologies are applied. Although the Thai economy has been significantly transformed during the past two decades or so, the biotechnology-based industrial sector will continue to play an important role in national and industrial development in the years to come.

Table 1.9 shows production and trends in some major biotechnology-based industries in Thailand. Only important biotechnology-based products, particularly those with good export prospects or import substitution prospects will be highlighted below.

As far as seed production is concerned, the Department of Agriculture has been the producer of seeds for agricultural extension purposes. However, the total production of various varieties of seeds produced by the Department (Table 1.9) accounted for only 0.01 and 0.21 percent of domestic demand in 1985 and 1986, respectively {Chamchong, et. al., 1987 (a)}. The rest of the demand for seeds was met by private seed production companies and by imports.

Table 1.9

PRODUCTION AND TRENDS IN SOME MAJOR

BIOTECHNOLOGY-BASED INDUSTRIES IN THAILAND

Major Industry Group	1980	1985	1986	1987
1. Agriculture				
Seed production (tons)	n.a.	832	829	n.a.
Biofertilizer production (tons)				
Rhizobia	150	150	150	150
Composts	100000	500000	500000	500000
Ornamental plants/flowers	530000	613000	484000	n.a.
Aquaculture (tons)				
Shrimp	118.3	135.0	n.a.	n.a.
Fish	179.3	2225.3	n.a.	n.a.
Livestock production (head of cattle)	3961540	4882326	4944168	n.a.
2. Agro-industry				
Dairy	85997	279367	337654	409879
Milk	445223	557117	613670	626787
Margarine	154	214	222	228
Cassava starch	1335478	1917946	2329802	n.a.
Sugar	1816439	4250861	5066261	4841396
Animal feed	2263238	2801119	3342865	3147227
Yarn				
Cotton	5073960	5816176	8150605	11774893
Jute	968046	443011	862716	792332
Silk	114204	310142	384728	472499
Leather tanning	380166	661244	882022	1690458
Pulp and paper	1143571	1681207	2468571	2638246
Rubber sheet	548488	655595	713719	822227
Tobaco	7604094	11829141	12469605	13356494

Table 1.9 (continued)

Major Industry Group	1980	1985	1986	1987
3. Food, beverages and specialty Chemicals				
Monosodium glutamate	357055	403290	383676	401656
Lysine (tons)	-	-	2000	2000
Citric acid (tons)	720	1800	2160	2160
Fermented food				
Soy sauce and soy curds	108251	252484	303017	350194
Fish sauce	646775	1115221	1143271	1243815
Non-alcoholic beverages	2594851	4183435	4735537	5396295
Alcoholic beverages				
Breweries	2244904	3405420	3146552	3240162
Distilleries	5779241	14147993	13676456	14043919
Preserved food				
Canned fish	985272	3576998	5321570	6034348
Canned fruit and vegetables	650962	2310704	2192827	2172745
Ice cream	398710	527152	509622	503270
Manufacture of oils and fats (animal and veg.)	625839	2271815	2399405	2839079
Soap and cleaning preparation	1099629	1589900	1521289	1589324
Paint, varnish and lacquer	492974	407633	464776	573944
4. Health and health related industries				
Drugs and medicine	127161	3180669	3636526	4268011
Cosmetics and other	604259	804946	1017685	1060232

Note: If not otherwise stated, the figures are value added at current prices (unit: per 1,000 baht).

Production of paddy, maize, sorghum, beans, ground nuts, green beans, cotton seeds, and jute seeds.

Source: National Account Division, NESDB (new series), and Agricultural Statistics Division, Ministry of Agriculture and Cooperatives.

Thailand relies heavily on imports of chemical fertilizer for agricultural production as only about 10 percent of the demand for fertilizer is met by local production. The application of various kind of biofertilizer, e.g., rhizobia and composts will not only reduce Thailand 's dependence on chemical fertilizer imports but also enhance soil fertility naturally. However, the production and application of biofertilizer in Thailand are still in the early stages of development. For instance, the Department of Agriculture has started the production of rhizobia for bean farmers in 1980 and has produced at the rate of about 200 tons per year. Additionally, various government organizations have been involved in promoting production and use of compost among farmers. Moreover, research projectare currently underway in several university laboratories and research units to look into the production feasibility of compost starters and nitrogen fixing algae for commercial purposes.

Production of ornamental plants and flowers are undertaken mostly by small producers. Some large producers such as the Bangkok Flower Center Co., Tropical Flora, Chaopaya Orchid, and Excel Orchids are actively involved in exporting ornamental plants and flowers to overseas markets. Many small producers are subcontractors of the large producers and exports. As far as production technology is concerned, Kasetsart University has played an important role in enhancing technology in the breeding and production of ornamental plants and flowers. As a result, most producers are equipped for such technologies as cross-breeding and plant tissue culture. In recont years, production and export of ornamental plants and flowers have increased sinceexport prospects are fairly good.

Production of aquacultural products, e.g., shrimp and fish has a very high growth potential. Frozen shrimp and fish have been among major exports in recent years. As far as production technology is concerned, Thailand has been successful in the development artificial cultivation techniques and in production of artemia, and daphnia for feeding the larva of shrimps and fish.

In the cattle industry, products such as meat, meat preparations milk and dairy products have been increasing and Thailand has even started to export some meat products, (e.g., sausages and ham). The domestic demand for milk and dairy products is rising. However, bullocks and cows for breeding have to be imported since native ones tend to give low yields. The most popular imported cattle are Holstein Friesians which account for as much as 66 per cent of total dairy cattle in Thailand, followed by Red Danes which make up another 11 per cent. The balance comprises Red Sindhis, Sahiwals, Swiss Browns and German and Indian breeds. The average import cost of these cattle is 38,000-40,000 baht per head. These foreign bullocks and cows are not only expensive but also generally poorly resistant to disease. Because of this, biotechnologies have been introduced for domestic production of animals by artificial insemination and embryo transfer. Artificial insemination is generally adopted by cattle farmers since it is simple, economical and can be carried out by the cattle farmers themselves. Embryo transfer technology, on the other hand, is very complicated and good bullocks and cows for breeding are expensive. Although artificial insemination programmes have been successful in the area of animal breeding, hoof and mouth disease remains one of the main obstacles to raising cattle in Thailand since the disease hinders export prospects for fresh meat.

As a natural resource-rich country, Thailand has a good potential for the development of agro-based industries. In one way or another, the production in agro-based industries involves application of biotechnology. As demonstrated in Table 1.9, production in agro-based industries, including food, beverages, and specialty chemicals has increased in recent years. This is due partly to the export promotion policy of the government and partly to the rise in domestic demand resulting from improved economic conditions. In the dairy industry, for instance, statistics show that the number of farms increased form 3,341 farms in 1982 to 5,226 farms in 1987, and output of raw milk in the same period increased from 27,240 to 74,000 tons while costs of production fell from 4.15 baht per kilo to about 3.86 baht per kilo. Beginning in the latter part of 1986, there was a turnaround in the local dairy industry due to population growth, a rise in per capita income, a general weakening of resistance to fresh milk consumption among the present generation of the Thais, and a more widespread recognition of the nutritional value of milk. The decline in the production cost was mainly due to the larger scale of production.

The Thai leather industry consists of two sectors, namely the tanning of hides at the upstream end and the manufacture of finished products at the downstream end. About 85 to 90 per cent of the total supply of hide is from cattle and buffalo. In general, local tanneries employ two processes, i.e. chrome tanning and vegetable tanning. While the former process is employed to produce light-duty leather suitable for making shoes, upholstery and bags, the latter process is applied in the production of heavy-duty leather used for shoe soles and various types of belts. Raw hides have been imported in growing quantity in the past decade as local demand has exceeded supply and local hides are by and large inferior in quality to those from overseas. The inflow of raw hides from aborad rose from 1043 tons worth 24.1 million baht in 1984 to 23,735 tons worth 447.6 million baht in 1986.

Prospects for the local rubber industry (comprising cultivation, concentrated rubber latex production, rubber sheet production, and downstream manufacture) are bright. As a primary commodity, rubber has increased in price. Because of the AIDS scare, which has led to an increased demand for condoms and rubber medical gloves, the production of concentrated latex has increased. Furthermore, the improvement in world economic conditions and purchasing power has resulted in increased demand in the car type industry which is the largest consumer of rubber (smoked sheets and blocks). As the world's third largest producer of natural rubber after Malaysia and Indonesia, Thailand is continuing with its programme to step up replantation, aiming at replanting 312,500 rai a year. It hopes to replace all rubber trees with hybrids in the next two decades. Thailand's share of world natural rubber production has grown steadily from 14.6 per cent in 1983 to 18 per cent in 1987 and it is expected to expand to an estimated 18.2 per cent in 1988. Application of plant tissue culture technology in the improvement of rubber trees and in the expansion of rubber tree plantations is still in the early stages of research and development due mainly to a lack a lack of serious promotion and lack of expansion of adequate laboratory equipment.

Thailand's food processing industry has grown at an impressive rate due mainly to export drive. Its products still have potential markets all over the world provided that the quality and packaging are improved. Fermented and canned foods are now major biotechnology-based food processing products that have registered a high growth rate and have bright export prospects. For instance, seafood canning is one of the country's fastest growing industries. In 1986, there were about 50 seafood canning factories, of which about 30 were large-sized producers mainly for export. Major products were canned tuna, sardines, shrimp, crab, clams, and squid. Canned fish and especially tuna is the most popular product, particularly in the US market. Exports of canned tuna have increased very rapidly, with a rate of growth averaging 47 percent a year in the past seven years. As a consequence, Thailand has become the world's largest exporter of canned tuna. The large exports of canned tuna have resulted in increased demand for fresh tuna by cannneries. However, the catch did not increase after the neighbouring countries declared 200 mile exclusive economic zones. As a result Thailand has to import a large and increasing amount of fresh tuna annually.

Besides the insufficient supply of raw materials, the seafood canning industry is facing many other problems, paricularly the protectionist measures implemented by importing conutries such as the

US, Canada, France, Italy and Japan. Moreover, some countries in Europe are calling for amendments in the standards set for the cans used to contain food. They want more emphasis on quality, on longer shelf life and on resistance to chemical reactions. The move is for a can's shelf life of between 9-12 months. If the amendment comes into effect, Thai canned food will be badly affected because its shelf life is only around six months. On the supply side, the continuing development of coastal farming and increased joing fishery ventures with neighbouring countries will help raise input and output. However, competition and protection in world markets are likely to intensify.

Canned fruit and vegetables have become an important foreign exchange earner for Thailand. Moreover, this industry provides a great number of job opportunities and has brought about a broad spectrum of advantages including the multiplication of value added for the concerned farm produce. The major products of this industry are canned pineapples and pineapple juice, lychee, rambutan, longan, rambutan stuffed with pineapple, baby corn, mushrooms and bamboo shoots. Canned pineapples and pineapple juice account for over 90 per cent of canned fruit and vegetable exports.

There are several problems besetting the canned fruit and vegetable industry. The most important one concern the irregular supply of raw materials. The shortage of fruit and vegetables to feed canneries all year round forces producers to stop production during the off season. Moreover, the industry still faces the persistent problems of the discriminatory GSP system in Europe, quotas in Japan and high freight cost.

Alcoholic and non-alcoholic beverages also represent major biotechnology-based products in the Thai economy. These industries have been one of the major sources of government revenue. The government revenue from the liquor industry alone accounts for about 6 per cent of the total annual revenue of the country. About 60-70 per cent of the price structure for liquor is for royalties, excise tax, and municipal tax. Production in the alcoholic and non-alcoholic beverage industries aims mainly to serve domestic demand. Most alcoholic beverage producing firms are wholly-Thai owned since the government exercises strict control of their production. In the non-alcoholic beverages industry, on the other hand, subsidiaries of transnational corporations get a lion's share of the market. There are at least 12 brands of soft drinks in the domestic market, but only two major producers share nearly 90 per cent of the market. The two are the Serm Suk Co. Ltd., producer of Pepsi-Cola, Mirinda, Teem and Mountain Dew; and the Thai Pure Drinks Co. Ltd., which produces Coca-Cola, Fanta, Sprite and Mello. The market battle between these two rivals is tough and quarrelling with no sign of either of them giving up.

Manufacture of oils and fats (animal and vegetable) is rapidly increasing. The surge of production is attributable mainly to the increase in the production of vegetable oils, especially from soybean and oil palm. Despite the fact that many problems remain for the vegetable oil industry, prospects for the future look bright. The product has a wide range of uses, and demand is likely to remain firm, irrespective of changes in the economic climate. The main raw material for the manufacture of edible vegetable oil is soybean. It is followed in order of importance by crude palm oil, rice bran oil, cotton seed oil, kapokseed oil, copra oil, seasame oil and groundnuts oil. The importance of groundnuts has decreased markedly since 1981, due mainly to the inability to control the contained amount of aflatoxin to under the maximum level of 20 ppb required by the Ministry of Public Health. The oil palm industry is growing in importance. Major problems facing local vegetable oil manufacturers and likely to continue in the near future, include rising raw material prices, inadequate supplies, irregular supplies, strong competition at home and abroad, high investment requirements, inefficient machinery, under-utilization of production capacity, and inadequate government support.

In the health and health related industries, major biotechnology-based products include antibiotics, vaccines, plant medicines, hormones, vitamins, and toileteries. In Table 1.9, the production of these biochemical products is presented under three main categories, namely drugs and medicine, soap and cleaning preparations, and cosmetics and others. Among the biotechnology-based products in the health and health related industries, antibiotics and vaccines are well-known to most people. The antibiotics include pennicillin, aureomycin, terramycin, chloramphenicol, streptomycin, erythromycin, and tetracycline. Domestic production of antibiotics may be classified into four main types, namely packaging, assembling, complete production, and the production of a final product using intermediate products. The first type involves importing of ready mixed antibiotics in bulk and repackaging it in small containers for distribution. The second type of production, assembling, concerns the import of various ingredients in bulk and the assembly into finished products. The third type of production starts from fermentation, cultivation and seperation of active microorganisms, purification of products, and packaging. Most Thai firms in this industry employ either the first or the second type of production. Although domestic demand exceeds domestic production at present, the industry has a good potential for self sufficiency and export since important raw materials are available in Thailand at relatively lower prices than imports. For example cassava starch used in antibiotic production by fermentation is very inexpentive. The most important problem, however, is competition from China.

The fourth type of production, using intermediate products to produce final antibiotics, has been carried out since 1986 mainly by the Government Pharmaceutical Organization in collaboration with United Pharma Industries Co., Ltd. to produce ampicillin and ampicillin derivatives. Pennicillin G is imported and then converted to 6-APA (6 Amino Penicillinic Acid) which is the intermediate product used in the production.

Current production of vaccines and serum is carried out mainly by government organizations (e.g., the Department of Livestocks Development and The Government Pharmaceutical Organization). In 1986, the Department of Livestock Development produced about 7.5 million doses and imported about 1.0 million doses of vaccine for foot and mouth disease. It is expected that the Department will be able to increase production of vaccines for animals to 40 million doses per year by 1989 at which time the country would be self-sufficient. The Government Pharmaceutical Organization produces several human vaccines and serum (e.g., cholera vaccine, typhoid vaccine and anti-cobra venom serum). The production of vaccines and serum by the GPO is mainly for domestic uses. While most vaccines and serum can be produced sufficiently for domestic use, some vaccines and serum have to be imported entirely partially or from abroad, due to either insufficient domestic production (e.g., DTP vaccine) or a lack of technological capability for production (e.g., OPV vaccine).

1.2.2 Exports of Biotechnology-Based Products

Major Thai merchandise exports are agricultural products and manufactured products. In 1960, exports of primary products formed the major export of Thailand, accounting for about 95 per cent of the total export value. It was only after 1970 that manufactured products made some ground in the export market, particularly with respect to resource-based and labour-intensive products.

The export earnings from Thai biotechnology-based agricultural products and manufactured products are presented in Table 1.10 for the period of 1986-1988. Canned seafood, sugar, frozen squids, canned pineapples, frozen fish, dried squid, raw coffee, and fresh fruit were among 10 top biotechnology-based exports, each accounting for more than 1,000 million baht worth of export value annually. These exports (except sugar) and most other biotechnology-b ased exports have increased in recent years. The increase was

Table 1.10

THAILAND'S EXPORT OF MAJOR BIOTECHNOLOGY-BASED PRODUCTS, 1986-1988

Volume: Metritons; Value: Million Baht

Products	1986		1987		1988 (estimates)	
	Volume	Value	Volume	Value	Volume	Value
1. Agricultural products	-	74,406.8	-	73,484.0	-	73,648.0
1. Tapioca products	6,325,644	19,111.0	6,200,000	21,080.0	7,000,000	21,610.0
2. Rubber	760,857	15,115.9	800,000	17,760.0	840,000	19,320.0
3. Maize	3,981,236	9,175.9	1,700,000	3,910.0	1,800,000	4,500.0
4. Tobacco leaves	33,056	1,486.7	30,000	1,560.0	28,000	1,400.0
5. Frozen chicken	64,796	3,121.3	80,000	4,028.0	120,000	6,120.0
6. Green beans	78,787	769.2	85,000	640.0	80,000	616.0
7. Fresh orchid	6,054	386.7	7,000	410.0	7,500	510.0
8. Fresh fruit	52,371	736.1	49,000	720.0	60,000	1,000.0
9. Fresh vegetable	22,649	136.3	25,000	176.0	30,000	220.0
10. Frozen pinapple	18,653	197.5	19,000	220.0	20,000	240.0

Table 1.10 (continued)

Products	1986		1987		1988 (estimates)	
	Volume	Value	Volume	Value	Volume	Value
2. Fishery products	-	13,474.2	-	15,830.0	-	18,575.0
1. *Frozen shrimp*	28,729	4,391.0	35,000	5,615.0	42,000	7,000.0
2. Frozen squid	58,925	3,760.5	62,000	4,100.0	66,000	4,620.0
3. Frozen fish	118,893	2,185.4	128,000	2,500.0	150,000	3,000.0
4. Process squid	4,662	726.2	4,800	800.0	5,050	880.0
5. Frozen cooked shrimp	5,120	464.3	6,400	650.0	6,900	710.0
3. Agro-industrial products	-	26,869.5	-	30,926.0	-	32,411.0
1. Canned sea food	205,737	10,928.2	230,000	12,800.0	243,800	13,411.0
2. Sugar	1,965,174	7,293.0	1,800,000	7,900.0	1,700,000	7,480.0
3. Canned pinapple	225,986	3,183.1	250,000	3,650.0	275,000	3,920.0
4. Molosses	830,824	1,018.5	550,000	760.0	600,000	696.0
5. Canned pinapple juice	23,392	361.0	26,000	400.0	28,600	450.0
6. Rice flour	31,505	221.4	26,000	186.0	27,000	222.0
7. Ethyl alcohol	24,231	166.5	24,000	170.0	30,000	213.0

Table 1.10 (continued)

Products	1986		1987		1988 (estimates)	
	Volume	Value	Volume	Value	Volume	Value
4. Manufactured products	-	14,904.0	-	17,922.0	-	20,660.0
1. Pharmacuetical products	-	278.7	-	322.0	-	390.0
2. Sweet condensed milk	8,677	158.8	13,500	250.0	16,070	300.0

Source: Economic and Social Journal, NESDB.

resulted from an improvement in technologies used in the production and marketing of these products. Biotechnology-based exports that have expanded rapidly (e.g., more than 10 per cent in 1988) include frozen chicken, fresh fruit, frozen shrimps, cut orchids, fresh vegetables, frozen fish, frozen squid, ethyl alcohol, and pharmaceutical products. However, exports of some biotechnology-based products have tended to fall in recent years. These include sugar, noodles and ground fish.

1.2.3 Import of Biotechnology-based Products

In terms of Thailand's imports, biotechnology-based products have constituted a substantial value. In the early 1960's when Thailand embarked on import-substitution industrialization as well as promotion of production in the agriculutral sector, essential imported biotechnology-based products were mainly raw materials and intermediates for the production of goods in the food, beverage, and pharmaceutical industries. When Thailand started to promote export-oriented industrialization and entered the second phase ofimport substitution industrialization in the second half of the 1970's, imports of biotechnology-based products mainly in the form of raw materials and intermediate products increased further.

Table 1.11 presents some major imports of biotechnology-based products for Thailand during the period 1981-1987. Although the values shown are in current prices, it is clear that the import value of most biotechnology-based products has tended to rise over the period. Therefore, there is still an opportunity for promotion of local production of these products since production technologies for most are fairly standardized, can be easily acquired and can be put into operation without much difficulty. Biotechnology-based products with annual import values exceeding 100 millinon baht include powered milk for infants, whole milk powder containing not more than 1.5 per cent by weight of fat, skimmed milk powder containing not more than 1.5% by weight of fat, butterfat, soya bean cake, antibiotics, synthetic organic dyestuffs, vaccines, varnishes and lacquers. It also should be noted that import values of some biotechnology-based products have decreased. These include vitamins and antibiotics for which local production has increased in recent years.

Table 1.11

SELECTED IMPORTS OF BIOTECHNOLOGY-BASED PRODUCTS, 1981-1987

(C.I.F. Value, Unit : 1,000 baht)

Products	1981	1987
1. Bullocks and Cows for breeding	19,639.0	216,873.0
2. Preserved fish (salted, dried or smoked)	n.a.	64,306.0
3. Powder milk for infants	1,047,108.0	721,316.0
4. Whole milk powder containing not less than 26% by weight of fat	113,023.0	521,278.0
5. Skimmed milk powder containing not more than 1.5% by weight of fat	688,316.1	886,090.0
6. Butterfat	244,660.8	258,904.0
7. Cheese and curd	12,933.9	41,012.0
8. Apples (fresh)	66,264.4	130,267.0
9. Pears and quinces (fresh)	33,615.5	48,205.0
10. Barley	61.3	24,685.0
11. Grain sorghum milo	3,194.1	17,473.0
12. Wheat or meslin flow	64,623.2	249,328.0
13. Malt, roasted or not	205,204.8	142,022.0
14. Maize starch and other starches	4,608.8	61,365.0
15. Vegetable seeds	61,803.3	98,543.0
16. Agar-agar	61,662.4	112,926.0
17. Sunflower seed oil (edible)	39.6	16,120.0
18. Soya bean oil (modified)	16,484.0	49,844.0
19. Fatty alcohols	33,755.2	57,934.0
20. Palm oil hydrogenated	31,237.0	11,891.0
21. Tuna in airtight containers	n.a.	56,652.0
22. Other fish preserved in airtight containers	6,203.2	19,483.0
23. Cocoa powder unsweetened	22,370.0	45,041.0
24. Chocolate	25,297.4	78,912.0
25. Other priparations for flow starch malt extract with cocoa less than 50%	272,037.5	385,197.0
26. Biscuits and crackers	n.a.	24,745.0
27. Infant milkfoods	436.1	155,794.0
28. concentrated extract for making beverages	215,191.7	206,909.0
29. Wines with absolute alcohol not exceeding 15%	20,514.3	51,052.0
30. Whisky	201,023.4	534,784.0
31. Brandy	359,744.0	291,864.0
32. Groundnut cake	24,188.1	307,902.0
33. Soya beans cake	1,027,577.0	1,277,056.0
34. Sunflower seed cake	542.3	172,357.0
35. Sweetened for age, other preparations a kind used in animal feeding	300,062.2	616,849.0
36. Citric acid	24,726.3	28,440.0
37. Vitamins	121,120.5	89,449.0
38. Hormones	60,790.5	98,084.0
39. Enzymes	17,247.7	42,614.0
40. Antibiotics, e.g., penicillins, aureomycin and tetracycline	407,673.3	770,065.0
41. Vaccines microbial	77,132.6	290,164.0
42. Synthetic organic dyestuffs	855,810.4	1,616,621.0
43. Food cours	35,476.0	120,190.0
44. Varniches and lacquers	103,171.7	312,971.0

Source: Department of Business Economics.

1.3 Past Studies Related to Technological Capability Development for Biotechnology-Based Industries

There has been no previous study in Thailand specifically concerning technological capability development in biotechnology-based industries. However, there have been a few studies on the development of biotechnology and biotechnology-based industries in developing countries in general. Thailand has been included in some of these, sometimes with particular focus. There have also been a number of studies on technological capability development in industries in developing and newly industrialized countries. These will be reviewed here briefly.

1.3.1 Development of Biotechnology and Biotechnology-based Industries: Major Issues, Status and Potentials

The major issues regarding development of biotechnology and biotechnology-based industries in developing countries are broad and complex. There are impacts to consider both for the countries themselves and for their international relations. For developing countries, the broad benefits and possible threats from global biotechnology development have been discussed in Section 1.1.2. A major question has been raised as to whether biotechnology can contribute to sustainable development (Junne, 1987; Elkington, 1986). In particular, the potential conflict of interest between biotechnology industries in developed countries and the public in developing countries has been pointed out. Specifically, there is concern that the private sector in developed countries will "lock up" new technologies through patents, and that the development of herbicide-and pesticide-resistant plants may increase the dependence of farmers in developing countries on imported agrochemicals. Also, possible adverse effects from product displacement through new biotechnology (Section 1.1.2) (Elkington, 1986; van den Doel and Junne, 1986), and adverse effects on employment (Ahmed, 1988) have been considered. Despite these potential drawbacks, the general conclusion is still that biotechnology can be very beneficial in development.

Strategies for developing countries to gain optimum benefits from biotechnology include acquisition of accurate intelligence on activities of transnational corporations and other biotechnology companies on their linkages, and on the socio-economic and environmental impacts of technology (Dembo and Morehouse, 1987). Of central importance, however, is the building of capability in biotechnology in the developing countries themselves (McConnell et al., 1986). The important factors for the success of capability building are considered to include: manpower education and training, creation of a critical mass through high-quality teamwork, creation of an adequate infrastructure (laboratories, chemical and equipment supplies, an innovative atmosphere), access to information and international technology transfer, formulation of national policy, research and development programs, and support mechanisms. In addition, important factors for bioscience based industry, in particular, include access to financing and joint venturing, especially with the private sector in developed countries. With respect to the problem of trade secrets and intellectual property rights, it is considered that lincensing is an extremely important method for biotechnology transfer.

The major constraints for the application of biotechnology in Thailand, as in other developing countries, are the still small manpower base and limited infrastructure (Yuthavong, 1987). A related constraint is the rapid pace at which the technology is moving. Technology transfer from abroad to the production sector in Thailand, although considerable at present, is still limited by the usual constraints encountered in various developing countries. These include lack of technology choice and restrictive practices by technology owners (Technology Transfer Center, 1986). The problems are further exacerbated by the limited interaction between the private sector and the university sector. Another major constraint is associated with the issue of intellectual property rights. Although Thailand has had copyright and patent laws for some years now, many unsolved issues still remain. The concern of technology owners from abroad is for more protection of their intellectual property rights. In contrast, local entrepreneurs fear that enhanced protection will hamper endogenous technological development. Furthermore, with regard to biotechnology in particular, the possibility of patenting living organisms raises the fear that endogenous genetic resources would be restricted in their use by the entrepreneurs themselves.

The status and potential of biotechnology in Thailand have been the subject of several analyses (Yuthavong and Bhumiratana, 1988; Yuthavong, 1987, Atthasampunna et al. 1988; Suwana-adth, 1986; Bhumiratana and Tanticharoen, 1986). The infrastructure for new biotechnology in Thailand is relatively strong when compared to other developing countries. For example, Thailand was the only developing country which met the criteria for the site of the International Centre for Genetic Engineering and Biotechnology (UNIDO, 1983; Zimmerman, 1987). However, there is still very little qualified manpower in this area. Furthermore, most research and development activities are located at the universities, and there is little linkage with private industry. Some government agencies such as those in the Ministry of Agriculture have extensive research programs, many of which are related to biotechnology. The main emphasis is on technology generation and diffusion for farmers. The role of the private sector in promoting modern agricultural technology development has been mainly through adaptive research involving field trials and through technology import by joint ventures and other arrangements (Working Group on Agricultural Technology Generation and Diffusion, 1982). Examples of important industries gaining from these modes of technology development are the poultry industry, the seed industry and the integrated farming industry.

Opportunities to commercialize biotechnology have been specifically considered for Southeast Asia (Resources Development Foundation, 1988). In line with the list in Table 1.5, commercialization efforts appear to be making the most headway in agricultural plant improvement, in bioconversion of plant material and in aquaculture. The Southeast Asian focus on agricultural biotechnology stands in contrast to the focus on pharmaceuticals and specialty chemicals in South Korea and Taiwan (Yanchinski, 1987). Some major immediate and near-term specific applications include shrimp aquaculture, algae culture, plant cell culture, biomass conversion, mammalian cell culture, germ plasm manipulation, hybridoma technology and recombinant DNA technology.

The importance of national policy and programs for development of biotechnology and its applications in bioindustry in Thailand has been increasingly recognized during the past decade (Yuthavong et al., 1984; Yuthavong et al., 1985; Suwana-adth, 1986; Atthasampunna et al., 1988). Major development has included the establishment of the National Center for Genetic Engineering and Biotechnology in 1983, and of the Science and Technology Development Board in 1985 to provide support to research and development projects in various universities and agencies, and to facilitate technology transfer to industry. In addition, the National Center provides information, training, and international links, while the Science and Technology Development Board also provides support to industry in terms of soft loans and access to US sources of technology. Other biotechnology research projects are funded by the National Research Council and by grants from the universities. International funding is also important, especially for biomedical and life science projects. The various programs and projects have made Thailand a notable developing country for efforts to strengthen and commercialize biotechnology.

1.3.2 Technological Capability in the Industries

In a study on the acquisition of technological capability at the firm level in four newly industrialized countries (South Korea, Brazil, Mexico and India), three major elements of capability were discerned: production capability, investment capability (for expansion and for new ventures) and innovative capability (Dahlman et al. 1987; Amsden and Kim, 1987). The process of deliberate learning was found to be of crucial importance. This could take the form of formal education, informal study in overseas factories, in-house training, information in foreign licenses, reverse engineering, design experimentation, etc. The firms in Korea, which were classified according to size (small vs. large) and technological strategy (passive vs. aggressive), had different patterns of technology acquisition. Small, technologically agressive firms established initial production with primitive self-developed technologies and gradually upgraded themselves through repair and reverse engineering of locally available foreign products. These firms were called "imitators". Large, technologically-agressive firms were normally in industries with economy of scale and least differentiated products (e.g., steel and cement) and they typically started with heavy foreign dependence (usually through turnkey operations). They subsequently actively participated in design and underwent extensive internal learning. They were therefore called "apprentices".

The focus of technological effort in technologically aggressive firms in developing countries like South Korea is initially on acquisition of production capability, followed by design capability and investment capability. These are, in turn, followed by strengthening of innovative capability. Korean firms enjoyed the advantage of being "late-comers", and benefited quickly from transfer of the newest technology from advanced countries. An important factor for this was success the role of government policy in encouraging learning.

A study on Philippine manufacturing enterprises (Philippine National Science and Technolgy Authority, 1986) gives an insight into the technological behaviour at the firm level in a Southeast Asian country. Although the firms relied heavily on foreign sources for their technological requirements, they engaged in technological development activities to a signficant degree. Considerable innovation potential was reported to exist within most of the firms, as indicated by presence of research and development units and engineering/quality control departments, although no specific examples were given indication of any significant innovative result. One reason for slack technological efforts was that the firms enjoyed a competitive edge on the basis of mostly non-technological factors. Most firms, however, were competent in operating their existing technology, and were able able to make minor changes in products and processes. Governmental incentive measures proposed to promote innovation were: tax incentives, availability of loans, suitable government regulations, research and information services.

The status of technological capability in Thai industries has been assessed with regard to degree of self-reliance (Thailand Institute of Scientific and Technological Research, 1986). The total technological capability index for each industry was calculated from a composite of sectorial capability indices (hardware, software of hardware, and software of process). Among the industries surveyed, it was found that the sugar industry had a moderately self-reliant capability followed by, (in decreasing order) the distilling, fruit canning, animal feed, industrial chemical and dairy product industries. The last two were classified as dependent industries because of their low capability indices. Self-reliant capability was found to be confined to industries where a low or rather low level of technology was required, and to small-scale industries, including those based on local technology. The factors contributing to self-reliance stemed from the potential for self-development. Policy guidelines were offered which included: promotion of engineering industries to cut down dependence on foreign machinery and spare parts, promotion of local small industries rather than joint ventures with foreign investors, promotion of industries in which the Thais already had basic knowledge, promotion of industrial export with high market potential, promotion of research and development, and reduction of business tax on products manufactured through Thai technology. The guidelines appear to underestimate the role of international technology transfer in capability development.

1.4 The Scope of The Present Study and The Hypotheses

1.4.1 The Objectives

The objectives of this study were

a. to undertake a survey of the status of Biotechnology-based industries and to determine potential capability in biotechnology in Thailand, especially at the firm level.

b. to identify existing weaknesses and strengths in biotechnology-based industries and in biotechnology in Thailand, and to understand the basis for these weaknesses and strengths.

c. to formulate strategies and propose policy measures for strengthening critical capabilities required for the development of present and future biotechnology-based industries.

1.4.2 The Conceptual Framework and Definitions

Technological capability is defined as the capability to perform technological activities. At the firm level, four major types of technological capability can be discerned:

a. Acquisitive capability: capability for search, assessment, negotiation, procurement, embodiment, start-up and test run; capability to choose technology and modes of technology transfer.

b. Operative capability: capability for process operation, control, and maintenance; capability in training and upgrading workers' skills; management capability.

c. Adaptive capability: capability for acquiring in-depth knowledge of technology, for technology digestion, for incremental or minor modifications to products or processes.

d. Innovative capability: capability to carry out research and development activities, to make radical modifications to products or processes, to originate major changes and to make new inventions.

Biotechnology, as defined in Section 1.1.1, is divided into specific technologies required for biotechnology-based products (Section 1.1.3.) These will constitute core, auxiliary and peripheral technologies for specific industries as shown in Table 1.8. The technological capability of the biotechnology-based industries will be discussed in terms of capability for technology acquisition, operation, adaptation and innovation with respect to these specific technologies. Technological capability is a key factor in determining technological dynamism, i.e., the pace and direction of technology change in firms. The change at the firm level takes place in a milieu of rapid changes both at the country and the global level. Hence, the gaps or the differences in capability levels between firms and the national frontier, and between the national and world forntiers are continuously changing.

The technological capability of a firm is manifest from its technological behavior, and this hehavior is determined by its attitude toward technology. The behavior and attitude can be gauged at the first level by the number of personnel and the amount of budget devoted to technology operation and development in a firm, but it can be understood in more detail through a study of its technology choices, its major technological events, its technology development activities, its practice in human capital formation, its managerial style, its entrepreneurial attitude and its business strategy.

The technological capability of a firm is determined not only by itself, but also by its interaction with the environment. Many technology agents continuously interact with firms. These range from private sector supportive agents (consulting and engineering firms, input suppliers and output users, and subcontractors) to government supportive agents (research and development agencies, education and training institutions, technical service agencies, promotion and regulatory agencies, policy agencies). The policy environment, regarding both industry and technology, is of particular importance in determining the nature and outcome of the interaction between firms and these various agents.

Criteria for choosing the industries to survey in this study comprised economic and social considerations and technological and policy considerations (for detail, see Section 1.4.4). A profile of technological capability for various biotechnology-based insutries was constructed, in order to assess the present levels and to see the gaps between the actual and desirable or frontier levels. Some potential future industries were also chosen, using data from the survey and from other sources. Strategic technologies (those which are of crucial importance in closing the present technology gaps and in providing access to future industries) were identified on the basic of their present industrial importance and their potential contribution to future industries. Major strategies needed for bridging present technology gaps and gaining needed future capabilities for biotechnology-based industries were then identified, and appropriate policy recommendations were made.

1.4.3 The Hypotheses and Questions

The major hypotheses to be tested and questions asked in this study were as follows

a. Relative importance of technology in a firms's survival and advancement

   i. Most companies assign low priority to technology as compared with capital, labour, management and marketing.

   ii. More "dynamic" companies assign greater importance to technology.

   iii. Open question: What is the relationship between "technology dynamism" and company advancement?

b. Core, auxiliary and peripheral technologies in a firms production process

   i. Most companies use conventional technologies.

   ii. Joint venture/foreign and large Thai companies are pioneers in new technologies.

   iii. Genetic engineering technology and other new leading-edge technologies responsible for the biotechnology boom in developed countries have not yet reached Thai industries.

c. Acquisition of technology

   i. Most large companies acquire their technology from foreign sources through technology transfer contracts, licensing etc.

   ii. Smaller companies acquire their technology from multiple non-formal sources, including diffusion from large companies (copying).

   iii. Technology superiority is a deciding factor in product competition.

d. Operative/adaptive/innovative capability

   i. Companies putting importance on technological competence of personnel have high operative capability.

ii. Companies with high operative capability have a crucial advantage over competitors.

iii. Companies with high operative capability also have high adaptive/innovative capability.

iv. Adaptive capability is widespread among companies of all sizes.

v. Innovative capability is found only in large companies.

e. Policy and plans/Private-public sector linkage

i. There is urgent need to produce qualified technical personnel.

ii. The government can help the private sector in developing innovative capability.

iii. Financial measures to support biotechnology industries are required.

1.4.4 Selection of Industries for the Survey

The selection of industries for the survey was accomplished in successive steps. Existing Thai industries using various components of biotechnology (Table 1.8) were subjected to further selection based on social, economic technological and policy criteria. The relative weights of the criteria were: output 15 %, trade variables (export, import) 15 %, technology content 30 %,, employment generated 10 %, linkages to other industries 10 %, government promotional status 5 % and growth rate and general impact on the economy 5 %. The results are shown in Table 1.12. This Table also presents some new potential future industries based mainly on technological, economic and social trends.

Table 1.12

LIST OF SELECTED PRESENT INDUSTRIES
AND SOME FUTURE INDUSTRIES

Selected Present Industries

I. AGRICULTURE

1. Seed Production
2. Seedling production
3. Rhizobia
4. Composts
5. Ornamental plants/flowers
6. Aquaculture
7. Livestock/embryo production

II. AGRO-INDUSTRY

8. Dairy
9. Sugar
10. Animal feeds/single cell protein
11. Biopolymers (modified starch, xanthans, surfactants, etc.)

III. FOOD, BEVERAGES AND SPECIALTY CHEMICALS

12. Monosodium glutamate
13. Lysine/methionine
14. Citric acid
15. Fermented foods
16. High fructose syrup
17. Alcoholic beverages/alcohol
18. Glucose syrup/sorbitol
19. Food flavours & colourings
20. Preserved foods

IV. HEALTH AND HEALTH RELATED INDUSTRIES

21. Antibiotics
22. Vaccines
23. Diagnostics
24. Plant medicines
25. Toiletries

V. ENERGY, ENVIRONMENT AND OTHERS

26. Methane production
27. Waste treatment

<u>Some New Future Strategic Industries</u>

I. AGRICULTURE

FS1 Biopesticides
FS2 Mycorrhizae

III. FOOD, BEVERAGES AND SPECIALTY CHEMICALS

FS3 Bioprotectants
FS4 Enzymes and proteins
FS5 Nucleic acid flavors
FS8 Food coloring agents

IV. HEALTH AND HEALTH RELATED INDUSTRIES

FS6 Vitamins
FS7 Hormones
FS9 New Drugs

The various biotechnology-based industries were linked through networks classified as plant-based (Fig. 1.1) or animal-based (Fig. 1.2), in order to see the inter-connections between previously identified products and processes. Figs. 1.3 and 1.4 show examples of specific networks based on cassava and on dairy cattle, respectively. These networks show that various products, processes and technologies are intricately linked, and improvement of technological capabilities may depend significantly on these linkages. Based on this information, a final selection of industries was made to represent important points in such linkage networks. Because of limitation in the scale of the survey to be carried out, a total of eight industries were finally chosen: the ornamental flower, seed, animal feed, aquaculture, dairy, fermentation (specialty chemicals and foods), alcohol, and health related industries. See section 3.1.1 for more discussion on the selection of these industries and their representative firms.

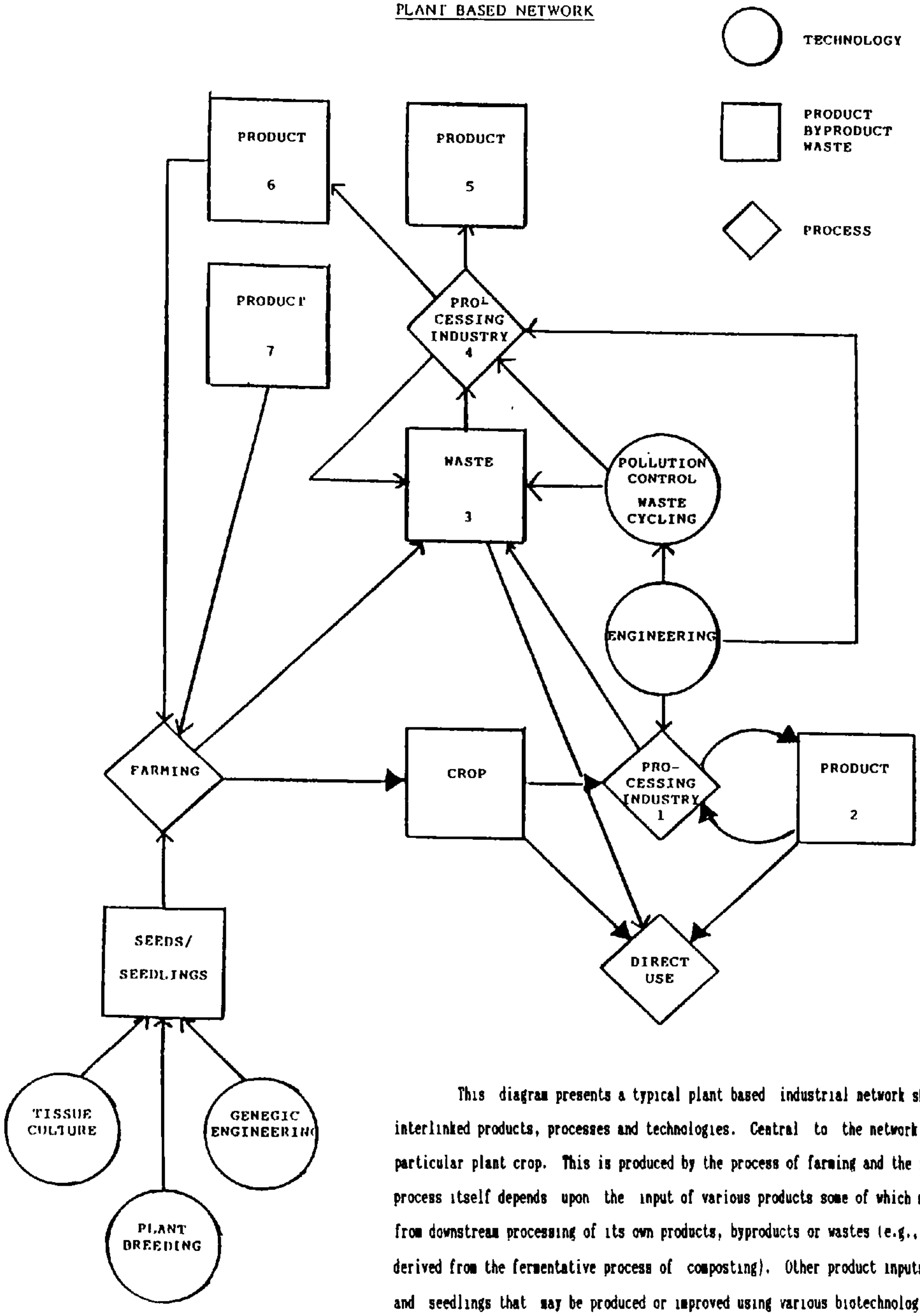
1.4.5 Outline of the Report

Chapter 1 **Introduction.** The scope, structure and state of development of biotechnology-based industries are discussed in general terms first, followed by a specific discussion of their roles in the Thai economy. A review is given of past studies concerning technological capability development for biotechnology-based industries. The scope of the present study and the conceptual framework are defined.

Chapter 2 **The Environment.** The environment for both industrial and macroeconomic policy and technology policy is examined, followed by a critical

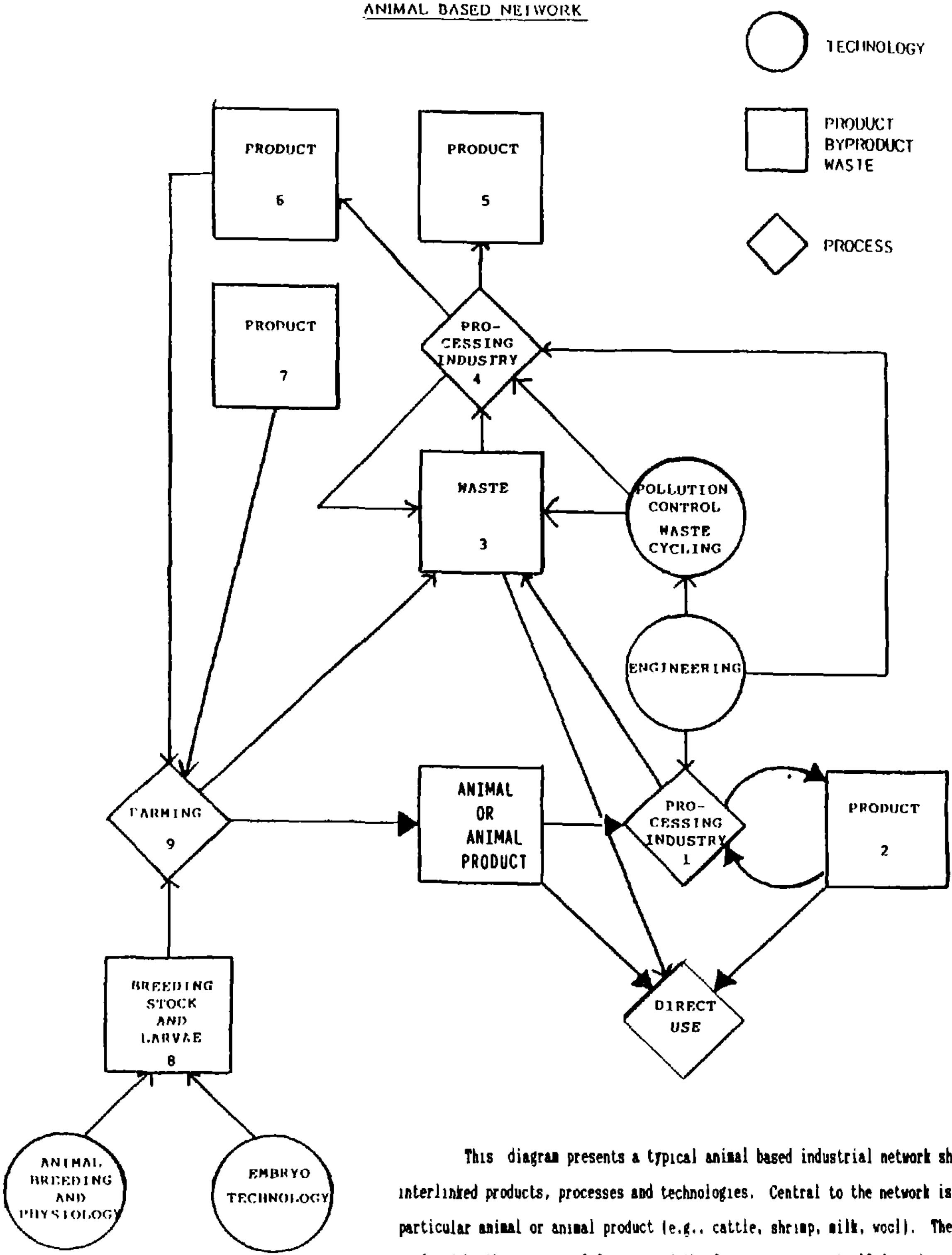
Figure 1.1

PLANT BASED NETWORK



This diagram presents a typical plant based industrial network showing interlinked products, processes and technologies. Central to the network is the particular plant crop. This is produced by the process of farming and the farming process itself depends upon the input of various products some of which may derive from downstream processing of its own products, byproducts or wastes (e.g., fertilizer derived from the fermentative process of composting). Other product inputs are seeds and seedlings that may be produced or improved using various biotechnologies. Downstream processing of the crop can lead to various products and wastes which require other technological inputs.

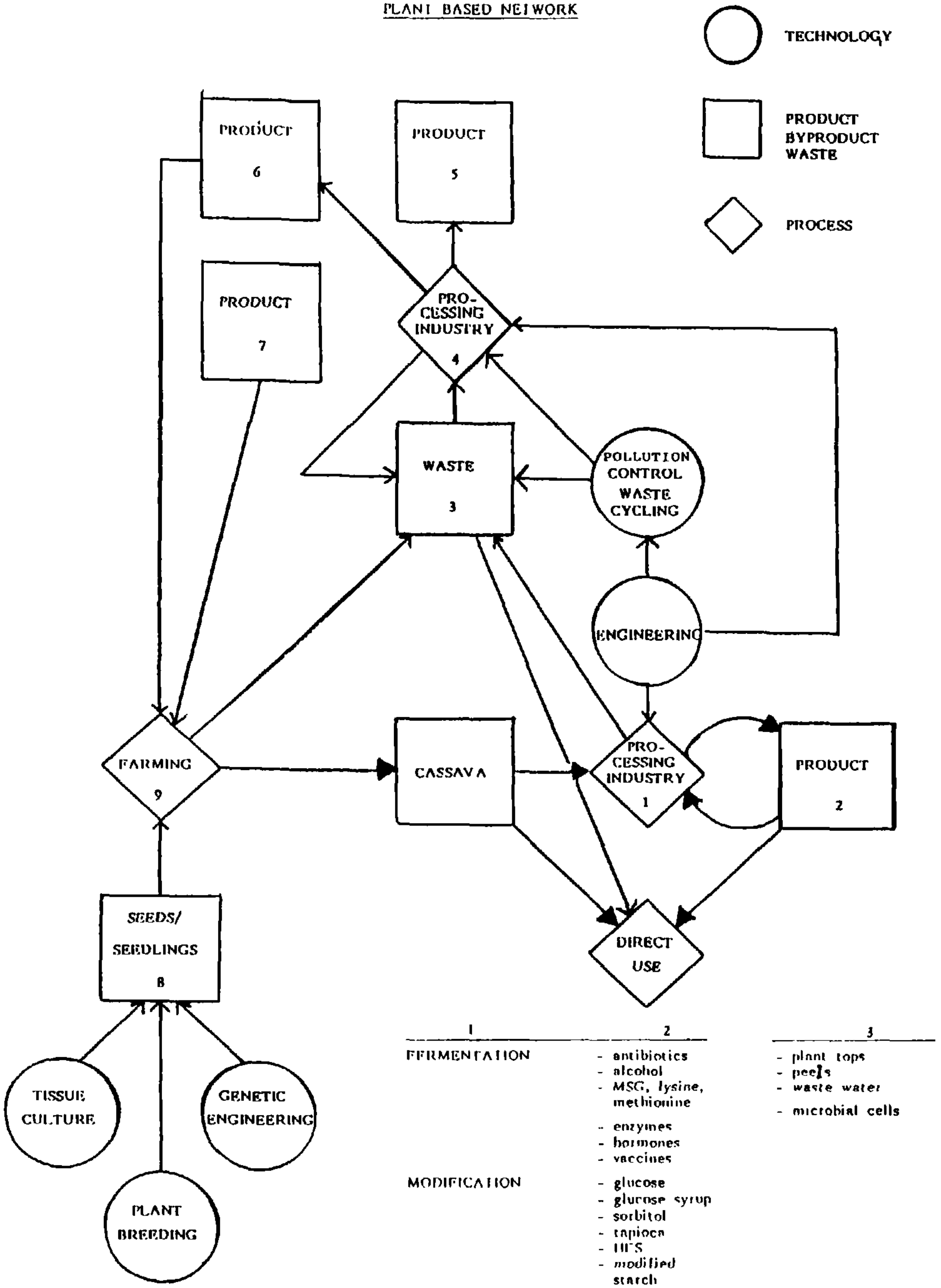
Figure 1.2
ANIMAL BASED NETWORK



This diagram presents a typical animal based industrial network showing interlinked products, processes and technologies. Central to the network is the particular animal or animal product (e.g., cattle, shrimp, milk, wool). These are produced by the process of farming and the farming process itself depends upon the input of various products, some of which may derive from downstream processing of its own products, byproducts or wastes. Other product inputs are breeding stock or larvae that may be produced or improved using various biotechnological technologies. Downstream processing of the animal or its products can lead to various products and wastes which require other technological inputs.

Figure 1.3

PLANT BASED NETWORK



1	2	3
FERMENTATION	- antibiotics - alcohol - MSG, *lysine*, methionine - enzymes - hormones - vaccines	- plant tops - peels - *waste water* - microbial cells
MODIFICATION	- glucose - glucose syrup - sorbitol - tapioca - HFS - *modified* starch	
MILLING	- starch	
FOOD PROCESSING	- *finished foods* - beverages	

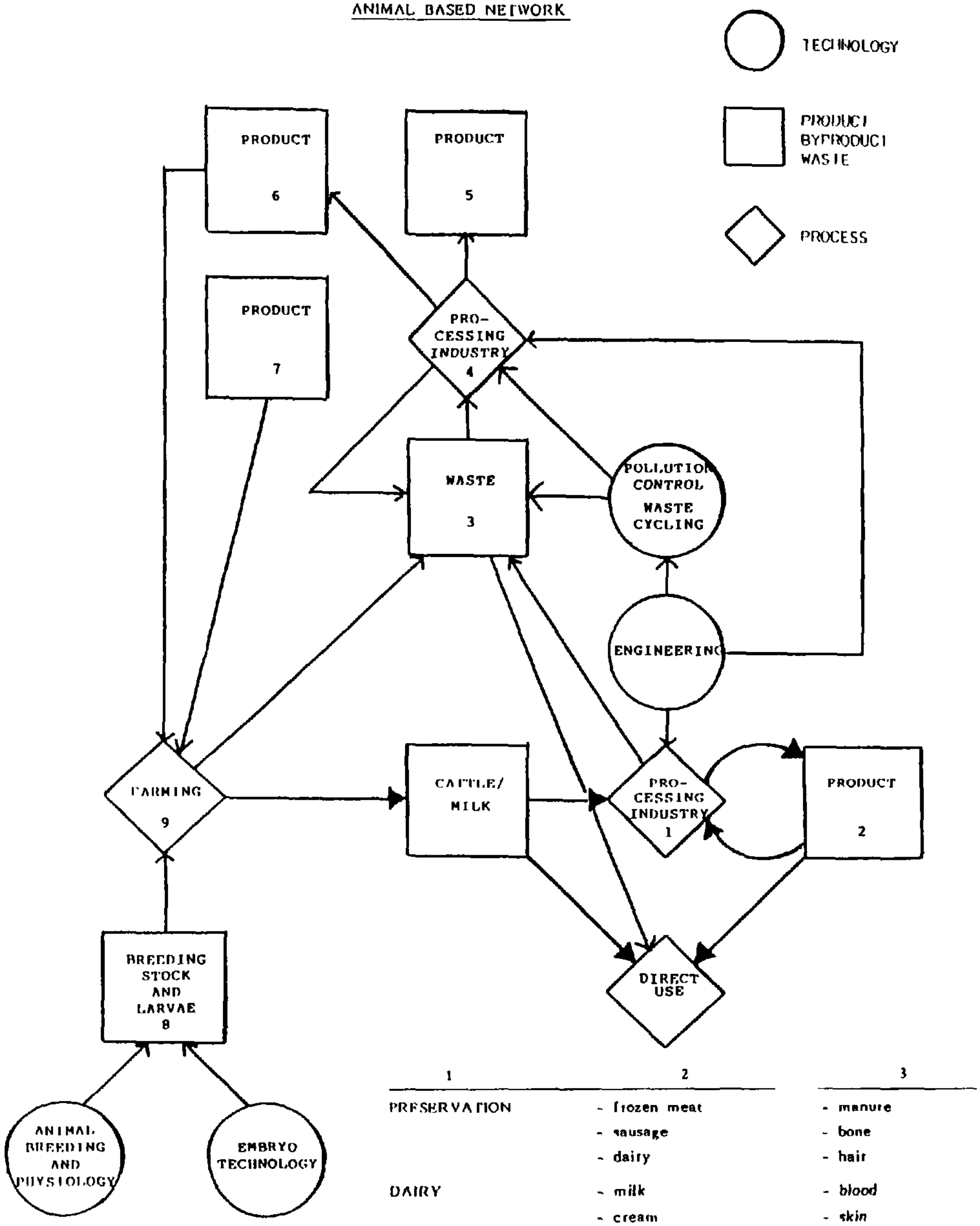
4	5	6	7
FERMENTATION	- citric acid - alcohol - vinegar - SCP	- pesticides - compost	- fertilizers - pesticides

Figure 1.3 is a specific illustration of a plant based network using cassava as the crop. The crop is fed to various processing industries including those for fermentation, modification, milling and food processing. Often the products from one processing industry serve as a raw material for another processing industry. For example, cassava starch produced by milling may be sent to a factory where it is enzymatically converted (modification) to glucose syrup. The glucose syrup may in turn serve as a raw material for the food processing industry to be used in confectionary products or beverages. These processing industries require engineering inputs and they produce wastes in addition to products. The wastes must be treated or cycled and waste processing industries can in turn produce various products, some of which may serve as inputs to the original animal production process. In the diagram, processes are enclosed in diamonds, products, byproducts and wastes are enclosed in squares and technologies are enclosed in circles. The various items are numbered in the diagram and specific example processes and products are listed for these numbers at the bottom right hand corner of the diagram.

Figure 1.4 is a specific illustration of a animal based network using cattle and milk as the central agricultural products. These products are fed to various processing industries including the dairy processing industry and those industries for fermentation and preservation. Often the products from one processing industry serve as a raw material for another processing industry. For example, powdered milk produced by one factory could be sent to another in the food processing industry to be used as an ingredient. These processing industries require engineering inputs and they produce wastes in addition to products. The wastes must be treated or cycled and waste processing industries can in turn produce various products, some of which may serve as inputs to the original animal production process. In the diagram, processes are enclosed in diamonds, products, byproducts and wastes are enclosed in squares and technologies are enclosed in circles. The various items are numbered in the diagram and specific example processes and products are listed for these numbers at the bottom right hand corner of the diagram.

Figure 1.4

ANIMAL BASED NETWORK



1	2	3
PRESERVATION	- frozen meat	- manure
	- sausage	- bone
	- dairy	- hair
DAIRY	- milk	- blood
	- cream	- skin
FERMENTATION	- butter	
	- yoghurt	
	- cheese	
	- yakult	

4	5	6	7
MILLING	feeds		- feeds
TANNING	leather		- vaccines
FERMENATATION	biogas	fertilizer	- diagnostics
			- antibiotics
			- hormones

assessment of the science and technology infrastructure. Major limitations in, and opportunities resulting from, the present infrastructure are outlined.

Chapter 3 **Profile of Present Technological Capability of Thai Industry** The products, processes and technologies of the biotechnology-based industries are presented, with profile of the companies chosen for survey. Profiles and assessments of operative, adaptive, innovative and acquisitive capabilities are given.

Profiles and roles of private sector supportive agents are then presented, followed by a discussion on the interaction between producing firms and infrastructure agents.

Chapter 4 **Behavior and Attitude of Firms toward Technology** Past behavior in choosing technology is analyzed. Evolution and economic significance of different types of capability are examined along with practice in human capital formation and development. Managerial capability, entrepreneurial attitude and business strategy are discussed in terms of their impacts on technological capabilities.

Chapter 5 **Bridging the Present Capability Gaps and Building Future Capability.** The strengths and weaknesses in technological capability in biotechnology-based industries are identified, leading to identification of the gaps between present capability and needed capability. Possible future industries and future technologies are given as examples. Commitment needed to bridge the present gap and build future capability is then put forward.

Chapter 6 **Major Strategies for Gaining Needed Future Capabilities for Thai Industry.** The various strategies discussed include: export promotion, protection and promotion measures, procurement regulations for strategic products, promotion of foreign technology acquisition and absorption, allocation of financial resources, promotion of research and development, selective strengthening of key institutions, targeted science and technology manpower planning, coordinated policies for industrial planning and technological development, positions on legal issues and positions on utilization and conservation of genetic resources.

Chapter 7 **The Policy Recommendations.** This chapter compites our policy recommendations on the following: industrial planning, investment promotion, tariffs and taxes, financial instruments, private-public cooperation, manpower development, research & development, industrial support, technical assistance, trade policy and legal issues.

2. THE ENVIRONMENT

2.1 The Policy Environment

2.1.1 Industrial and Macroeconomic Policies

Industrialization in any country is a fairly long process. In Thailand, it was not until the 1960s that industrialization began to be actively promoted. During the 1960s and early 1970s, the manufacturing industry in Thailand was mainly aimed at import-substitution. Export oriented industrialization and second phase import-substitution industrialization has been promoted since the second half of the 1970s. In order to promote industrialization in the country, various industrial and macroeconomic policy measures have been pursued. They include promotion of direct foreign investment, protection of domestic industries against competition from imports, provision of fiscal and financial incentives for production of goods for domestic consumption and for export, and encouraged development of large, medium, and small scale industries, particularly those in the agro-based, labour intensive, and resource-based industries.

As far as technological capability is concerned, the formulation of the above industrial and macroeconomic policies was not aimed specifically at enhancing technology and skills in the Thai industries. When the policies were implementd however, they did affect technology indirectly. The following paragraphs assess the effects of the industrial and macroeconomic policies and measures on the enhancement of technology and skills in the biotechnology-based industries.

a. Direct Foreign Investment

Although the principles behind the Thai government's promotion of direct foreign investment were concerned with balance of payments, trade, and employment considerations, it is often argued that it was also a means by which needed technology was brought into the country. However, this arguement has been strongly challenged by several research studies examining technology transfer by multinational corporations in Thailand. Moreover, studies of licensing agreements of local and joint-venture firms in Thailand testifies that the local technology buyers are often restricted by several requirements and prohibitions.

Direct foreign investment in the biotechnology-based industries in Thailand has been concentrated in the food, beverage, health, and health related industries. One of the important motivations for direct investment by foreigners was to maintain their share of the domestic market and production was mainly concerned with mixing and packaging of imported ingredients. Process and product technologies were only slightly modified to suit local requiremets. However, there was greater technological adaptation in the area of raw materials in order to exploit cheaper materials abundant locally. Under these circumstances, empirical studies suggested that technology transfer by foreign invested firms was not singnificant (Santikarn, 1981: Tamboonlertchai, 1984; and Khanthachai, 1987).

Government intervention in technology transactions between private enterprises in Thailand and foreign technology suppliers is virtually non-existent, Examination of technology contracts of the large payers for technology revealed that producers in cosmetic and toileteries, and food industries were among the top six payers despite the fact that a major proportion of the contractually purchased technologies were relatively unsophisticated technologies involving batch mixing and assembling techniques. For example, it cost one technology recipient 14 percent of its gross sales to produce a famous brand name of Chicken Stock (ESCAP,1983: p.41).

With respect to restrictive business practices, studies on the role of multinational corporations in technology transfer revealed that they imposed restrictive conditions on their counterparts in terms of purchase of inputs, sale to export markets, and technology transmission. For example, joint-venture firms in the food and beverage industries were not allowed to export their products. Moreover, some firms in these industries had to buy raw materials, intermediate inputs, and machinery from their technology suppliers. Conditions affecting technology transmission included prohibition of the use of know-how upon expiration of contract, prohibition of know-how duplication and/or reverse engineering, and the termination of production and sales after the expiry of the contract (ESCAP, 1983: p.64).

Nevertheless, examination of technology contracts also revealed that certain conditions enhancing technology transfer were provided. Important provisions for the enhancement of technological skills in Thai industries were provision of foreign experts at the recipients'plant, training of the recipients' staff at the suppliers' factory, and quarantees for certain achievements in quality or quantity of production.

b. Industrial Protection

Arguements for industrial protection are generally defended in terms of effect on local infant industries, on employment of local manpower, and on balance of payments. In a partial equilibrium analysis, protected industry becomes an attractive area for investment since protection from foreign competition ensures firms of markets for their products and enables them to produce at a higher cost or a higher profit. Moerover, protection can result, at least in the short run, in the enhancement of technology and skills in the protected industries.

Table 2.1 Input-Output Sector Nominal and Effective Rates of Protection for Biotechnology-based Products, April 1985 and January 1988.

(Unit:per cent)

Input-Output Sector	Nominal Protection Rates			Effective Protection Rates		
	Apr. 85	Jan. 88	Change	Apr.85	Jan. 88	Change
Agriculture						
1. Vegetable	46.4	46.4	0.0	53.0	53.0	0.0
2. Fruits	93.4	93.4	0.0	107.0	107.0	0.0
3. Kenaf and Jute	30.0	30.0	0.0	31.0	31.0	0.0
4. Coffee and tea	53.3	53.3	0.0	56.0	56.0	0.0
5. Cattle and buffalo	6.7	6.7	0.0	7.0	7.0	0.0
6. Swine	5.0	5.0	0.0	6.0	6.0	0.0
7. Other Livestock	25.8	25.8	0.0	39.0	39.0	0.0
8. Poultry	13.3	13.3	0.0	22.0	22.0	0.0
Agro-industries						
1. Dairy products	22.2	22.2	0.0	28.0	28.0	0.0
2. Rice milling	-2.5	-2.5	0.0	-13.0	-13.0	0.0
3. Flour	46.4	46.4	0.0	168.0	168.0	0.0
4. Sugar	0.0	0.0	0.0	-3.0	-3.0	0.0
5. Tobacco processing	60.0	60.0	0.0	999.9	999.9	0.0
6. Tobacco products	54.0	54.0	0.0	62.0	62.0	0.0
7. Jute mill products	43.5	43.5	0.0	57.0	57.0	0.0
8. Leather finishing	60.0	60.0	0.0	249.0	249.0	0.0
9. Rapints and Lacquers	24.9	24.9	0.0	28.0	28.0	0.0
10. Rubber sheet	-15.0	-15.0	0.0	-40.0	-40.0	0.0
11. Animal feet	10.0	10.0	0.0	5.0	5.0	0.0
Food, beverages and specialty chemicals						
1. Canning & pres. meat	61.0	61.0	0.0	123.0	123.0	0.0
2. Pres. fruit & vegetable	0.0	0.0	0.0	-26.0	-26.0	0.0
3. Pres. fish & seafood	0.0	0.0	0.0	-14.0	-14.0	0.0
4. Coconut palm oil	13.7	13.7	0.0	-3.0	-3.0	0.0
5. Animal and veg. oil	22.8	22.8	0.0	18.0	18.0	0.0
6. Bakery product	75.0	75.0	0.0	272.0	272.0	0.0
7. Noodles	95.4	95.4	0.0	999.9	999.9	0.0
8. Monosodium glutamate	60.0	60.0	0.0	152.0	152.0	0.0
9. Food products	43.0	43.0	0.0	60.0	60.0	0.0
10. Distrilling & spirits	104.6	104.6	0.0	168.0	168.0	0.0
11. Breweries	63.7	63.7	0.0	76.0	76.0	0.0
12. Soft drinks, etc.	44.8	44.8	0.0	66.0	66.0	0.0
Health and health related industries						
1. Drugs and medicines	12.9	12.9	0.0	6.0	6.0	0.0
2. Soap and cleaning mats	41.0	41.0	0.0	62.0	62.0	0.0
3. Cosmetics	57.5	57.5	0.0	82.0	83.0	1.0

Source : Brimble, Peter, 1988 (Mimeographed)

Table 2.1 presents nominal and effective rates of protection for biotechnology-based products concerning the period April 1985 to January 1988. It is evident that most biotechnology-based products were given high protection, i.e. the nominal and/or effective rates of protection are higher than 50 percent. Most products in the food, beverages, and specialty chemical industries, in particular, enjoy very high protection. It is also obvious that the structure of tariff protection in the biotechnology-based industries remained stable for several years after the major tariff adjustments that took place in April, 1985. Only the effective rates of protection for flour and cosmetics have slightly increased. Higher tariff rates were imposed on imports of final products than on raw materials and intermediates.

The past expansion in the industrial sector is partly due to benefits from the government's investment promotion policy which has provided high protection to new industries. The system of protection has also created a situtation where some of these industries have become rather inefficient and internationally uncompetitive (NESDB, 1986). For some biotechnology-based products that enjoy high effective rates of protection (ERP), but have low respective indexes of revealed comparative advantage (RCA) (less than unity) are shown in Table 2.2. These include vegetable oil, medical and pharmaceutical products, coffee, tea, cocoa, cereals and their preparations, and organic chemicals (Wiboonchutikula, 1987). The revealed comparative advantage index is defined as the ratio of the share of a commodity in total exports of a country, to the commodity's share in total world exports. A ratio of unity reveals an export specialization that is equivalent to the global average (Wibonchutikula, 1987). According to Balassa (1977, cited in Wiboonchutikula, 1987) the degree of specialization and diversification of manufactured exports can be indicated by the standard deviation of revealed comparative advantage indexes and may be explained by reference to the size of domestic markets, by the level of technological development and by natural resource endowment.

Table 2.2

REVEALED COMPARATIVE ADVANTAGE OF BIOTECHNOLOGY-BASED PRODUCTS

SITC	Commodity	Thailand		Indonesia		Malaysia		Philippines	
		1970	1983	1970	1983	1970	1980	1970	1983
0114	Poultry, Flesh, Cheld, Frzn	n.a.	7.78	n.a.	0.00	n.a.	0.00	n.a.	0.00
03	Fish & their preparations	3.00	9.57	0.68	1.39	2.49	1.39	0.25	3.31
04	Cereals & their preparations	14.18	13.41	0.13	0.00	0.00	0.07	0.02	0.19
05	Vegetables & fruit	5.36	10.31	0.40	0.00	0.73	0.39	2.45	4.75
06	Sugar & preps, honey	1.24	12.91	0.30	0.00	0.00	0.00	24.33	17.38
07	Coffee, tea, cocoa, spicies	0.00	0.49	5.54	3.44	0.84	1.03	0.00	1.55
081	Feeding stuff for animals	1.33	2.26	0.94	0.71	0.00	0.54	2.58	17.90
09	Misc. edible products	0.00	2.22	0.00	0.00	0.00	1.85	0.00	0.00
12	Tobacco and manufacturers	2.80	3.35	0.98	0.00	1.91	0.00	2.73	1.87
22	Oil scene, Oleaginous frt.	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.42
23	Rubber, crude	0.00	24.68	0.00	12.28	0.00	42.88	0.00	0.00
42	Fixed vegetable oil, fat	0.00	0.00	7.16	3.05	12.64	55.82	20.32	57.94
51	Organic chemicals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64
541	Medicinal, pharn products	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00

Source : United Nations : International Trade Statistics Yearbook, various issues

Table 2.2 also compares RCA indexes for biotechnology-based products among the ASEAN countries, and their changes over the period 1970-1983 (1980 in the case of Malaysia due to unavailability of data). For Thailand, the level of international competitiveness of most biotechnology-based products tended to improve despite the fact that some products had RCA indexes less than unity. Since January 1988, tariff adjustments have little changed the system of industrial protection described earlier, and it can be said with some degree of certainty that the RCA indexes for various commodities presented in Table 2.2 still represent current levels of competitiveness in the biotechnology-based industries in the Thai economy.

It should also be mentioned that the relatively lower rates of tariff imposed on imported raw materials and intermediates (as reflected in the ERP indexes) would tend to result in a low rate of local adaptation and substitution of raw materials and intermediates for some industries (e.g., those producing soap and cleaning materials, soft drinks, and cosmetics). Morever, sub-contracting for production or supply of raw materials and intermediate products would also be discouraged. These in turn hamper technological development in Thai industries.

c. Import-substitution Policy

It was not until the second half of the 1960s that the Thai government began to actively pursue import-substitution policies in the industrial sector via the use of trade taxes to protect domestic industries. The pursuance of these important substitution policies contributed substantially to the industrial expansion (29.4%) from 1966 to 1972. In the biotechnology-based industries in particular, beverage and tobacco production growth accounted for about 26.4 per cent of the import-substitution effect. However, there was no net import-substitution effect on the expansion of the biotechnology-based industries during the period of 1972-75. The periods of 1976-78 and 1977-80 even saw negative import-substitution effects on the growth of the processed food, beverage and tobacco industries (World Bank, 1982).

The import-substitution policy has led paradoxically to import dependence in Thai industries. This is partly due to the fact that the assembling industries still have to import raw materials and intermediate products from outside the country. The beverage and pharmaceutical industries may be cited as examples of biotechnology-based industries in Thailand which have exhibited some degree of import-dependence as well as technological dependence. For example Table 2.3 shows that domestic production and imports of drugs and medicine for Thailand increased during the period 1983-1986.

Table 2.3

PRODUCTION AND IMPORT OF DRUGS AND MEDICINE FOR THAILAND FROM 1983 TO 1986

Year	Production	Import
1983	3,892,272,213	2,346,420,732
1984	5,569,338,426	2,118,939,644
1985	6,754,204,049	2,915,564,724
1986	4,959,002,482	7,028,680,519

Source : Office of the Committee on Food and Drug.

Table 2.4 demonstrates increasing trend of imports of Antibiotics, i.e. Penicillins, Aureomycin, Teramycin, Chloramphenical Chaloramphenicolpalimitates, Erythromycin, Tetracycline, and other Antibiotics from 1972 to 1986.

Table 2.4

IMPORT OF ANTIBIOTICS FOR THAILAND, 1972-1986

Year	Penicillins	Aureomycin	Terra-mycin	Chloram	Erythro-mycin	Tetracy-cline	Other Antibiotics
1972	12,752.0	1,465.4	869.8	7,048.2	538.0	24,183.4	18,204.6
1975	24,037.5	1,706.0	2,145.6	19,215.9	713.1	39,665.0	47,752.4
1980	47,707.6	2,903.2	5,875.6	5,612,751.0	5,352.6	66,055.2	179,299.8
1985	135,136.4	14,703.3	5,440.8	33,822.6	29,480.7	62,271.5	355,643.0
1986	273,721.9	15,162.4	12,142.2	49,076.0	36,824.0	59,450.6	218,735.8

Source :Department of Customs : Foreign Trade Statistics of Thailand (various issues)

To demonstrate the technological dependence in some biotechnology-based industries, payments made for technology from aboard may be considered. Table 2.5 presents the payments made for technology in the cosmetics, pharmaceutical and food and beverage industries during the period 1978-1983. The payments were in the forms of royalties, trademark fees, technical assistance fees, and management fees and they tended to increase over the period. The increasing trends of technology payments suggest an increasing degree of technological dependence in Thai industries. It should also be noted that the food and beverages industries made the second largest technology payment in 1983. The largest payment for foreign technology in the same year was made by the automobile and spare parts industries.

Table 2.5

PAYMENTS MADE FOR TECHNOLOGY FROM ABOARD IN SOME BIOTECHNOLOGY-BASED INDUSTRIES, 1987-1983

Industry	1978	1980	1983
Cosmetic	43.8	102.5	143.7
Pharmaceutical	53.7	79.3	103.3
Food and beverage	41.4	110.8	222.9

Source : Bank of Thailand

d. Tax Structure

The present business tax, which has been an important source of government revenue, encourages vertical integration of business activities. In fact, several biotechnology-based firms in Thai industry, particularly those in agro-industry are highly vertically integrated. The calculation for business tax is based on the total value of sale, not on the increase in value of a product at each stage of production, distribution or sale, as in the value-added tax (VAT) system. Thus, it is biased against separation of a production process into several stages to be carried out by separate producers and against subcontracting systems. In this way, the business tax system discourages specialization and technological development in the various stages of economic activity. Moreover, this type of business tax hampers exports in the sense that there are too many different rates, it is complicated and difficult to interpret, not to mention too many loopholes that exist.

e. Small and Medium Scale Industries

More than 95 per cent of the firms in the biotechnology-based industries in thailand are small and medium. They employ less than 200 workers. They are also numerous in the various regions of

Thailand as they tend to be established in the areas where there is proximity to supply of raw materials. Most of these firms use rudimentary technologies in their production.

Although small and medium establishments in the biotechnology-based industries have great potential for laying down the foundation of technological development in the Thai industries, the government has not seriously promoted their development. Thus, these industries frequently encounter financial, operational, production and marketing problems. Production linkages or subcontracting amongst small scale, medium scale and large scale industries are still very limited, resulting in slow expansion and slow technological modernization in the small and medium scale establishments in thebiotechnology-based industries.

2.1.2 Technology Policies

a. General Issues and Priorities.

Technology policies in Thailand are generally considered as a part of science and technology policies. Presently the National Economic and Social Development Board (NESDB) is responsible for five-year national plans which include science and technology aspects. The NESDB works in collaboration with the Ministry of Science, Technology and Energy (MOSTE) in formulation of the plans and major projects. Major difficulties are encountered, however, in the implementation of the plans and projects, since they usually involved other agencies than MOSTE. Recently, the problem of policy formulation and implementation in the various agencies has been addressed in the Sixth National Plan (1987 - 1991) by proposed formation of an inter-agency advisory committee.

A close analysis of the status of science and technology in Thailand reveals that it is relatively strong in some areas such as biosciences, but rather weak in many areas of physical sciences. In engineering, while strong services are available, there is very little research and development activity. These considerations, plus considerations of relative advantage in terms of resources and demand led to selection of priority areas and targeting of goals in the medium term. Such analysis contributes to the formulation of concrete targets in the science and technology development plan in the Sixth National Economic and Social Development Plan and the recently launched Science and Technology for Development Project. In brief, the targets include strengthening of capability in three main areas: biotechnology, metallurgy and materials science, and electronics and computer technology. Specific sub-areas within these main areas were defined, so that the course of future development can be closely determined and monitored.

Although these refinements in targeting and prioritization represent major improvements in science and technology policy formulation in Thailand, they still suffer from lack of thorough and systematic studies on the status of technological capabilities, and the assessment of the impact of the introduction of new technologies or strengthening of presently existing technologies. Assessment of both present status and future impacts of various sub-areas of science and technology is a major requirement before an attempt can be made to improve the policy and planning process, especially in the medium and long term.

The major components of the science and technology development plan in the Sixth National Plan are listed in Table 2.1. Apart from this, science and technology are also integral components of other parts of the Sixth National Plan, such as the program for development of the production system, marketing and employment (Table 2.2).

Until very recently, there has been very little long-range planning in science and technology in Thailand. This issue has been considered in the Sixth National Plan, and a long-range planning process (time scale of 20 years) has recently been launched by MOSTE. Concurrently, the Ministry of University Affairs has also been engaged in long-range planning for higher education, and science and technology have been included as parts of the environmental scanning required for this plan.

The components of technology policies include technology transfer and diffusion policy, research and development policy and manpower policy. These will be discussed in brief below.

b. Technology Transfer and Diffusion Policy.

The extent of technology import from foreign countries to Thailand is increasing at the rate of approximately 8% per year and, in 1985, stood at Baht 2,044 million (MOSTE, 1987). Although these imports have helped the flow of technology into the country, technology transfer contracts often include restrictive clauses, such as prohibition of product export, compulsory purchase of raw materials

Table 2.1

MAJOR COMPONENTS IN SCIENCE AND TECHNOLOGY DEVELOPMENT OF THE SIXTH NATIONAL ECONOMIC AND SOCIAL DEVELOPMENT PLAN
1987 - 1991

1. Policy formulation and planning capabilities
   - Formulation of long-term policy.
   - Development of a science and technology indicator system and of technology assessment capability.

2. Institutional and infrastructural strengthening
   - Establishment of a high-level mechanism for formulation of science and technology policy.
   - Strengthening of management mechanisms for programs and projects in science and technology.
   - Improvement of the legal framework, rules and regulations to promote science and technology.

3. Development of scientific and technical manpower and public promotion
   - Development of manpower in needed areas of science and technology, with emphasis on increase in supply of engineers.
   - Promotion of technical skill at the craftsman level.
   - Development of science and technology manpower at the school level.
   - Promotion of public awareness and appreciation of science and technology

4. Promotion of research and development
   - Formulation of research and development policies.

- Targeting the research and development budget to reach 0.5 % of GNP (about 2 % of government budget)
- Improvement of research and development to meet the demand of users.
- Support for research and development especially in priority areas (biotechnology, materials and metals technology, electronics and computer technology), including setting up of special supporting institutions in the Ministry of Science, Technology and Energy.

5. Promotion of technology transfer
   - Setting up a national policy and plans for technology transfer.
   - Improvement of the Technology Transfer Center, including setting up an information bank on technology transfer agreements.
   - Improvement of promotional measures by the Board of Investment so as to include a focus on technology as well as on economics and the environment.
   - Improvement of the data system on technology import and export kept by the Bank of Thailand.

6. Improvement in the scientific and technological information system, including policy information
   - Establishment of a Network for Scientific and Technological Information.
   - Development of a Science and Technology Indicator System.

7. Promotion of development and use of technology by the private sector
   - Improvement of the revolving fund system for technology development loans to the private sector.
   - Development of incentives for the private sector to fund technology development through income tax deduction, and reduction of import duty on research equipment.

- Setting up a Technology Development Subcommittee under the Joint Public-Private Sector Coordination Committee.
- Support for professional societies so as to increase their role in technology development.

Source: NESDB (1987)

Table 2.2

WORK PLANS WITH SCIENCE AND TECHNOLOGY COMPONENTS
IN THE PROGRAMME FOR DEVELOPMENT OF THE PRODUCTION SYSTEM,
MARKETING AND EMPLOYMENT OF THE SIXTH NATIONAL PLAN

1. Production for sale
   - Developing the system of production for sale
   - Restructuring agricultural production
   - Developing agricultural knowhow and technology
   - Developing agro-industries

2. Production diversification and poverty eradication
   - Product diversification
   - Developing agriculture in backward agricultural areas
   - Developing engineering industries
   - Developing small scale and provincial industries

3. Marketing
   - Diversifying export markets

4. Restructuring of the management system for production and marketing
   - Promoting agricultural production
   - Restructuring systems of management and export incentives

Source: NESDB (1987)

and machinery from the seller. The importers of technology are often forced to agree to these terms because of lack of information on technology sources and lack of bargaining power. This is especially true with small and medium-sized industries.

Technology transfer and diffusion policy has been designed to help the industries in choosing and bargaining for technology import, and in gaining access to new local technologies.

In order to encourage technology transfer from abroad and to increase its effectiveness in benefitting economic and technological development, the Technology Transfer Centre was set up as an agency for promotion and facilitation of transfer in the interests of Thai entrepreneurs. A data bank on technology transfer is being established to serve the private sector. In addition, it coordinates the transfer of foreign technology with the development of domestic technological capabilities and also serves as an agency for diffusion of both foreign and domestic technologies. Measures to promote the Technology Transfer Centre have been proposed in the Sixth Plan. In the Sixth Plan, the Board of Investment has also been encouraged to consider technological issues as well as economic and environmental issues in investment promotion.

Since technology transfer involves a number of agencies (e.g., the Ministry of Science, Technology and Energy, where the Technology Transfer Centre is located, the Board of Investment, the Bank of Thailand, the Ministry of Industry, and the Ministry of Agriculture) the Sixth Plan has provided for the establishment of a national committee comprising these agencies and the private sector. The national committee will prepare national policies promoting technology transfer, and propose laws and procedures for ensuring that the transfer benefits the development of local technology.

c. Research and Development Policy.

The Fifth and the Sixth National Plans have set the target for research and development budget at 0.5 % of GNP.

Presently, the government budget for research and development (1986) stands at only 0.19 % of GNP, and it has been on a decreasing trend since 1975, when it was 0.40 % of GNP (MOSTE, 1987). Although the National Research Council has a role in monitoring the research and development budget, there is presently no organization to plan the national research and development budget to achieve the set target. Up until only a few years ago, there was no organization to provide research and development funding to specific areas of science and technology. The establishment of the National Centres for Genetic Engineering and Biotechnology, for Materials and Metal Technology, and for Electronics and Computer Technology represents the first examples of the attempt to support priority areas of research and development in a coordinated fashion. The Science and Technology for Development Project, established through US-Thai cooperation, also provides substantial input into research and development in these three priority areas (see also 2.2.4). The long-term planning process (Section 2.1.2 a) should provide insight into new priority areas in which to place research and development efforts in the future.

The private sector has played a minimal role in research and development up until now. A survey (MOSTE and UNESCO, 1983) showed that the top industrial companies in Thailand spend only 0.11 % of their sales on research and development. This is very low compared with the figures of 2 - 3 % for companies industrial countries. The Sixth National Plan has called for an increase in the role of the private sector in technology development. The research and development revolving fund has been set up in the Ministry of Science, Technology and Energy to support priviate industry, by providing low interest loans with long repayment periods. The private sector will also be encouraged to establish their own technology development fund through various incentives, namely, special income tax deduction for the fund established, income tax exemption on revenues from goodwill, patents and trademarks derived from technology development, and input duty reduction on research equipment. A subcommittee for technology development will be set up under the Joint Public Private Sector Coordination Committee to facilitate technology development in the private sector, and to link public sector research and development efforts to the private sector.

d. Manpower Policy.

The present science and technology manpower policy emphasizes the quality and use of science and technology manpower in engineering, science and agriculture. According to a recent survey (MOSTE and HRI, 1986), Thailand has only 154,000 science and technology manpower in the public sector, of which only 57,000 have degree education. The latter represents only 10 scientists and technologiests per 10,000 population, very low by international standards. There is therefore a great need to increase both the quality and the quantity of manpower supply. Unfortunately, although the Fifth National Plan called for an increase in the supply (e.g., an increase in engineers of 10 % per year owing to a foreseen acute shortage) there has not been any substantial implementation of this policy. A recent study by TDRI (1988) also forecasted a deficit of manpower supply in the priority areas of science and technology.

Apart from the plans to develop manpower at the degree level, the Sixth National Plan also calls for improvement of technical and vocational manpower. In particular, an agency will be established to assess the demand for various qualitative and skill levels of vocational manpower, so that both the quality and quantity of manpower production can be adjusted according to needs. The importance of science and technology at the school level, and of public perception of science and technology will be emphasized as well.

e. Main Problems and Future Policy Directions.

One main problem in technology policy in Thailand is the lack of effective mechanisms for plan implementation. For example, although a target for the research and development budget was set at

0.5 % of GNP in the Fifth Plan there was no mechanism provided to plan and realize this target. It was also proposed in the Fifth Plan that a National Council for Science and Technology be established to elaborate the plans and coordinate their implementation, but this body was never formed. Another plan to increase the production of engineers and scientists during the period of the Fifth Plan was also not substantially implemented. Other plans in science and technology formulated in the Fifth Plan had various difficulties in implementation.

Attempts to implement the plans to promote the role of the private sector in technology development have also been frustrated. For example, there are presently no laws or provisions to promote technology development in the private sector, by allowing income tax incentives for funding set aside for technology development and by exempting research equipment of import duty, although attempts have been made to draft appropriate laws (see eg. TDRI, 1985).

Despite these various problems, there has been some significant development during the last few years in several areas of technology policy. The establishment of national centres for support of specific technologies, and of the Science and Technology Development Board are examples of new institutional arrangements. TDRI, with science and technology policy as a major concern, has also contributed significantly to policy development. With regard to policy implementation, a recent development is the establishment of the revolving fund at the Ministry of Science for loan by the private sector in technology development. A similar loan scheme is operated by the Science and Technology Development Board.

Major directions for the future, put forward in the Sixth National Plan, include, 1) development of a comprehensive and reliable system of science and technology indicators to show the status of science and technology in various aspects, and 2)development of a technology assessment capability especially for medium and long-term planning, both in specific technology areas and in broad areas where technology is a major component, (e.g., the patent system). The outcome of the present study should also point to many new policy directions. These will be dealt with in detail in Ch. 6 and 7.

Another major development in the future is the increasing internationalization of science and technology in Thailand. There are various indications that Thailand is rapidly moving towards the status of a newly industrialized country. This implies that the country must have internationally competitive technology. It can be expected that there will be an increasing flood of technology import, which requires various measures to receive and adapt the technologies effectively. Indigenous research and development will also need to keep pace with technology import, again implying various measures to bring them up to international standard. In the short term, we believe that the policy direction should aim for improvement of regional co-operation in science and technology in southeast Asia. Since the great majority of science and technology activities are performed by the government sector, it is clear that government policies of the various countries can have an enormous influence on this co-operation. For example, many co-operative programmes launched through the ASEAN Committee on Science and Technology, with well co-ordinated activities in the member countries and assistance from dialogue partners, may be more dynamic and create a greater impact than small programmes launched individually or through a bilateral mechanism. The nature of such preferred programmes, of course, depends on the common interest of the countries. Compared with programmes in other areas, such as industry and trade, science and technology programmes are relatively free from competition and conflicts of interest among the countries, and therefore should be relatively easy to develop through regional co-operation. The ASEAN countries should place much more emphasis on this regional co-operation, in order to achieve substantial capability and self-reliance in science and technology for the region.

Specifically, regional centres of excellence and their networks on important areas, such as biotechnology, microelectronics and materials science may need to be designated, in order to build up capability in these areas rapidly. Collaborative programmes, including research and development, technology transfer and training aspects, need to be formulated. Support for the centres, networks and programs may be sought in part from the ASEAN countries themselves.

The private sector in ASEAN is not well linked with the government sector, and although it imports substantial amounts of commercial technology, it fails to develop it further. Linkage with the government sector is needed in view of the fact that most research and development activity is performed there. When suitably coupled with technology import, it can lead to more mature technology in the long run. However the role of the government sector should be promotive and flexible, allowing productive interaction with the private sector. The government sector in many ASEAN countries still needs to undergo major changes in order to meet these criteria. The ASEAN organization may be a significant factor in promoting this public-private sector linkage. While detailed mechanisms need to be worked out for such linkage, it is possible that such ASEAN private sector organisations as the ASEAN Chamber of Commerce and Industry (ASEAN CCI) can become involved. The research, development and training activities in the government sector in ASEAN can be modified with the end users in the private sector in mind.

2.2 The Science and Technology Infrastructure: Profile of Supportive Capability in Biotechnology

2.2.1 Education and Training

Among developing countries, Thailand is considered as having a relatively good potential in biotechnology, with "a good quality but limited infrastructure in the relevant sciences, and a gathering momentum" (UNIDO, 1983). However, the present education and training programs still concentrate mainly on traditional areas of science, agriculture and medicine, with little capacity for production of manpower in new biotechnology areas. Biotechnology education in Thailand has been assessed in a number of reports (Chulavatnatol, 1987; Yuthavong, 1987; Atthasampunna et al., 1988). Presently, two universities are producing bachelor degree graduates in biotechnology, with a combined total of 40 graduates per year, and two other universities are starting bachelor programs. However, the manpower production capacity of current bachelor programs related to biotechnology and engineering totals about 2000 graduates per year (Table 2.3). The production capacity at the master degree level totals about 10 in biotechnology specifically, and about 450 in biotechnology-related areas. The capacity for doctoral degree education is still very limited at present, with programs only in biosciences and medicine.

In the near future, four more universities will offer bachelor degree programs, and four others will offer master degree programs in biotechnology, substantially increasing the production capacity. A doctoral degree program in biotechnology will also be offered shortly at Kasetsart University. This will be additional to the biosciences doctoral degree programs offered at Mahidol University.

The contents of bachelor degree programs comprise both basic and applied sciences, with emphasis on fermentation technology and applied microbiology. Up to two thirds of the contents are very similar to those of food technology or agro-industrial product development programs. The graduate degree programs usually emphasize research in areas similar to those of biosciences and food science and technology programs. There is still rather little emphasis on the new aspects of biotechnology. Both the bachelor and graduate degree programs need to be strengthened with respect to new and essential aspects of modern biotechnology. Furthermore, since biotechnology is

Table 2.3

PRESENT MANPOWER PRODUCTION CAPACITY OF CURRENT PROGRAMS
RELATED TO BIOTECHNOLOGY AND GENETIC ENGINEERING

A. Bachelor Degree's Program

Classification	University/Institute							TOTAL
	CU	KU	MU	KMITT	KKU	CMU	SU	
Agriculture	-	338	-	-	170	137	85	730
Biochemistry	16	-	-	-	-	-	-	16
Chemical Engineering	26	-	-	39	-	-	12	77
Chemical Technology	49	-	-	-	-	-	-	49
Biotechnology	-	12	22	-	-	-	-	34
Food Technology	34	-	-	-	-	-	-	34
Food Science	-	31	-	-	-	36	-	67
Genetics	7	-	-	-	-	-	-	7
Medicine	137	-	416	-	70	114	75	812
Microbiology	22	-	-	10	-	-	-	32
Sanitary Engineering	17	-	-	-	-	-	-	17
Environmental Engineering	-	-	-	-	6	16	-	22
Fisheries Science & Aquaculture	-	65	-	-	-	-	14	79
Marine Science	3	-	-	-	-	-	-	3
Veterinary Science	44	51	-	-	-	-	-	91
TOTAL	356	497	438	49	246	303	186	2070

CU = Chulalongkorn University; KU = Kasetsart University;
MU = Mahidol University; KMITT = King Mongkut's Institute of Technology; Thonburi
KKU = Khon Kaen University; CMU = Chiang Mai University;
SU = Prince of Songkhla University

All figures represent 1986 data

Note: New programs have been started at Khon Kaen University and King Mongkut Institute of Technology, Ladkrabang.

B. Master Degree's Program

Classification	University/Institute							TOTAL
	CU	KU	MU	KMITT	KKU	CMU	SU	
Agriculture	-	184	-	-	13	3	-	200
Biochemistry	3	-	16	-	-	-	-	19
Biomedical Instrumentation	-	-	6	-	-	-	-	-
Chemical Engineering	11	-	-	6	-	-	-	17
Chemical Technology	-	-	-	-	-	-	-	-
Biotechnology	5	-	-	5	-	-	-	10
Fisheries & Aquaculture	-	9	-	-	-	-	-	9
Food Technology	9	-	-	-	-	-	-	9
Food Science	-	5	-	-	-	-	-	5
Food Chemistry	-	-	-	-	-	-	-	-
Genetics	3	4	-	-	-	-	-	7
Marine Biology	10	-	-	-	-	-	-	10
Medicine	16	-	57	-	14	3	-	90
Microbiology	3	12	12	-	-	-	-	27
Sanitary Engineering	17	-	-	-	-	-	-	17
Tropical Medicine	-	-	27	-	-	-	-	27
TOTAL	77	214	112	11	27	6	-	447

C. Doctoral Degree's Program

Classification	University/Institute							TOTAL
	CU[a]	KU[a]	MU[b]	KMITT	KKU	CMU	SU	
Agriculture	-	3	-	-	-	-	-	3
Biochemistry	-	-	22	-	-	-	-	22
Microbiology	-	-	22	-	-	-	-	22
Tropical Medicine	-	-	1	-	-	-	-	1
TOTAL	-	3	45	-	-	-	-	48

[a] = Estimated number of graduates

[b] = Total number of graduates since establishment of program (1970)

interdisciplinary in nature, it has been proposed that other graduate degree programs than biotechnology should also be strengthened, including biochemical engineering, bioinstrumentation and molecular biology (Suwana-adth et al., 1986).

Presently, there is a healthy demand for bachelor graduates by the industries, which also take a significant role in practical training of the students. However, there is still rather limited demand for master and doctoral graduates in the industries, due to limited research and development activities. The bachelor graduates recruited by the industries have been found to be mainly engaged in analysis and quality control work. The training programs during their education appear to be beneficial both in preparing them for the jobs and in linking the universities with the industries, that is, bringing industrial problems to the attention of the academia and activating industries to become aware of the potentials of academia in solving their problems.

2.2.2 Research and Development

Research and development in biotechnology are presently done mostly in universities. Table 2.4 shows an estimate of manpower engaged in biotechnology at various universities and government agencies in Thailand (Yuthavong, 1987; Atthasampunna, 1988). The combined core strength of manpower in research and development in some major 20 institutions is less than 500.

The present research strengths are in biomedical and agricultural sciences, while such areas as bioprocess engineering are still to be further developed.

Mahidol University has various active research groups, with emphasis on molecular biology and genetic engineering in various biomedical areas, and especially in those concerning tropical diseases and industrial microbiology. Kasetsart University is active in various areas of agricultural biotechnology, including tissue culture

Table 2.4

LOCATIONS AND CORE STRENGTHS OF INSTITUTIONS ENGAGED IN BIOTECHNOLOGY IN THAILAND

Institution	Location	Core Strength
Asian Institute of Technology	Bangkok	10
Chiang Mai University - Research Institute for Health Sciences - Institute for Science and Technology Research and Development	Chiang Mai	20
Chulalongkorn University - Institute of Biotechnology and Genetic Engineering - Marine Biotechnology Laboratory	Bangkok	50
Kasetsart University - Central Laboratory and Green House Complex - Institute of Food Research and Product Development - Plant Genetic Engineering Laboratory	Bangkok and Nakhon Pathom	70
Khon Kaen University	Khon Kaen	20
King Mongkut's Institute of Technology Thonburi - Biochemical Engineering and Pilot Plant Research and Development Laboratory	Bangkok	20

Institution	Location	Core Strength
Mahidol University - Center of Biotechnology - Center of Molecular Genetics and Genetic Engineering - Microbial Genetic Engineering Laboratory	Bangkok	70
Maejo Institute of Agricultural Technology	Chiang Mai	10
Prince of Songkhla University	Songkhla	10
Srinakarinwirote University	Bangkok and Chon Buri	20
Armed Forces Research Institute of Medical Science	Bangkok	20
Department of Agriculture - Field Crops Research Institute - Rhizobium Research Center - Rice Research Institute	Bangkok and provinces	40
Department of Fisheries	Bangkok and provinces	20
Department of Medical Sciences	Bangkok	10
National Institute of Health	Bangkok	10
Thailand Institute of Scientific and Technological Research - Biotechnology Department - Food Industry Department - Pharmaceutical and Natural Products Department	Bangkok	30

Institution	Location	Core Strength
The Thai Red Cross and National Blood Centre	Bangkok	20
	TOTAL	450

[a] = Researchers at M.S. level and higher engaged in R & D in biotechnology.

Sources: Atthasampunna et al. (1988); Yuthavong (1987), and this work for improvement and propagation of various plants, embryo transfer technology and fermentation technology. Chulalongkorn University is well known for research on aquaculture of shrimps, rice tissue culture and processing technologies. King Mongkut Institute of technology Thonburi has various activities on bioengineering and biomass utilization. All of these institutes are locted in the Bangkok area. Among the provincial universities, Chiang Mai University is the most active, with work on tissue culture of various crops, including orchids, teak and potato, and work on post-harvest biotechnology.

Among the government agencies, the Department of Agriculture has a very large research program, much of which is related to biotechnology. An AID supported project enabled the production of Rhizobium on a large scale. Specialized research institutes in this Department deal with rice, rubber, and other crops. Other departments which have research with biotechnology components include the Departments of Fisheries, Livestock, and Forestry. The Thailand Institute for Scientific and Technological Reseach, a Government-funded institute operating as a public enterprise also has many activities in biotechnology areas, mostly concerning industrial microbiology.

Profiles of selected institutes doing research and development in biotechnology will be described here in brief (Research personnel designates only those at M.S. level or higher unless otherwise stated; research budget normally excludes the budget for salaries and routine work).

<u>Center of Biotechnology/Department of Microbiology, Faculty of Science, Mahidol University</u>

Research personnel: 13 Ph.D. (biotechnology and industrial microbiology), 14 Ph.D. (medical microbiology), 10 M.S.

Research budget: Approximately B 5.9 million/yr. (B 0.6 million international grants)

Major areas: Applied microbiology, medical biotechnology

Major achievements: Development of silage fermentation, soy sauce fermentation, new antibiotics, immunodiagnostic agents.

Industrial links: Consultancy for 5 soy sauce factories, 2 sugar mills, 1 agro-industrial company.

<u>Department of Biochemistry/Center for Molecular Genetics and Genetic Engineering/Microbial Genetic Engineering Laboratory, Faculty of Science, Mahidol university</u>

Research personnel: 16 Ph.D., 7 M.S.

Research budget: Approximately B 6.9 million/yr. (B 4.8 million international grants)

Major areas: Medical biotechnology, genetic engineering, enzyme technology.

Major achievements: Development of diagnostics for malaria and mosquitoes, mosquito control agents, diagostic enzymes.

Industrial links: Collaboration with 1 international biotechnology company, 1 local diagnostic company.

Institute of Food Research and Product Development, Kasetsart University

Research personnel: 1 Ph.D., 20 M.S.

Research budget: B 10 million

Major areas: Food technology, food biotechnology, food processing, fermentation technology, enzyme technology, applied microbiology.

Major achievements:
1. Wine production for industry.
2. The development process of wine production to industrialized level.
3. Utilization of microbial enzyme amylase and glucoamylase.

Industrial links: Provide information, technology on food processing and recommendation to food processing industries.

Central Laboratory and Green House/Plant Genetic Engineering Laboratory, Kasetsart University

Research personnel: 70 Ph.D., 50 M.S.

Research budget: B 5.5 million

Major areas: Agriculture.

Major achievements: Seed improvement, fermentation industry.

Industrial links: Providing information and technology to the related industries.

Institute of Biotechnology and Genetic Engineering,
Chulalongkorn University

Research personnel: 2 Ph.D.(Microbiology); 1 Ph.D.(Pharmacology);
4 Ph.D.(Biochem.); 4 Ph.D.(Bioengineering)
2 M.S.(Microbiology);
5 Ph.D.(other institutions cooperating)

Research budget: B 2 million (B 50 million from JICA)

Major areas: Process engineering, biochemistry, microbiology, genetic engineering, organic chemistry, plant tissue culture

Major achievements: Completed pilot scale plant: medical grade glucose

Industrial links: Technical consultancy

Department of Marine Science/Marine Biotechnology Laboratory
Faculty of Science, Chulalongkorn University

Research personnel: 11 Ph.D.; 7 M.S.

Research budget:

Major areas: Basic research in marine science and marine ecology

Major achievements: Projects with ESCAP, STDB, environmental institute; about 5 M.S. per year graduates

Industrial links: - None direct
- Individual consultances on irregular basis

Biochemical Engineering and Pilot Plant Research and Development Unit, King Mongkut Institute of Technology, Thonburi

Research personnel: 8 Ph.D., 8 M.S.

Research budget: 1986: B 1.6 million, 1987: B 1.4 million, 1988: B 1.4 million

Major areas: Process development for yeast, spirulina, industrial alcohol & industrial biogas production

Major achievements:
1. Single-cell protein pilot plant (10 kg dry-yeast/day)
2. Biogas pilot plant (300 cu.m. gas/day)
3. Spirulina pilot plant (30 kg dry/day)
4. Alcohol pilot plant (501 95% ethanal/8 hrs)

Industrial links: Development of biogas and spirulina processes for treatment and utilization of waste effluents from Banpong Tapioca Flour Industry Co., Ltd.

Institute for Science and Technology Research and Development/ Faculty of Agriculture/Faculty of Science, Chiang Mai University

Research personnel: 56 Ph.D., 39 M.S.

Research budget: Approximately B 11.0 million

Major areas: Plant tissue culture, improvement of animal breeding, post harvest technology, fermentation technology, enzyme technology, food technology, natural pharmaceutical products

Major achievements: Production of disease-free strawberry, disease-free potato seeds, salt-tolerent potato seeds, tissue culture of teak; food color additives, single-cell protein from yeast, production of cellulase, glucoamylase and glucoisomerase, production of food yeast and yeast autolysate

Industrial links: -

Research Institute for Health Science, Chiang Mai University

Research personnel: 3 Ph.D., 11 M.S.

Research budget: Approximately B 13.0 million
(B 6.0 million international grant)

Major areas: Nutrition, fertility control, infectious diseases.

Major achievements: Information on nutritional status and foods, infection and fertility control, especially of Northern Thailand.

Industrial links: -

Maejo Institute of Agricultural Technology

Research personnel: 5 Ph.D., 40 M.S.

Research budget: 1985 : B 1.03 million, (B 0.37 million international grant and other sources)
1986 : B 1.29 million, (B 0.7 million international grant and other sources)
1987 : B 3.45 million, (B 2.90 million international grant and other sources)

Major areas: Plant technology, animal technology

Major achievements: Gerbera seed production, improvement of local breeds of chicken, improvement of animal feed

Industrial links: -

Pharmaceutical and Natural Products Research Department

Thailand Institute for Scientific and Technological Research

Research personnel: 1 Ph.D., 15 M.S

Research budget: 1987: Approximately B 4,554,600 (B 1,348,000 from UNIDO/UNDP)

Major areas: Pharmaceutical and natural products

Major achievements: R & D on stevioside, terpinen-4-01, vitamin B, vitamin E, and oryzanol from rice polish, anti-histamine, and RPAS and DRPAS

Industrial links:
1. Testing and quality control
2. Consultative services

Food Industry Department

Thailand Institute of Scientific and Technological Research

Research personnel: 1 Ph.D., 6 M.S.

Research budget: 1986: Approximately B 2,849,122 (B 861,602 international grant from IDRC and ACIAR)

Major areas: Food technology, Process development, Post havest technology

Major achievements:
1. Improvement of production process in small industries
2. Fruit and vegetable post harvest technology implementation system
3. The development of dextrose and other tapioca products
4. Thermal processing of parameters of canned food
5. Physiological, chemical and storage charactertics of mangoes (and some other tropical fruits) in South East Asia

Industrial links:
1. Consultative services
2. Testing and quality control
3. Design and development of production process, technology, plant layout, machinery, etc.

Bangkok Microbiological Resources Center
Thailand Institute of Scientific and Technological Research

Research personnel: 2 M.S.

Research budget: B 0.2 million (B 0.1 million international grant)

Major areas:
1. Microbial technology, and fermentation technology;
2. Culture collection - collection and conservation of bacteria and fungi, including yeasts, and selected tissue cultures important for biotechnological development, education and applied research;
3. Technical training
4. Research promotion

Major achievements:
1. Algal inoculum biofer
2. TISTR culture collection
3. Phosphate solubilization by microorganisms

Industrial links:
1. Consultative services
2. Technical training
3. Dissemination of information in various forms, e.g. newsletter
4. Cultures are supplied with charge to research and industrial laboratories, except for educational purposes

Rhizobium Research Center, Department of Agriculture, Ministry of Agriculture

Research personnel: 1 Ph.D., 6 M.S.

Research budget: B 3.5 million

Major areas: Mycorrhiza: Rhizobium production

Major achievements: Rhizobium production 150 MT/year

Industrial links: Providing Rhizobium to farmers

Rice Research Institute, Department of Agriculture, Ministry of Agriculture

Research personnel: 430 (including field personnel)

Research budget: B 165.21 million

Major areas: Rice development and improvement, rice protection

Major achievements: Seed improvement, seed selection, seed production

Industrial links: Seed production, rice production technology, plant protection

Field Crops Research Institute, Department of Agriculture, Ministry of Agriculture

Research personnel: 420 (including field personnel)

Research budget: B 142.21 million

Major areas: Agronomy

Major achievements: New seed development, sorghum 60, Chainat mungbean 60 Khon Kaen peanut 60-1, 60-2, Cuba-Khon Kaen kenof 60, Mahasaracum sesame 60, Chiang Mai soy bean 60, Rayong cassava 60

Industrial links: Providing production technology to farmers and related industries including seed and fertilizer distribution

Department of Fisheries, Ministry of Agriculture

Research personnel: 302 (including field personnel)

Research budget: B 82.21 million

Major areas:
1. Fisheries research & development
2. Fisheries resource conservation
3. Fisheries service
4. Fisheries promotion

Major achievements:
1. Fisheries seed production, development, improvement conservation
2. Artificial fish insemination
3. Fisheries promotion

Industrial links: Fisheries Promotion
Fisheries seed production & distribution
Fisheries disease protection & control

Armed Forces Research Institute of Medical Science, Ministry of Defence

Research personnel: 1 Ph.D., 25 M.S.

Research budget: B 2.0 million/year (U.S.$ 2.8 million international grant)

Major areas: Protection and baseline for soldiers, diagnostic tool

Major achievements: Vaccines, drugs

Industrial links: Testing new drugs as requested by industries, information dissemination

<u>National Institute of Health, Ministry of Public Health</u>

Research Personnel: 7 in Biological Products Unit out of total of 200

Research budget: Approximately B 1.5 million for Biological Products Unit

Major areas: Development of vaccines, quality control of commercial vaccines

Major achievements: Japanese encephalitis vaccine, acellular pertussis vaccine

Industrial links: Monitoring of commercial vaccines to ensure standard quality

Special feature: Starting grant of B 400 million from the Japanese Government, Japanese experts collaboration.

<u>National Blood Center, The Thai Red Cross Society</u>

Technology personnel: 16 (B.S., and M.D.) out of total of 244

Total budget including research: Approximately B 30 million

Major areas: Blood quality controls, blood fractionation, blood products

Major achievements: Reference laboratory, blood products including immunoglobulins.

<u>National Institute of Constal Aquaculture</u>
<u>Department Fisheries, Ministry Aquaculture</u>
<u>and Cooperatives, KavSeng, Songkhla</u>

Research Pesonnel: 10 MSc.
22 BSc.
26 Technicians
76 Labours
60 Temporary labours

Research Budget: 2 million baht

Major Areas: Applied research, extension and development services for all aspects of marine aquaculture.

Major Achievements: - Initiation of shrimp hatcherie and intensive farms.

Industrial links: - Seminars and training courses.

2.2.3 Technical Services

Technical services available to the biotechnology-based industries in Thailand can be obtained from both the private and public sector. The services offered by consulting and engineering firms, input suppliers and output users will be discussed in Section 3.6. Technical services available from public sector agents include information services (which can help increase acquisitive, adaptive and innovative capabilities), analytical and quality control services (which can help increase operative capability), and problem solving/development services (which can help increase overall capability).

Information services available in major universities concern mostly academic disciplines and technical information useful for adaptive and innovative activities. A large percentage of the information concerns biosciences and biotechnology. In addition, the National Center for Genetic Engineering and Biotechnology has a small information unit devoted specifically to biotechnology. Some 70 special reports have been prepared by the Center on the status of specific areas of biotechnology and biotechnology-based industries in Thailand, and the Center regularly issues "Biotechnology Business News" as the communicating medium among technologists and entrepreneurs. Industrial information services are available at the Department of Science Service, MOSTE, which has a special patents information section. The Thai National Documentation Center also carries a large amount of industrial information for service to industries. The Technology Transfer Center has information relevelant to technology transfer contracts and licensing, and plans to operate a technology data bank within the period of the Sixth Plan. Table 2.5 summarizes information services available at various universities and government agencies.

Analytical and quality control services for biotechnology-based industries are available at the Department of Science Service

Table 2.5

SELECTED INFORMATION SERVICES AVAILABLE TO BIOTECHNOLOGY-BASED INDUSTRIES

Institution	Information Areas	% Relevant Biotechnology	Size	Services Available	Budget (B/yr)
Mahidol Univ. (Fac. of Sci.)	Bioscience, Biotechnology, General	80 %	32,000 books 298 journals	Lending, Search (manual, on-line, international)	4 million
Kasetsart Univ.	Agriculture, Science and Technology, Social Science Humamities	55 %	210,668 books 18,505 theses 1,861 journals	Lending, Interlibrary-loan, Photocopying, Bibliographical Compilation, Search (manual, on-line, AGRIS)	5 million
KMITT Thonburi	Science, Technology and Engineering	10 %	70,000 books 600 journals	Reference and Interlibrary loan	1 million
Chulalongkorn Univ. (Faculty of Science)	Science & Technology and Related Subjects	60 %	10,500 books 565 theses 311 journals	Lending, Photocopying Search (Manual)	1.8 million
National Center for Genetic Engineering and Biotechnology	Genetic Engineering Biotechnology and Related Subjects	100 %	964 books 139 journals	Lending, search (manual, on-line, international)	600,000

Department of Science Services	Science and Technology	50 %	30,000 books 400 journals 83,000 standards	Lending, Micro reading and printing, Search (manual)	2 million
Thai National Documentation Center	Science and Technology	65 %	260,324 books 349 journals	Lending, Bibliographical compilation, Search (manual), data processing	803,000
Technology Transfer Center	Tranfer of Technology, Technology Licencing and Technical Khow-how for rural development	30 %	-	Consulting, search from computerized data bases	150,000

and the Thailand Institute for Scientific and Technological Research. In addition, many universities have services available, either in individual deparments or at centralized service centers, for both analysis/quality control services and problem-solving/development services. The latter are particularly important in that they serve to link the universities with industry on a potentially firm basis. Table 2.6 gives a summary of some of these services for the biotechnology-based industries in Thailand.

2.2.4 Promotion and Regulation

The major promotional agency for biotechnology-based as well as for other industries is the Board of Investment. The Board operates under the provision of the Law for Investment Promotion, which provides various incentives to investors, including income tax incentives, reduction of import duty and special permits for foreign experts. However, the Board chiefly considers financial investment, employment and environmental factors but does not give any special incentives for technology transfer or development. Many biotechnology-based industries nevertheless have obtained the promotional privileges (Table 2.7). Many firms in our survey were granted promotional privileges and this appeared to constitute an important factor in the firms survival and progress.

Specific promotion of biotechnology and biotechnology-based industries started in Thailand in the late seventies, first with formation of research and development centers and with education/train ing programs in major universities. In 1983, the government set up the National Center for Genetic Engineering and Biotechnology to be the main policy, support and co-ordination center for biotechnology research and development projects, and to form linkage with the private sector. The establishment of the National Center marked, for the first time, significant local funding from the government towards development of a specific technology. Support for the technology is,

Table 2.6

SELECTED ANALYSIS/QUALITY CONTROL AND PROBLEM SOLVING/ DEVELOPMENT SERVICES AVAILABLE TO BIOTECHNOLOGY-BASED INDUSTRIES

Institution	Service Type	% Relevant to Biotechnology	Examples
TISTR	Product and Technology development/R&D Market orientation/Quality testing/consultancy/ feasibility study	25	- Product development and market orientation of drugs from natural products - Food product development
Dept of Science Service	Quality testing/product development	20	- Food processing/Quality testing
Chula Unisearch	R&D/consultancy/Process or technology development/Training	28	- Development of new technology for mushroom culture
Mahidol Univ. Applied and Technological Service Center	R&D/consultancy/Process or technology development	60	- Environmental Impact of Lignite Project - Waste water treatment of Sura Ayudhaya - R&D on waste treatment process - Biogas production from industrial waste water
KMITT	Consulting/Technical Services		1. Feasibility of Dairy Production Plant 2. Study on Tomato Production for Processing Plant in the Northeastern Area 3. Utilization of Cashew Apple

TISTR = Thailand institute of Scientific and Technological Research
KMITT = King Mongkut Institute of Technology, Thonburi

Table 2.7

SOME BIOTECHNOLOGY-BASED INDUSTRIES GIVEN SPECIAL CONSIDERATION IN APPLICATION FOR INVESTMENT PROMOTION

A. Production Industry

1. Cashew nut production
2. Field crop production
3. Fiber crop production
   - 3.1 Cotton
   - 3.2 Kenaf/Jute
   - 3.3 Ramie
   - 3.4 Kapok
4. Wheat production
5. Seed production
6. Aquaculture

B. Processing Industry

1. Production of garlic tablets and capsules
2. Modern packaging of fruits and vegetables for export
3. Fruit puree and juice
4. Modified starch production from tapioca starch
5. Maize oil and other maize products

moreover, provided as a complete package with provision of funding, information, training, links to industries and international links. The National Center has 4 affiliated laboratories, including pilot plants, and it has funded about 50 projects in 9 institutions in the network. The emphasis is on development, transfer and utilization of biotechnology, including genetic engineering in the following areas: industrial applications, agricultural applications, public health, energy and environmental applications, and strengthening of the basic infrastructure in genetic engineering and biotechnology. Under these guidelines, the National Center commissions various studies on the status of specific technologies or industries to assess the economic and social importance of the specific areas and to pinpoint the research, development and technology transfer needs to be fulfilled. Designated research projects are then formulated by researchers, often from more than one institution working together, and are funded after proper peer review. Table 2.8 gives the titles of the projects supported by the National Center. The support per project is 0.1-1.7 million Baht per year.

Table 2.8

Research and Development Projects Supported by National Center for Genetic Engineering and Biotechnology

Project Title \ Institution	Chulaongkorn University	Mahidol University	Kasetsart University	King Mongkut Institute of Technology, Thonburi	Chiang Mai University	Prince of Songkhla University	Khon Kaen University	Srinakharinwirot University Prasarnmit Campus	Thailand Institute of Scientific and Technological Research	Others
Industrial Applications										
1. Research and Development for Industrial Production of Glucoamylose and α -Amylase *	b	a	b	b					b	
2. Production of Pure Glucose for Pharmaceutical Purpose *	a									
3. Citric Acid Production in Submerged Culture		b	a							
4. Production and Utilization for High-test Molasses in Fermentation Industry *									a	
5. Design of a Pilot Plant to Produce SCP from Casava - Diversification of Existing TISTR Alcohol Pilot Plant *			b	a					b	
6. Production of 6-Aminopenicillanic Acid by Biotechnological Process		a		b						
7. Improvement of Yeast Strains for Productions of Food Yeast and Yeast Autolysate			b		a					
8. Development of Wine Production from Wine Grapes			a							
9. Antibiotic Production for Use in Animal Feed and Disease Control			a		b					
10. Production of Mosquito Larvicide from <u>Bacillus</u> <u>sphaericus</u> in semi pilot scale		b							a	c
11. Quality Improvement of Vegetable Oils by Application of Enzyme										
11.1 Application of Lypase for Quality Improvement of Vegetable Oils			a							j
11.2 Lipase-catalyzed interesterification of Triglycerides in Lipids		a								
12. Improvement of Quantity and Quality of Monascus Pigments from Cassava Fermentation	b		a						b	
13. Production of Baker's Yeast for Commercial Purpose			b	a						

Project Title \ Institution	Chulalongkorn University	Mahidol University	Kasetsart University	King Mongkut Institute of Technology, Thonburi	Chiang Mai University	Prince of Songkhla University	Khon Kaen University	Srinakharinwirot University Prasarnmit Campus	Thailand Institute of Scientific and Technological Research	Others
<u>Agricultural</u> <u>Applications</u>										
1. The Development of Embryo Transfer Technology in Dairy Cattle and its Applications under Thailand Conditions	b		a							d,e,f
2. Steroid Immunization to Recover Ferlilization in Swamp Buffalo	a									
3. Strain Selection and Cultivation of Terrestrial Snails		a								
4. Technological Development of Good Oil Palm for Thai Growers Through Tissue Culture *			a			b				
5. Production of Disease-free Potato Seeds for Commercial Scale			a		b		b			
6. Technological Development of Industrial Horticulture Crop Production			a							g
7. Conservation Technology of a Unique Characteristic Plants <u>in</u> <u>vitro</u> *			a							h
8. <u>In</u> <u>vitro</u> Propagation and Screening of Indigenous <u>Costus</u> <u>lacerus</u> for High Diosgenin Production Cultivars		a	b							i
9. Association between Rice (<u>Oryza</u> <u>sativa</u> L.) and Nitrogen Fixing Bacteria *	a									j
10. The Enhancement of Biological Nitrogen Fixation by Genetic Engineering Techniques *	a									j
11. Research and Development on Microorganisms for Compost Production in Thailand			a						b	k
12. Research and Development on the Utilization of Vesicular-Arbuscular Mycorrhiza and Their Combined Effects with Nitrogen-Fixing Bacteria in Legumes									a	
13. Screening and Improving Genetic Potential of N2-Fixing Blue-Green Algal Strains for Use as Biofertilizer to Improve Rice Yield			b						a	
14. Biotechnological Technique for Selection and Breeding of High-Yielding Rubber Clones						a				l
15. Development of Biotechnology for Cultivation of Shiitake Mushroom	a	b								g,j

Project Title \ Institution	Chulalongkorn University	Mahidol University	Kasetsart University	King Mongkut Institute of Technology, Thonburi	Chiang Mai University	Prince of Songkhla University	Khon Kaen University	Srinakharinwirot University Prasarnmit Campus	Thailand Institute of Scientific and Technological Research	Others
16. Research and Development on Rattan Production for Future Trading			a							h,m
17. Development of Tissue Culture Techniques for Propagation and Improvement of Oil Palm Cultivars						a				
18. Identification of Rhizobium Strains by Genetic Engineering for Enhancement of N2 Fixation and Inoculant Production		a								j
19. Field Trials of Mosquito Control Using Spore-forming Bacteria in Thailand	b	a							b	c,i
20. Conversion Solid Wastes to Methane Gas by 2 Stages Anaerobic Digestion	a									
21. Technological Development for the Commercial Production of Viral Insecticide			a							j
22. Utilization and Treatment of Tapioca Starch Wastewaters	b		b	a					b	
23. Preparation of <u>Opisthorchis Viverrini</u> antigens by genetic engineering techniques for use in immunodiagnosis		a					b			
24. Hormone Immuno Neutralization to Increase Productivity in Cattle and Buffalo	a									
25. Molecular Cloning of Herpes Simplex Virus Type2 DNA in Transcription Vector for Use in Rapid Diagnosis		a			b					
26. Production of Growth Hormone by Genetic Engineering for Use in Promoting Growth of Economically Important Animals	b	a								
27. Utilization of Phosphate Dissolving Microorganism for Agriculture							b		a	
28. A Multisectorial Integrated Research for Development of Weight-Control Diets from Elephant Yam		a	b							j

Project Title \ Institution	Chulalongkorn University	Mahidol University	Kasetsart University	King Mongkut Institute of Technology, Thonburi	Chiang Mai University	Prince of Songkhla University	Khon Kaen University	Srinakharinwirot University Prasarnmit Campus	Thailand Institute of Scientific and Technological Research	Others
Strengthening of Basic Infrastructure										
1. Preparation of Genetic Engineering Materials for service to Researchers *		a								
2. Research and Development of Cell Technology for Production, Collection and Supplying of Cell Culture		a								
3. Culture Collection and Services to Biotechnology									a	
4. Study the Methods of Agrarose Production from *Gracilaria spp*. in Thailand								a		
5. Development on the Production of Glucose and Fructose from Sucrose by Chromatographic Methods *			a							
6. *In vitro* Germplasm Collection and Exchange of Economic Plants			a							
7. DNA Typing of Oil Palm						a				

* Completed project

a = Principal Investigator
b = Co-investigator
c = Department of Science Service
d = Department of Livestock Development
e = Udom Dairy Farm
f = ADSCO Co., Ltd.
g = Maejo Institute of Agricultural Technology
h = The Royal Chitralada Projects
i = Department of Medical Sciences
j = Department of Agriculture
k = Land Development Department
l = Rubber Research Center, Songkhla
m = The Royal Forestry Department

The Science and Technology for Development Program, established in 1985 with cooperation of the US agency for International Development (AID), is another major supporter of biotechnology research and development in Thailand. The Science and Technology Development Board (STDB), which runs this program, has a wide interest covering bioscience and biotechnology, material technology and applied electronics and computer technology, areas which were determined to be of high priority. Table 2.9 gives the titles of the projects supported by the STDB in biotechnology/bioscience areas. STDB has special interest in promoting industrially relevant research and development, and has a special program of low-interest loans to industries for company-directed research and development. The average support per project is 4.5 - 5.0 million Baht per 3 years.

Table 2.9

Research and Development Projects in Biotechnology/Bioscience Supported by the Science and Technology Development Board

Project Title \ Institution	Chulalongkorn University	Mahidol University	Kasetsart University	Prince of Songkhla University	Srinakharinwirot University Prasarnmit Campus	Department of Fisheries
1. Employ Plant Regeneration and Other Tissue Culture Methods in Clonal Propagation and Improvement of Aracaceae				*		
2. Application of Tissue Culture Techniques for Improvement of Steroid and Alkaloid Yield from Solanum and Duboisia Spp.		*				
3. Development and Apply Plant Biotechnological Methods for the Production of Virus Resistant Plants			*			
4. Development and Application of Tissue Culture Methods for Rapid Multiplication and Improvement of Coconut and Arecanut			*			
5. In vitro Selection for Soybean Lines Tolerant to Saline Soil and Acid Sulfate Soils			*			
6. Dry Bean (Phascolus Vulgaris) Improvement Through Mutation Breeding and Tissue Culture Technique			*			
7. Prevention and Control of Aflatoxin in Corn			*			
8. Researc and Development for Complet Cycle of Seaweed Hydrocolloid Industry in Thailand					*	
9. Development of Specific DNA Probes for the Diagnosis of Babesiasis in Cattle		*				
10. The Development of Biotechnology for an Improvement in the Production of Dairy Cattle		*				
11. Improvement of Aquaculture of Giant Freshwater Prawn (Macrobrachium rosenbergii de Man) Through Hormonal and Reproductive Manipulations		*				
12. Improved Breedstock Maturation Techniques for the Giant Tiger Prawn (Panaeus monodon) in Thailand	*					

Project Title \ Institution	Chulalongkorn University	Mahidol University	Kasetsart University	Prince of Songkhla University	Srinakharinwirot University Prasarnmit Campus	Department of Fisheries
13. Biological and Economical Studies on the Mekong Giant Catfish						*
14. Production of Modified Starch with Desired Rheological and Physical Properties from Cassava Starch		*				
15. Construction of Hybrids from Aspergillus sp. for High Yield Citric Acid and Glucoamylase Activity			*			
16. The Application of Biotechnology for Processing and Product Improvement of Fermented-Rice Noodle			*			
Total	1	5	7	1	1	1

A number of regulatory agencies are concerned with standards, safety and environmental impacts of biotechnology-based industries. The Thai Industrial Standards Institute issues both compulsory and voluntary specifications for standard industrial products, including biotechnology products. Products which meet the standards are issued certificates, which can help win consumers' acceptance. Food and drugs have to meet compulsory standards issued and montitored by the Food and Drug Administration. The Administration is responsible for enforcement of 7 laws concerning food, drugs, cosmetics, medical equipment, narcotics, toxic substances and neuroactive agents. The Department of Medical Science also has a role in issuing standards and maintaining quality control of some biological products, (e.g., vaccines). Apart from regulatory functions, these agencies also have promotional functions in helping industries to achieve good manufacturing practice and more importantly, in creating consumers' awareness and in guiding consumers on the purchase and use of these products. The latter is an important function in view of the lack of strong consumer groups in the country. Finally, the environmental effects of industries are monitored by the National Environment Board, which is responsible for enforcerment of the Environment Control Law. The important regulatory agencies and areas of responsibility are summarized in Table 2.10.

2.2.5 Policy Planning and Administration

A number of agencies are concerned with policy planning and administration involoving biotechnology and related industries. The National Economic and Social Development Board (NESDB) has the responsibility for overall planning, including planning in science and technology in order to meet economic and social objectives. The Sixth Five-Year Plan (1987-1991), for example, has a section on science and technology development, in which development of biotechnology is given a high priority along with material technology and electronics. The

Table 2.10

IMPORTANT REGULATORY AGENCIES AND AREAS OF RESPONSIBILITY IN BIOTECHNOLOGY-BASED INDUSTRIES

Agency	Laws/Regulations	Areas of Responsibility Concerning Biotechnology
Thailand Industrial Standards Institute	Industrial Product Standards Act B.E.2511 (1968) as amended by Industrial Product Standards ACT (No.2) B.E.2522 (1979) and Industrial Product Standards Act (No.3) B.E.2522 (1979) together with Ministerial Regulations	Consumer Products, Chemicals, Food, Agricultural Products
The Food and Drug Administration	- Food Acts B.E.2522 - Drug Acts B.E.2510 and amended B.E.2518, B.E.2522, B.E.2528, B.E.2530 - Cosmetic Acts B.E.2517 and amended B.E.2518 - Toxic Substance Acts B.E.2510 and amended 2516 - Psychotropic Substance Acts B.E.2518 and amended B.E.2528 - Narcotic Drug Acts B.E.2522 and amended B.E.2528, B.E.2530 - Medical Devices Acts B.E.2530	Food, Drug, Cosmetic, Toxic Substances, Psychotropic Substances, Narcotic Drug and Medical Devices
Office of the National Environment Board	Improvement and Conservation of National Environmental Quality Act	Air Quality (Industrial Emission), Drinking Water, Industrial Effluent, Solid Waste and Nightsoil Management in Factory, Toxic Substances (Pesticide Residue), Industrial Toxic Substance, Nuisance Abatement

Ministry of Science, Technology and Energy and Energy has the function of formulating and implementing detailed work plans along the framwork provided by the Five-Year Plan. The Policy and Planning Office in this ministry takes general responsibility for these functions. The responsibility for specific policy, plans and administration concerning biotechnology goes to the National Center for Genetic Engineering and Biotechnology, which also has the main task of supporting and co-ordinating research and development projects, and facilitating transfer of technology and information to the industries (see also 2.2.4)

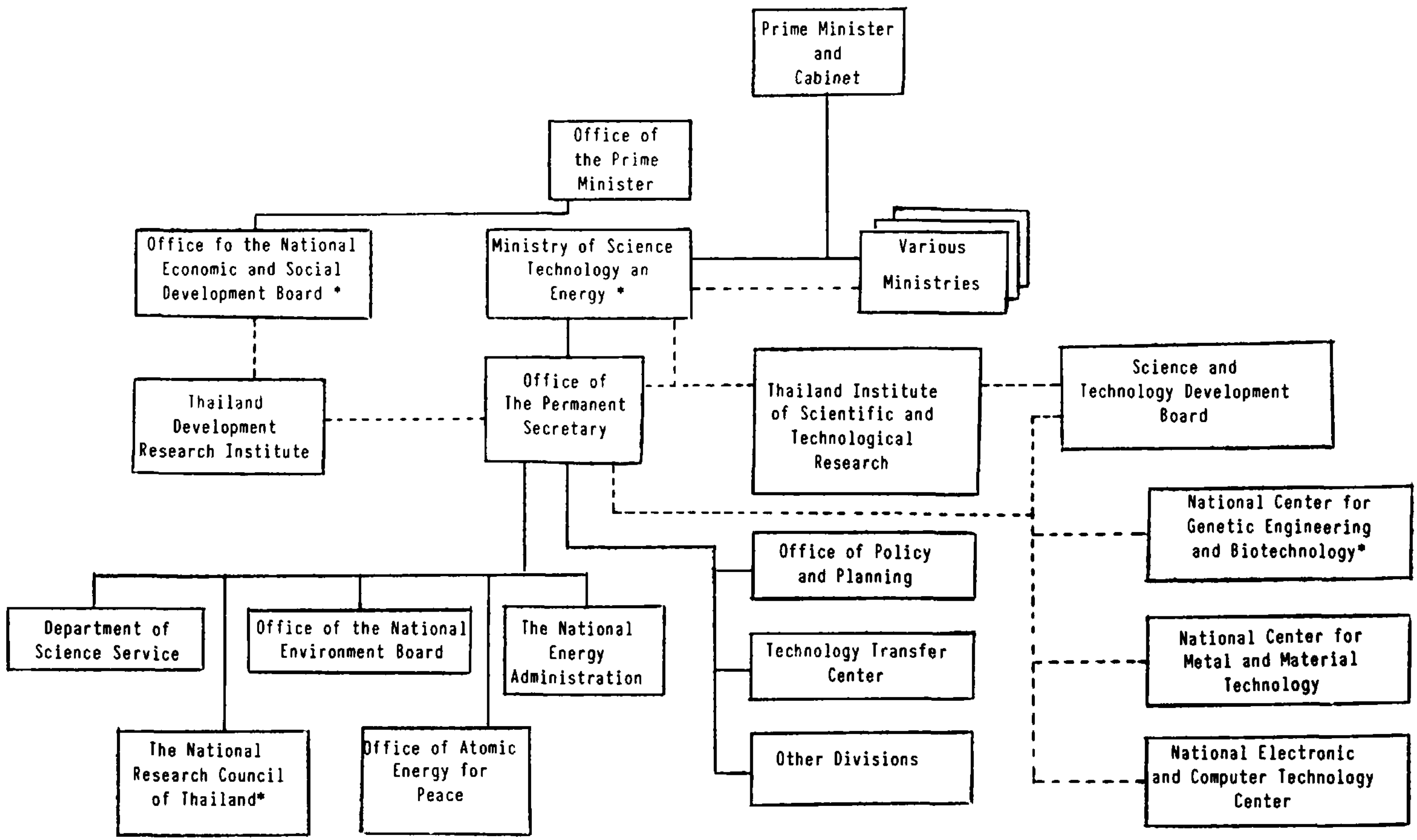
Two other public sector agencies are significantly involoved in policy planning and administration fo biotechnology. The Science and Technology Development Board (STDB), (see 2.2.4) is concerned with policies for support of bioscience and biotechnology, material technology and applied electronics and computer technology, especially in areas linked with problems of interest to industry. The National Research Council (NRC) is responsible for national research policies in various science and technology areas, and provides support to various projects, many of which are in areas of biotechnology.

Fig. 2.1 shows an organizationa chart of major public sector agencies dealing with policy planning and administration in science and technology, including biotechnology.

In addition, the Federation of Thai industries provides crucial input policy for increase of technological capabilities of the private sector. The Joint Public-Private Sector Coordination Committee, which is set up specifically for cooperation between the two sectors on industrial production, also has a role in encouraging technology transfer and development of capabilities of the private sector.

Figure 2.1 Organization of agencies with science and technology policy function in Thailand.

Agencies of special relevance to biotechnology are shown with asterisks.



2.3 Major Limitations and Opportunities in the Infrastructure

2.3.1 Manpower

Although the scientific and technological infrastructure in Thailand is quite good for a developing country, it is still quite limited and has to develop much further in order to be able to support the biotechnology-based industries optimally. The educational system is producing a rapidly increasing number of bachelor graduates in biotechnology, and judging from the ease with which the graduates are obtaining jobs, this increasing capacity will be well absorbed by the industries (Chulavetnatol, 1987; Atthasampunna, 1988). However, these graduates still need a period of on-the-job training before they can perform their jobs effectively. The main problem is that the educational programs do not adequately prepare them for various types of skills and knowledge at the operational level. It has been proposed (Chulavatnatol, 1987) that a period of internship be provided for the new graduates, sponsored by both the government and the private sector.

The educational and training programs still need to evolve so that university professors, students and entrepreneurs can interact more effectively to create more operative capability in industry. The problems for educational and training programs are even more difficult when the acquisitive, adaptive and innovative capabilities are considered. These capabilities can mainly be addressed at the graduate program level. Since industries still interact minimally with universities at this level, prefering to import technology for proprietary and other reasons, the graduate programs are not significantly contributing to these capabilities, and are thereby in danger of being irrelevant. Mechanisms must therefore be found to induce the universities and industries to come closer together in problem solving and development work.

2.3.2 Research and Development

The graduate programs also provide an important avenue for universities to do more industrially relevant research and development work. Up to now, most research and development work at the universities is poorly linked with industrial needs. As will be seen later in this report, the biotechnology-based industries are at present minimally engaged in research and development at the innovative level. The large reservoir of expertise in the universities, mostly interested in the research end of the research and development spectrum is therefore not being optimally used to enhance the capabilities in industry. A proper balance of emphasis on research problems of long term and academic interest and on development problems of interest to industry needs to be struck. This will require appropriate institutional and personnel arrangements to bring about effective interactions between academia and industry.

Research and development programs in government programsagencies are mainly directed for public benefit (e.g., towards small farmers), and these agenices are likewise poorly linked with the biotechnology-based industries in the private sector. A proper balance is needed here also, in order both to pursue the interest of the public at large and to interact with industry for mutual improvement of technological capability.

Another major limitation of the research and development system in Thailand, apart from the lack of linkage between universities, government agencies and private industries, is the lack of access to new technology. Although the problems for Thailand, with an open economy and easy communication with developed countries, are not as severe as for many other developing countries, they are substantial and specific policy measures are needed to overcome them. The access problems are complicated by the prerequisite for technologies embodied in skills, knowhow and experience not easily transferred through formal channels of communication.

Inspite of various limitations in the research and development system there are some good opportunities for its strengthening. As section 2.2.2 shows, Thailand has, for a developing country, a very good research and development capability in the infrastructuse agents in various areas of biotechnology, especially in agricultural and biomedical aspects. Cooportunities are open for biotechnology-based industries to utilize this capability to improve their products and processes through contract research joint research and development and other co-operative activities. The program to support company-directed research and development through provision of soft loans by the Science and Technology Development Board should encourage this co-operation in the future.

2.3.3 Technical Services

Technical services offered by infrastructure agents to biotechnology-based industries still need to be substantially improved. The proposal put forward in the Fifth Plan (1982-1986) to set up the Science and Technology Information Center has not been implemented, and access to technical information remains a major problem for industries, especially those of small and medium sizes. The provision to set up a technology date bank at the Technology Transfer Center during the Sixth Plan would be of some help. So would the setting up of the planned Technology Information Access Center by the Science and Technology Development Board.

As Table 2.6 shows, analysis and quality control services offered by the infastructure agents are limited at present. However, new opportunities are open for problem solving and development services offered by the universities to industry. This relatively new trend may, in the future, provide the much needed linkage between the universities and industry.

2.3.4 Promotion and Regulation

The major limitation of present promotional measures for the

Thai industries is the lack of technology transfer and development aspects. Although there are signs that the Board of Investment is beginning to consider specific measures to promote technology transfer and development as a part of investment promotion, there has been little practical progress up to now. Promotion of technology transfer and development in general suffers from the lack of special laws and regulations which can facilitate the measures, akin to laws for technology promotion and development in South Korea. Previous attempts to consider these laws and regulations in Thailand have been mainly unsuccessful, and although these issues are outstanding for the Sixth Plan, much more work still remains to be done.

Specific promotional measures for biotechnology-based industries are presently under the responsibility of the National Center for Genetic Engineering and Biotechnology and the Science and Technology Development Board. In addition, the National Research Council and various universities are also supporting various research, development and other activities pertaining to biotechnology. It is important to ensure that the various activities are co-ordinated and done with cooperation among the concerned agencies so as to ensure maximal effectiveness.

Although the regulatory agencies in Thailand are functioning quite effectively at present, a major issue which has hardly been touched and will require increasing attention in the near future concerns regulations and regulation enforcement with respect to new biotechnology products (e.g., drugs and plants from genetic engineering). Due to strict and complicated regulations in the USA and other developed countries, technology developers in these countries might increasingly look to countries like Thailand as venues forfield trial and environmental release of new products. Furthermore, many indigenous research and development activities, and adaptive research on new biotechnology products require new quidelines concerning safety to the public and the environment. There is a need therefore to strengthen the regulatory system in anticipation of future development.

2.3.5 Policy Planning and Administration

A major limitation in policy planning and administration is the lack of mechanisms for effective implementation and monitoring of the plans. A major reason is the lack of optimum linage between the Ministry of Science, Technology and Energy and other ministries and agencies which significantly use science and technology (e.g., the Ministry of Industry and the Ministry of Agriculture). The Fifth Plan proposed to solve this problem through the creation of the National Council for Science and Technology, to be chaired by the Pring Ministes and consisting of ministers of relevant ministries. The proposal was, however, rejected by a high-level government committee. The Sixth Plan now calls for the establishment of an interministerial committee to coordinate polities concerning science and technology. This plan remains to be implemented.

In the specific area of biotechnology, however, some achievements have been made in recent years. First, biotechnology has been chosen to be an area of high priority in the Sixth Plan. Secondly, two special agencies, namely the National Center for Genetic Engineering and Biotechnology, and the Science and Technology Development Board, have been set up to provide policy planning and support for the technology. Thirdly, biotechnology is now an important area for manpower and research planning in various major institutions in the country. These recent developments should provide for improvement of technological capability in the biotechnology industires in the future, through interaction with the infrastructure agents.

3. PROFILE OF PRESENT TECHNOLOGICAL CAPABILITY OF THAI INDUSTRY

3.1 The Products, Processes And Technologies

3.1.1 General

The industries surveyed in this study were selected according to the criteria outlined in section 1.4.4. As stated in that section, the industries and firms included in the survey do not comprise a comprehensive set of all the industries in the Biotechnology sector. This would have been impossible, given the time and resources allotted to the study. Instead, important industries which employed very different technologies were chosen as representatives of the sector. These firms were drawn as representatives of various linkage networks (Annex 3) important to the Thai economy. The rationale was that common problems for these very different industries would be sector wide problems experienced even by industries not included in the survey. Such problems were of cardinal importance for this study since they were the problems most likely amenable to rectification by policy measures. As a consequence of this selective process, it was accepted that problems would be missed if they were specific to excluded industries and unsolvable by general policy measures. This does not infer that such problems do not warrant attention. They were simply beyond the scope of this study.

A total of approximately 350 individual firms from the Biotechnology sector were originally considered for this study (see section 1.4.4). These were found from the telephone directory, the BOI list of supported industries and the list of the top 200 Thai companies. Because of limitation in resources, this list was reduced to a secondary grouping of 12 different industries comprising approximately 150 firms based on the biotechnology content of the industries. The final survey group was then reduced to 8 industries selected to be as unrelated as posssible and to cover industries from both plant and animal based networks (see Section 1.4.4). In each of these industries we included at least four firms amongst which we attempted to have at least one large Thai firm, one large foreign or joint venture firm, one small to medium Thai firm and one small to medium foreign or joint venture firm. These industries are listed in section 1.4.4 along with the major technologies they employ. In that list, the technologies are indicated as core, auxiliary or peripheral, for each industry.

At the end of the survey, a total of 5 firms had been examined in the "aquaculture" industry. Four of these firms were involved in aspects of shrimp cultivation only and one was additionally involved in fish cultivation. These firms were considered examples from an upstream industry in an animal based network. The four firms in the feed industry were involved int the production of animal feeds for poultry, swine, ruminants, shrimp and fish. These were considered to be downstream industrial firms, which were part of both animal and plant networks, since they employed raw materials from both plant and animal networks to produce feeds used in anmial based networks. The four seed production firms were chosen as examples from an upstream industry in a plant based network. The three dairy firms were representatives from a downstream industry in an animal based network. The ornamental plant firms were examples from another upstream industry in plant based networks. Most of these firms were export oriented and concentrated on the production of orchids and temperate cut flowers. They are referred to here under the heading "Flower Industry". The organic acid industry included four downstream firms, one producing citric acid, one producing acetic acid (vinegar), one producing glutamic acid (as monosodium glutamate or MSG), and one producing MSG and lysine. All these firms employed fermentation processes and were considered as part of plant based networks since the major raw materials for production were agricultural plants. The survey of the alcohol industry included six firms, although only the four firms producing pure alcohol were included in the figures. The two excluded firms produced only alcoholic beverages. Like the organic acid industry firms, these firms used fermentation processes and were in plant based networks. The survey of the health industries covered six firms producing pharmaceutical products. They were considered downstream industries in plant based networks.

Since the various figures and tables in the study were prepared continuously, some data was not complete at the time of their preparation and it was not feasible to revamp all these when further data were acquired. Nor was this felt necessary, since the sample size for the analysis was considered adequate and the few added data were unlikely to change the conclusions significantly. Therefore, the total number of firms presented for different tables and figures in the report varies around 40.

For purposes of the survey and for analysis of the survey data, it was necessary to develop systems of rating for levels of various technologies and for levels of various technological capabilities. This system is shown in Table 3.1 and Table 3.2, respectively. Two examples will illustrate the use of this system.

With respect to level of technology (level of sophistication), a rating of 5 for a particular technology indicates a level of sophistication equivalent to that found in the leading world firms in the particular industry being examined. At the other extreme, a rating of one indicates a lower than local average sophistication or a complete absence of the technology. In between, are various degrees of sophistication. For example, let us look at microbial technology for firms in the soy sauce fermentation industry. A firm operating a factory equivalent to those used by Kikkoman (monitoring of microbes throughout processing; maintenance and improvement of microbial strains; use of controlled microbial inoculum; trained microbiologists on the staff) would be given a rating of 5 for microbial technology. Without stain improvement but with a trained microbiologist on the staff, with microbial monitoring, stain maintenance and controlled inoculum, the rating would be four. With further absence of a microbiologist and microbial monitoring but with strain maintenance and the use of controlled inoculum, the rating would be three. Without microbial maintenance but with the use of purchased inoculum, the rating would be two. The further lack of controlled microbial inoculum use would result in a rating of one. See section 3.1.3 for survey data concerning technology levels.

TABLE 3.1. Rating of technological level for key technologies used by Thai firms in the biotechnology sector.

RATING	EXPLANATION
5	Techniques in use equivalent to the most advanced being used in industrialized countries.
4	Techniques in use equivalent to the average being used in industrialized countries.
3	Techniques in use below the average of industrialized countries but better than those of most other local firms.
2	Techniques in use well below the average for industrialized countries but commonly found in Thailand.
1	Techniques in use below the local norm or not in use.

TABLE 3.2. Rating of technological capabilities.

RATING	EXPLANATION
5	Capability level equal to that of world frontier firms
4	Capability level equal to the average for firms in industrialized countries
3	Capability level below the average of firms in industrialized countries but higher than most local firms
2	Capability level well below the average of industrialized countries but common locally
1	Capability level below the local norm or no capability

In section 1.4.4 concerning the conceptual approach for this sutdy, technological capability was subdivided into four major capability categories; acquisitive capability, operative capability, adaptive capability and innovative capability. For purposes of easy analysis, these capabilities were further subdivided as shown in Table 3.3. Each of these sub capabilities for each firm was scored according to the rating system shown in Table 3.2, so that the total capability score for each of the four major capabilities represents an average of the sub capability scores. The detailed scores are listed in Annex 2 while graphic presentations of the average scores are shown in sections 3.2 to 3.5.

It should also be pointed out here that the capability rating given for the firms surveyed was a rating based on indigenous capability. This is especially important when examining joint venture and fully foreign owned firms which could have a quite different capability rating if their global capabilities were considered. For example, we scored the local innovative capability of a joint venture firm with no local R&D division as very low even if the foreign based partner had excellent research facilities abroad.

Another precaution with respect to these technological capability ratings is that they do not indicate the degree or sophistication of the technology used by a particular industry. For example, a firm in an industry requiring comparatively simple technology (e.g., aquaculture) could be given a capability rating of 5 if it were close to the world frontier in that industry, while a firm in an industry using much more sophisticated technology (e.g., alcoholic fermentation) could be given a rating of only 2, if its technology, relative to the developed standard, were inefficient and out of date.

3.1.2 Company profiles

Table 3.3. Sub capabilities for each of the four major technological capabilities listed in Table 3.2.

Capabilities	Sub capabilities
Acquisitive	Search - to seek new technology
	Assess - to assess various technology options
	Negotiate - to obtain favourable transfer terms
	Procure - to buy new technology
	Transfer - to complete a successful transfer
	Install - to successfully install new technology
Operative	Operate - to effectively operate current or new technology
	Maintain - to maintain production equipment
	Skills - to carry out technical activities
	Manage - to manage efficient production
	Train - to train manpower
Adaptive	Modify product - for minor product modification
	Modify process - for minor process modification
	Knowledge - to acquire relevant new knowledge
	Digestion - to successfully apply new knowledge
Innovative	Product change - to make major product changes
	Process change - to make major process changes
	Major change - to change product line or introduce new process R&D - to carry out true research and development
	Invention - to create new products

Of the 40 firms included in the survey, approximately half (14) were founded within the last 10 years. The remainder (16) were founded 11 years or more ago and of these older firms, approximately 70% (11/16) were founded over 20 years ago (see Fig. 3.1).

With respect to ownership, promotional status and market orientation, the firms were distributed as shown in Fig. 3.2. Because there was only one fully foreign owned firm, comparisons would not have been meaningful. Therefore, it was lumped together with joint venture firms for means of analysis. The majority of the firms surveyed (63% or 20/32) were fully Thai owned. With respect to promotional status, approximately half enjoyed promotional privileges. In terms of market orientation, the firms were classified into export oriented, import substitution oriented or both. The import substitution oriented firms constituted the largest group.

As can be seen from Fig. 3.3, most of the firms surveyed (72% or 23/32) were large firms with investments greater that ten million baht. The majority of the firms engaged between 50 and 500 employees (Fig. 3.4).

From Fig. 3.5, it can be seen that almost all the firms surveyed (94% or 30/32) had quality control or analysis laboratories. However, these laboratories were usually of a very restricted nature and focused on specific tests necessitated to comply with Thai regulations or with requirements of export markets. Only 53% (17/32) of the firms had some type of research activity going on. However, in all cases, this research activity was restricted to solving current production problems and to adaptation of imported technology to local conditions. There were no planned research programs directed towards the development of new or novel products or processes. Approximately half of the firms had regular training programs while half did not.

3.1.3 Technology levels

Fig 3.1 AGE OF FIRMS SURVEYED

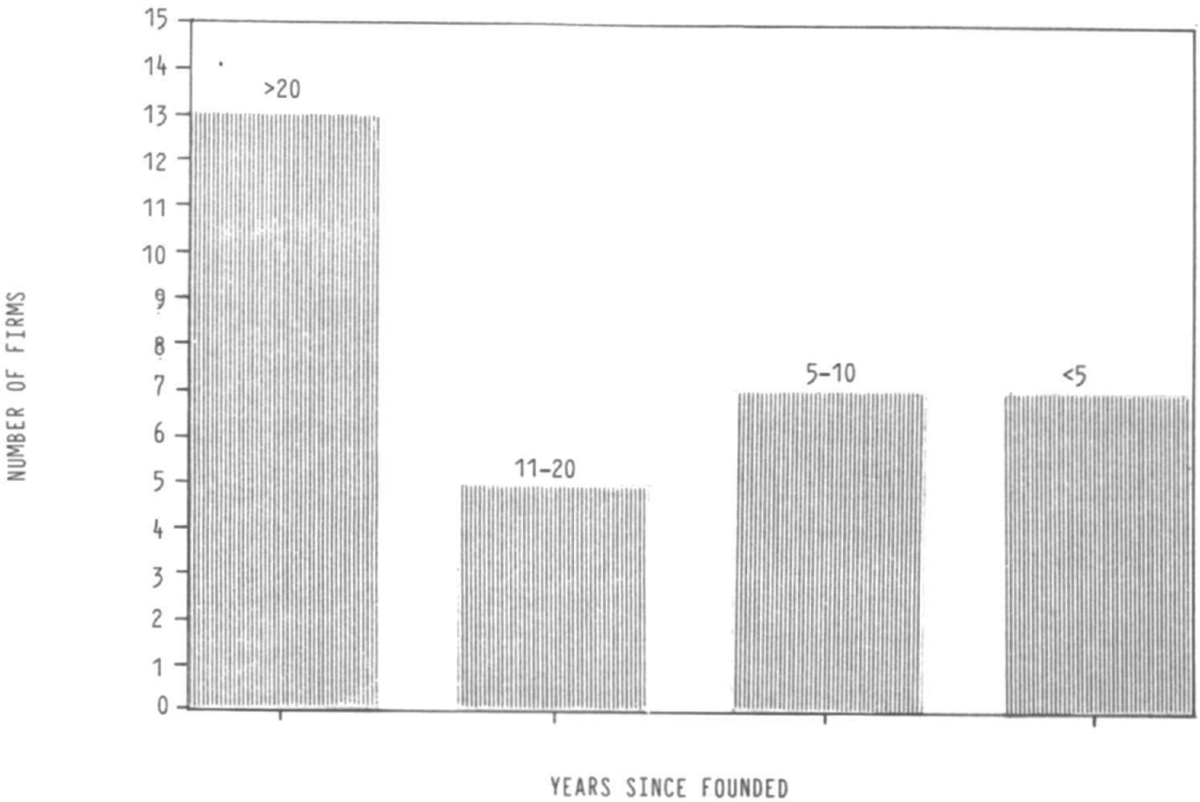


Fig 3.2 FIRM OWNERSHIP, PROMOTION AND MARKET

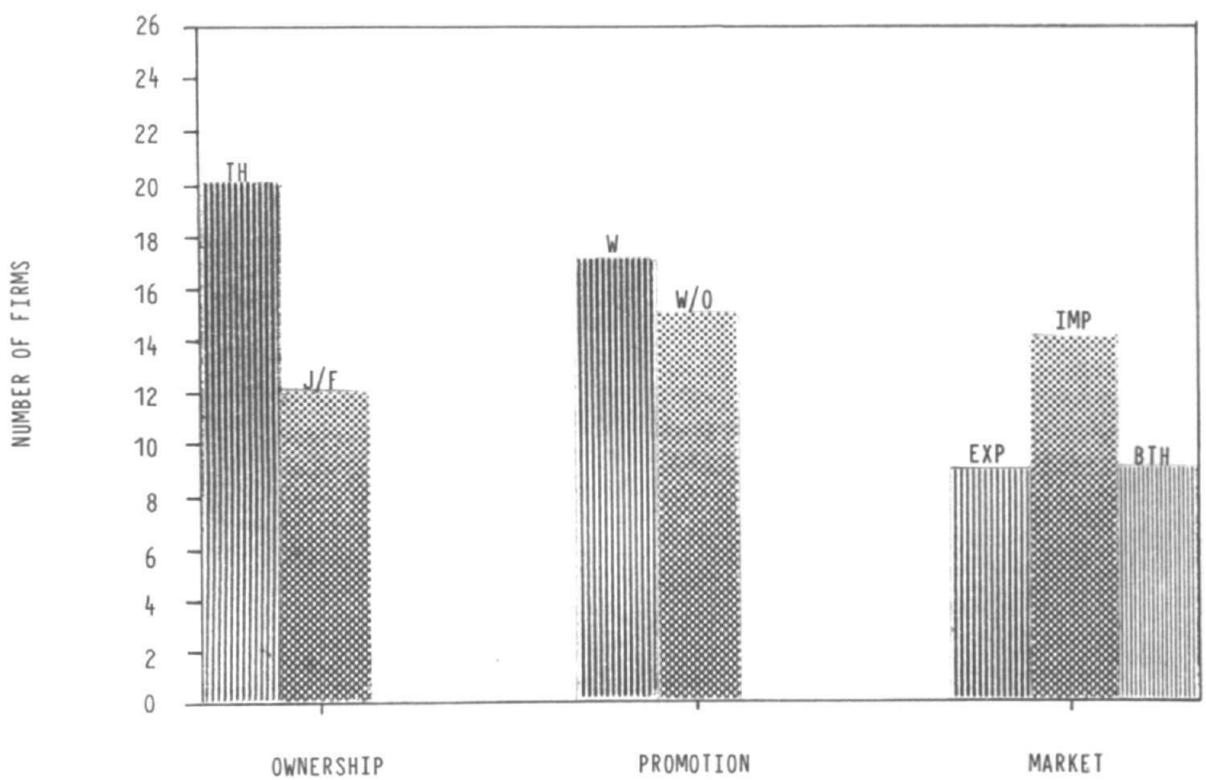


Fig 3.3 SIZE OF INVESTMENT

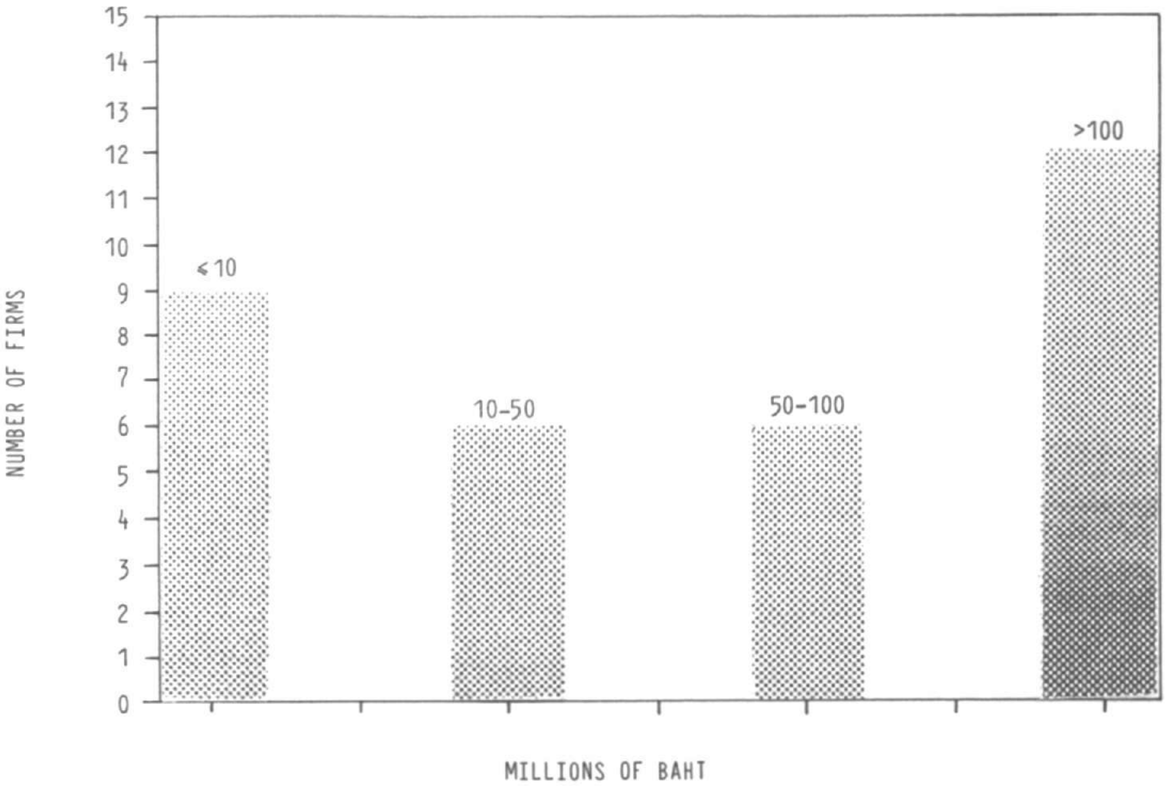


Fig 3.4 SIZE OF EMPLOYMENT

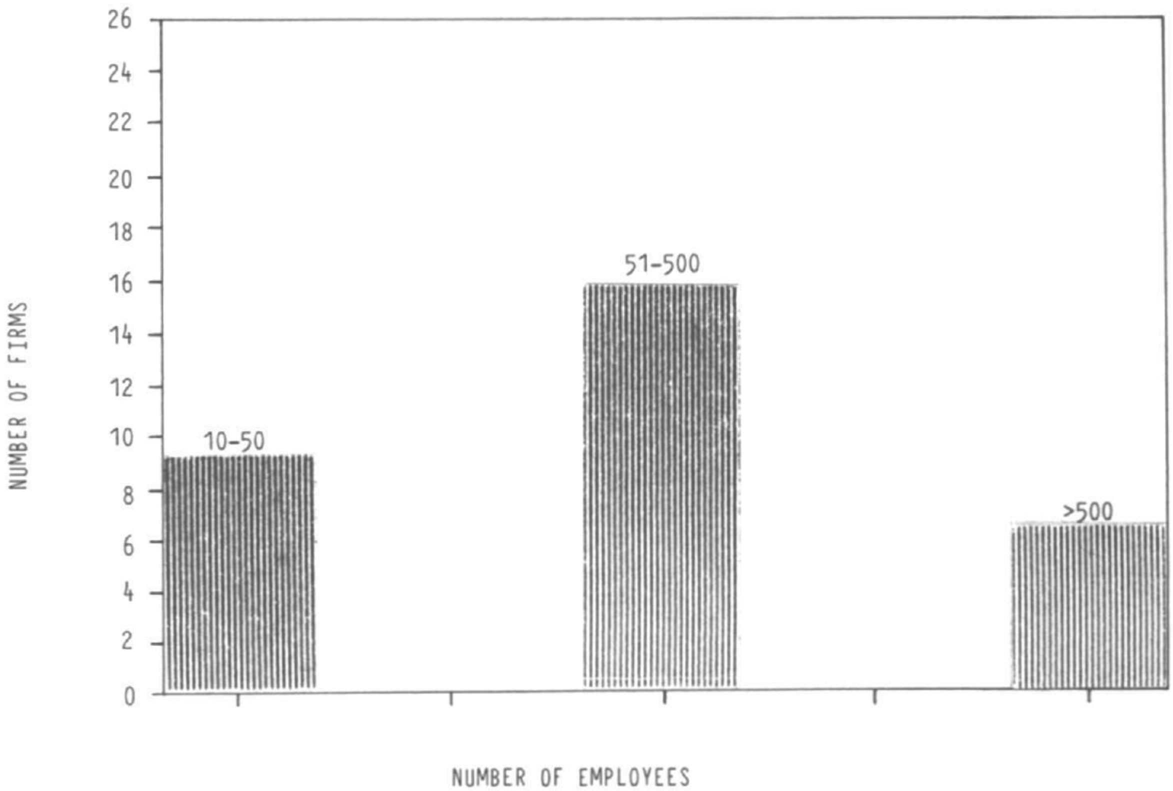
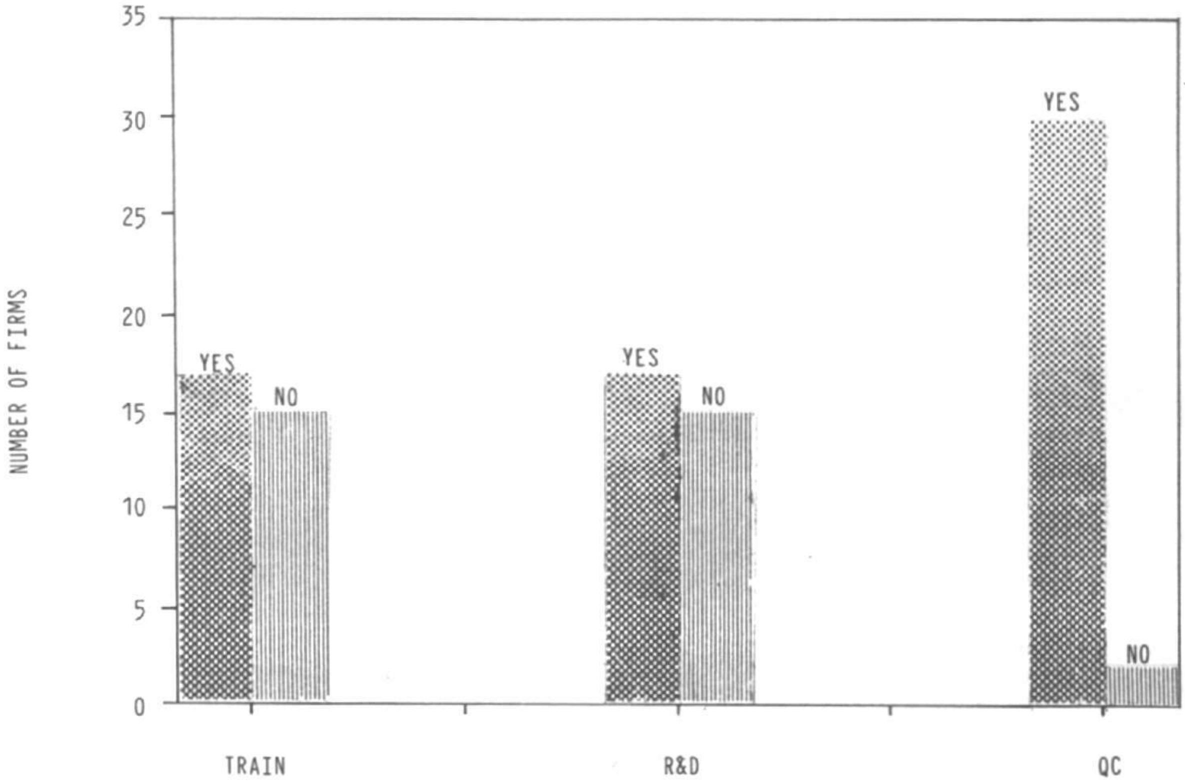


Fig 3.5 RESEARCH, TRAINING AND QC



Using the rating system outlined in Table 3.1, Table 3.4 was prepared to display data concerning the level of technological activities found at the 40 firms surveyed. Three major conclusions can readily be drawn from this table. First, many of the technologies are not employed by Thai firms. Second, when they are employed, the level of the technological activity is generally rather low. Third, few of these technologies are planned for use in the near future.

Although there was a general lack or a low level use for some of these technologies, most firms were aware of their existence and of their potential. However, they felt that they could not justify the cost of implementing these new technologies in terms of current market factors. Asked whether they would readily be able to acquire these technologies if required, most firms answered yes. They assumed with confidence that they could purchase the most advanced technologies from abroad if and when the need for them arose.

The assumption may be true, but it in turn requires that appropriate personnel to properly implement the technology will be on hand or available also by import. This attitude and mentality results in a technology acquisition pattern that we may call "follow the leaders" type. It may work if other factors such a low employment costs (not perpetual!) exist and allow for international competitiveness. It is our contention, however, that a more secure future can be obtained by eventually assuming a role as a "technology leader".

Thai firms in the biotechnology sector are generally poorly prepared for such leadership by comparison with firms in either old or newly industrialized countries. In industrialized countries, for example, firms in the health related industries are amongst the leaders in development of biotechnology. These firms have staff with advanced qualifications in all the relevant core, auxiliary and peripheral technologies. In Thailand, by contrast, firms in the health related industries have either very low or no capability with these technologies. Part of the reason for this poor capability is that they are mostly concerned with relatively simple formulation work. Also, with joint venture firms, the R&D activities and facilities are usually foreign based, so that they simply have very low local capability.

Table 3.4

USE OR PLANNED USE, LEVEL OF TECHNOLOGIES USED BY THE FIRMS INCLUDED IN THE SURVEY.

TECHNOLOGY	#USING	# PLANNED	TECHNOLOGY LEVEL				
ENGINEERING AND RELATED			1	2	3	4	5
Chemical engineering	21		1	3	9	6	2
Chemical technology	2				2		
Chemical analysis	16		1	9	4	1	1
Control and measurement	30		1	5	17	6	1
Controlled environment	24			6	10	7	1
Computer aided production	6	1			2	2	2
Dehydration technology	17			8	5	2	2
Reactor technology	10			2	3	4	1
Industrial engineering	20			4	9	7	
BIOLOGICAL TECHNOLOGIES							
Biochemical	5	1			4	1	
Biochemical analysis	17		1	4	6	4	2
Enzyme	5	1			4	1	
rDNA (Genetic engineering)							
Hybridoma/fusion							
Microbial	21	2		12	6	3	
Plant tissue culture	4	1			1	2	1
Plant breeding	9				3	2	4
INTERMEDIATE							
Fermentation	11			2	3	5	1
Biochemcial engineering	2				2		
Pollution control	21		1	9	8	2	1
OTHERS							
Consumer testing	10			1	9		
Clinical field testing	14		1	1	3	8	1

3.2 Profile and Assessment of Acquisitive Capability

Figure 3.7 graphically presents the acquisitive capability ratings for the eight industries included in this survey. The actual numerical data used to prepare these graphs are included in Annex 2. It is clear from examination of the graphical profile, that there is no serious problem with the biotechnology sector as a whole with respect to the acquisition of new technology. Most of the problems are firm specific. On the other hand, there are some industry specific problems. For example, there is an industry wide deficiency in negotiative capability with the ornamental plants industry (Fig. 3.7, E) and there is a generally poor capability in all categories for the organic acid and alcohol industries (Fig. 3.7, F).

The range of ratings for the sector was from 2.79 for the organic acid industry to 4.54 for the aquaculture industry and the average for the whole sector was 3.48. This corresponds to a capability under the average for the industrialized countries.

For the ornamental plants industry, the reason for the poor negotiative capability is that all of the firms are local and use technology of indigenous origin. Also, the technology used is not extremely sophisticated. As a result, they were not involved and do not perceive the necessity of getting involved in purchasing technology from abroad. Therefore, they have not demonstrated a negotaitive capability. At the same time, their awareness and ability to assess new developments is relatively good. They have staff with sufficient training to examine the literature and to assess its relevance to their current and future activities.

With respect to the organic acids industry, the reason for the overall low capability for acquisition is partly related to the nature of the technology used. The technology employed by these firms was essentially obtained as turn key projects in what is a rather mature and therefore rather slowly changing industry world wide. Most competitive advantage is derived from the microbes being used in processing and these are usually jealously guarded. One of the firms in our survey was a large joint venture firm with high acquisitive capability at its parent company abroad, but the local representative firm itself did not possess these capabilities. Therefore, we gave the firm low scores for indigenous acqisitive capability. If the foreign partners pulled out, taking their experts and microbial strains with them, we considered that the local staff remaining would have a relatively low capability for acquiring equally effective replacement technology on their own.

Similarly, the alcohol industry is rather mature and somewhat static. One of the companies in our survey acquired its technology from abroad and the supplier provided a short term expert during the initial production period. During this time, there was not sufficient training of local staff for replacement. As a result, a rather poor understanding of the overall process remained after the expert departed and this resulted in rather low production efficiency (i.e., approximately 40% conversion of raw materials to alcohol instead of 49%) and a rather inconsistent production. At the same time, this firm was not confident that local experts could be hired as consultants to help improve the situation. There was a lack of relevant literature on hand at the factory and noone on the staff had sufficiently advanced training to be able to seek out, understand and utilize information that was available elsewhere in the country. Like the other firms in this industry group, the company enjoyed the privlege of high protection in the sense that the licences for alcohol production cannot be obtained by potential competitors. As a consequence, these alcohol firms have a generally complacent attitude, and do not actively seek new possibilities. There are potential competitors in the form of sugar producers would like to have the option of producing alcohol from their molasses bybroduct, as is done elsewhere in the world. However, they have been refused licences for alcohol production.

We may contrast these low capability firms with relatively higher capability firms in the aquaculture (shrimp) industry, feed industry and seed industry. The highest capability firm in the feed industry (Feed 1) was characterized by an outward looking and actively acquisitive stature. It had developed a highly qualified technical staff and kept them supplied with the latest developments in the field by regular subscription to technical publications and trade journals, by regular contact with the local academic community, by regular staff attendance at relevant meetings both locally and abroad, and by regular visits from foreign consultants. These were characters also shared by the better firms in the aquaculture and seed industries. In these respects, they contrasted sharply with the lower capability firms describe above. When purchasing new technology from abroad, Feed 1 used its technical staff resources and consultants to assess the available options, to choose the best available, and to negotiate favourable terms of transfer. Sufficiently qualified staff were involved during installation and start up to ensure complete local operational capabilty.

A common complaint of the small firms interviewed (and sometimes also from large firms) was the lack of a good central information service which was sufficiently current, sufficiently extensive and sufficiently accessible to keep them abreast of current technology options. This could partly arise from the scattered nature of much of the information that is available and the inability of the firms to locate it. For example, a manager in one large feed company told of how he had discovered an article concerning a particular topic on animal nutrion and written by a Thai only after consulting a library in England. He had not succeeded in discovering it during an earlier search in Thailand. We also found that there were no firms which could offer specific consulting services in biotechnology assessment to industries in the biotechnology sector. In addition, the services offered by the Technology Assessment Division of the Ministry of Science, Technology and Energy are not widely known.

In an attempt to determine whether there was any correlation between firm characteristics and acquisitive capability, Table 3.5 was prepared from the raw data presented in Annex 2. It compares the overall acquisitive capability of 32 firms in the survey with various firm characteristics. It can be seen that the only categories where the differences were significant ($p = 0.05$) were technology group and R&D activities. Upstream industries industries such as the aquaculture and seed industries tend to have less sophisticated technologies, and this could explain the correlation between technology group and acquisition. The correlation between "R&D activities" and higher acquisitive capability can be explained by the fact that the presence of technically qualified R&D staff would help the firm in seeking, assessing, and installing new technologies. This is particularly important since the senior management for many of these companies rarely includes technocrats and they therefore depend upon their technical staff, consultants, etc. for advice and recommendations.

Figure 3.7 Profiles of aquisitive capabilities in eight industries in the biotechnology sector. See Tables 3.2 and 3.3 for an explanation of the scoring system.

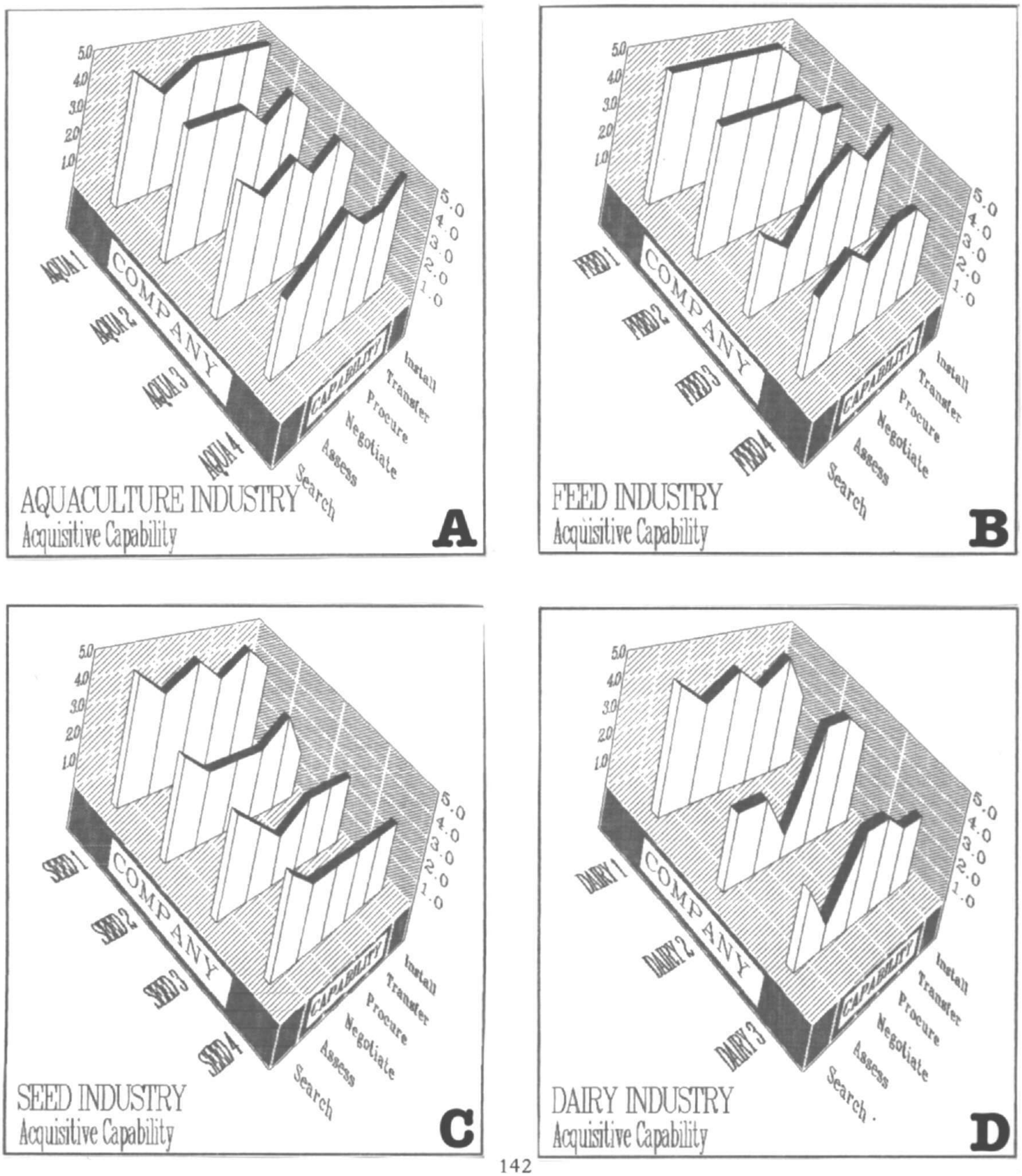


Figure 3.7. Continued

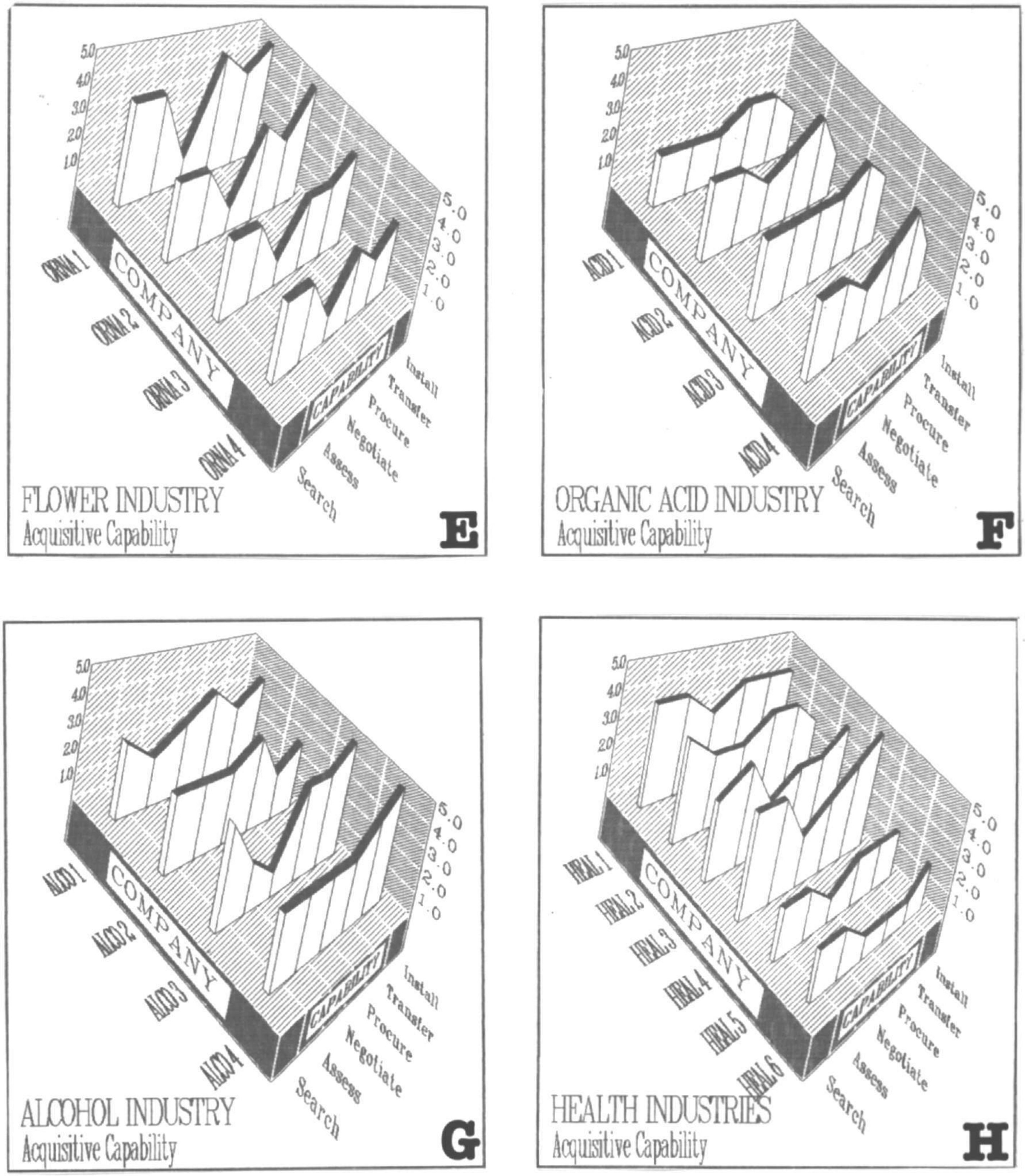


Table 3.5. Acquisitive capability versus various firm characteristics.

	MEAN CAPABILITY LEVEL	STANDARD DEVIATION	N	STATISTICAL SIGNIFICANCE
SIZE OF FIRM				NS
Large	3.57	0.84	23	
Small	3.17	0.78	9	
TYPE OF INVESTMENT				NS
Thai	3.34	0.84	20	
Joint/Foreign	3.65	0.74	12	
TECHNOLOGY GROUP				S (p = 0.05)
Upstream	3.72	0.75	14	
Downstream	3.22	0.78	18	
MARKET ORIENTATION				NS
Export	3.55	0.73	9	
Import	3.39	0.86	14	
Both	3.45	0.83	9	
PROMOTIONAL STATUS				NS
With BOI	3.46	0.97	17	
Without BOI	3.45	0.61	15	
TRAINING PROGRAM				NS
Yes	3.31	0.91	17	
No	2.62	0.66	15	
R&D				S (p = 0.05)
Yes	3.73	0.77	17	
No	3.14	0.76	15	

3.3 Profile and Assessment of Operative Capability

Figure 3.8 graphically presents the operative capability ratings for the eight industries included in this survey. The actual numerical data used to prepare these graphs are included in Annex 2. As with the profiles of acquisitive capability presented in section 3.2, it is clear that there is no serious problem with the biotechnology sector as a whole with respect to operating capability, and that most of the problems are firm specific. However, as above, there are industry specific problems. For example, there is an industry wide lack of organized training activity in the alcohol industry (Fig. 3.8, G) and there is a generally poor capability in all categories for the alcohol and organic acid industries (Fig. 3.8, F).

The range of ratings for the sector was from 2.80 for the alcohol industry to 4.15 for the aquaculture industry and the average for the whole sector was 3.49. This corresponds to a capability under the average for the industrialized countries.

As in the preceding section, the poor performance of the organic acid industry is probably partially related to the fact that it is a mature industry. However, this does not mean that all the firms in the group performed poorly. For example, Acid 1 (a joint venture firm), had a relatively high indigenous operative capabilty because of good staff training, good management and good maintenance programs. They also offered good salaries and benefits; thus being able to hire well qualified technicians. All of this contributed to a high capability embodied in the Thai staff. This firm was the only one in the group able to make the transition from MSG production to lysine production for the animal feed market both locally and internationally. They could capitalize on their trained and skilled staff to facilitate this change, although the technology used was all developed by the parent firm and imported as a turnkey project. Other firms in the group had poorer capabilities which mostly stemmed from the attitude of the management towards the method of operating the firm and the relatively lower priority they gave to maintenance and to the quality and qualifications of their staff.

Being a mature industry is also part of the reason for the poor rating of the alcohol industry. They gave relatively poor attention to maintenance, had technicians with relatively low qualifications and lacked training programs. The common lack of concerted training programs in the whole alcohol group was unique for the industries we surveyed. The generally poor ratings in this industry group probably also resulted from the low level of competition due to overprotection. In contrast to Thailand, for example, many alcohol producers in industrialized nations are competitive in the international market and have active research programs in biotechnology aimed at future production improvements and diversification.

There may be other factors also involved. The two largest alcohol and alcoholic beverage producers in Thailand have amalgamated into a giant oligopoly which dominates the market and buys up any production licence which becomes available for an existing firm that goes bankrupt or sells out. Since the Government does not issue new licences, the oligopoly is gradually assuming complete market control. One small producer in the survey who manufactured alcoholic beverages in addition to alcohol was asked why he did not make an aggressive marketing drive to capture a larger share of the beverage market. He said that this was impossible since his company would be quickly and easily eliminated by the largest producers (the oligopoly) at any time it was considered a significant threat to their market share. He was satisfied to occupy his current niche and not disturb the status quo.

These poor capabilities may be contrasted with the high capabilities in the aquaculture and feed industry groups. The aquaculture (shrimp) firms are relatively new and the best in the group (Aqua 1 and 2 and Aqua 5, not included in Fig. 3.8) were started after the completion of feasibility studies prepared in close collaboration with technocrats. These technocrats later assumed key positions in the senior administration when the firm was established.

By offering good salaries and by providing on the job training, thesew firms have attracted and produced well qualified technical staff. They did express some concern about the impending shortage of qualified personnel because of rapid expansion in the industry. Notice that all of the firms in this group did not assign equal importance to training. We feel that this is short sighted attitude which will eventually lead to a lowering of the capabilities of the skilled staff. A similar argument applies to the feed industry group, where only one firm (Feed 1) assigned high priority to staff training.

In interpreting the capability ratings given here, it must be emphasized that the technological complexity and industrial engineering requirement for the various industries in the biotechnology sector is very different. In the relatively new field of acquaculture, the complexity and physical plant requried for being at the world frontier is relatively less than that required for being at the world frontier in the pharmaceutical industry. Therefore, achieving a high operative capability with a relatively unsophisticated process requires fewer and perhaps less extensively trained personnel, particularly with respect to peripheral engineering needs.

In an attempt to determine the relationship between operative capability and firm characteristics, Table 3.6 was prepared from the raw data presented in Annex 2. It compares the overall acquisitive capability of all the firms in the survey with various firm characteristics. The only features which showed significant ($p = 0.01$) correlation with high operative capability were joint venture/foreign investment and R&D activities. This indicates that firms with R&D units had higher operative capabilities than their counterparts without. Since these so called "R&D" units were largely engaged in adaptive activities, the data simply shows that successful adaptation leads to higher operative capability. The significantly higher capability rating for joint venture firms probably results from the inputs of the parent firm in terms of training, management and policy concerning maintenance.

Figure 3.8. Profiles of operative capabilities in eight industries in the biotechnology sector. See Tables 3.2 and 3.3 for an explanation of the scoring system.

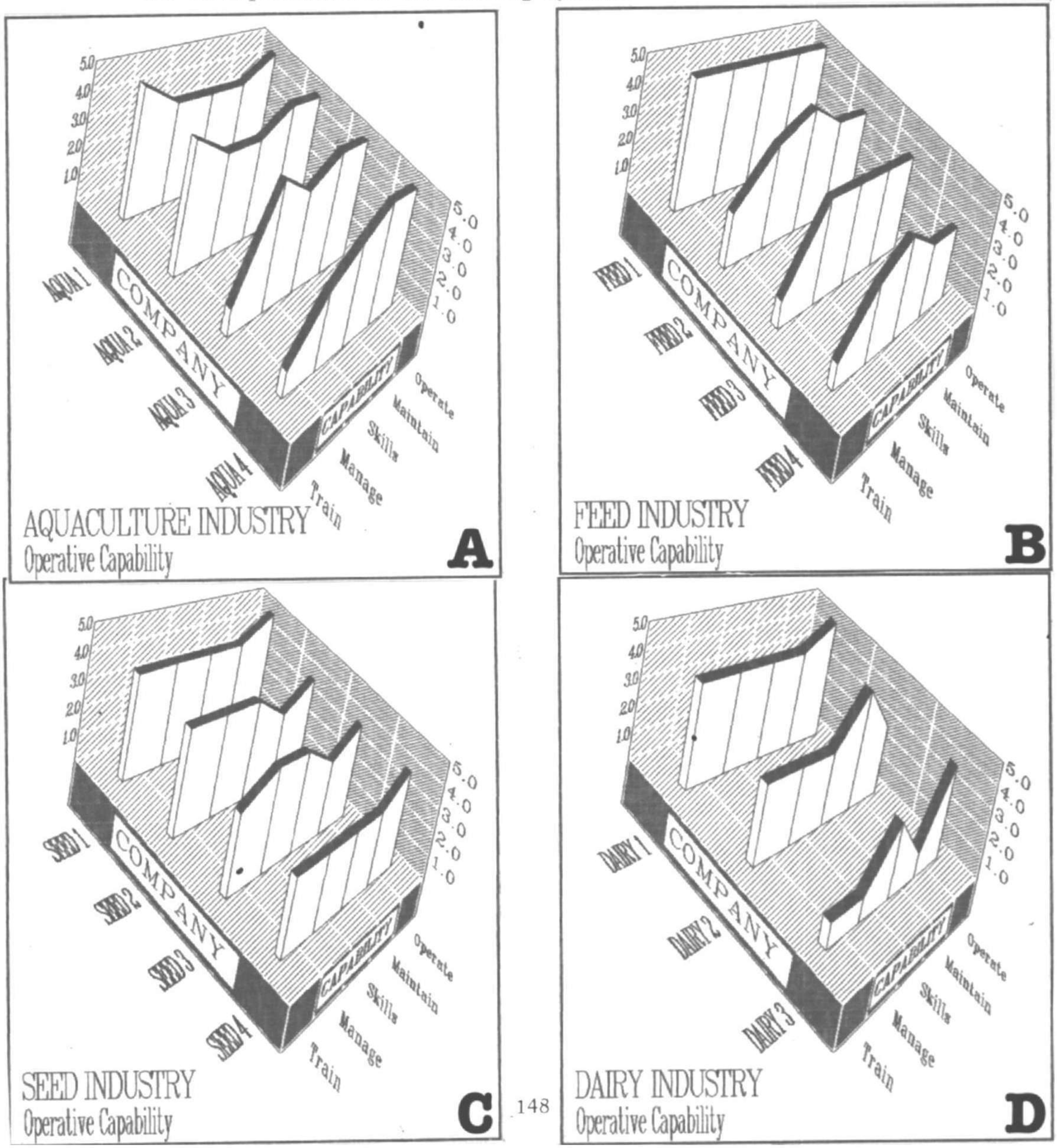


Figure 3.8. Continued

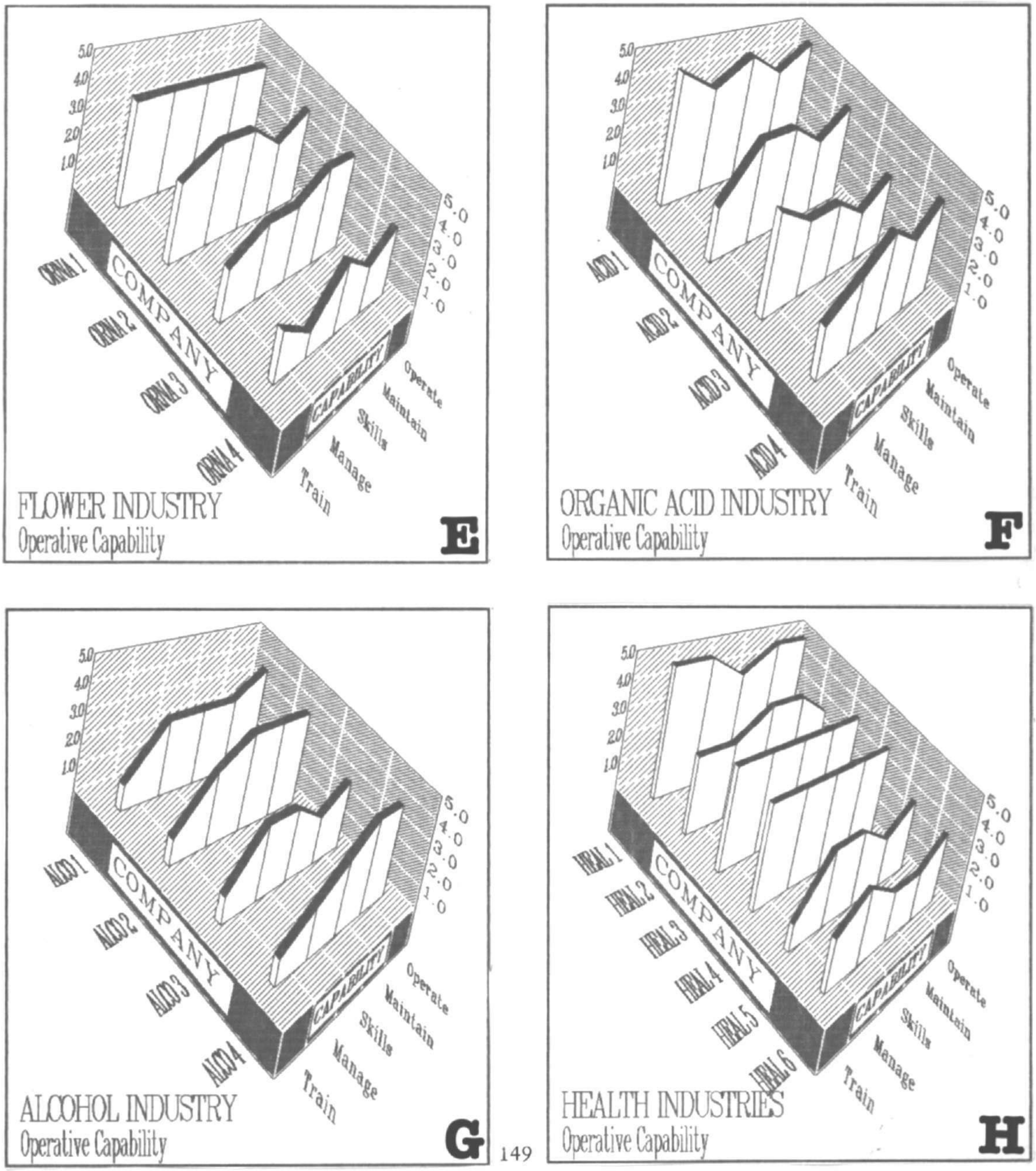


Table 3.6. Operative capability versus various firm characteristics.

	MEAN CAPABILITY LEVEL	STANDARD DEVIATION	N	STATISTICAL SIGNIFICANCE
SIZE OF FIRM				NS
Large	3.58	0.77	23	
Small	3.27	0.71	9	
TYPE OF INVESTMENT				S (p = 0.01)
Thai	3.20	0.74	20	
Joint/Foreign	3.98	0.54	12	
TECHNOLOGY GROUP				NS
Upstream	3.59	0.74	14	
Downstream	3.51	0.79	18	
MARKET ORIENTATION				NS
Export	3.42	0.64	9	
Import	3.36	0.82	14	
Both	3.77	0.74	9	
PROMOTIONAL STATUS				NS
With BOI	3.65	0.65	17	
Without BOI	3.31	0.85	15	
TRAINING PROGRAM				NS
Yes	3.61	0.82	17	
No	3.36	0.69	15	
R&D				S (p = 0.01)
Yes	3.84	0.74	17	
No	3.10	0.60	15	

3.4 Profile and Assessment of Adaptive Capability

Figure 3.9 graphically presents the adaptive capability ratings for the eight industries included in this survey. The actual numerical data used to prepare these graphs are included in Annex 2. As with the profiles of acquisitive capability presented in section 3.2, it is clear that there is no serious problem with the biotechnology sector as a whole with respect to adaptive capability and that most of the problems are firm specific. Unlike the previous two capabilities there do not seem to be any industry specific problems.

The range of ratings for the sector was from 2.63 for the health industry to 4.13 for the aquaculture industry and the average for the whole sector was 3.36. Again, this corresponds to a capability under the average for the industrialized countries. When found, strengths tended to be in the area of product modification and in the ability to acquire new knowledge and apply it to product improvement. The so called "research work" carried out to a limited extent in some quality control laboratories was usually of this adaptive nature. There was an overall general weakness in ability to modify processes probably due to the lack of sufficient numbers of highly qualified process engineers.

The relatively high rating for the aquaculture industry is because the technology used there is not very sophisticated. Modification of processes involves changes in rearing techniques and usually does not involve the use of very complex equipment. Also, the industry is young and in a stage of rapid change, so that seeking stability is part of the normal production process worldwide. Thus, the capability to change the species cultured and to modify the production process is therefore an integral part of the flexibility required by the nature of the industry. The highest capability firms surveyed (Aqua 1 and Aqua 2) regularly subscribed to journals and had sufficient technical staff (even in senior management) so that they could keep abreast of current developments in the field and apply these to their business, where appropriate. The firm with the lowest adaptive capability in this group was weak in the area of new knowledge aquisition and digestion. It had no technical unit with appropriately qualified staff assigned the task of seeking and testing new developments that might be appropriate to the business. The reason for this difference appeared to be one of mangagement policy.

In the feed industry group, the firm with the highest adaptive capability was Feed 1. This firm had a high capability to modify its feeds to suit the local market demands and their quick response to the demands from the rapidly growing shrimp industry is a case in point. Using their relatively large, highly qualified technical staff they quickly came up with an appropriate feed formulation which was being further modified as the results of ongoing feeding tests came in. Existing facilities accommodated the new formula and computers were used to determine least cost feeds. Cooperation with the local academic community, government agencies and consultants; a regular program of training; regular subscription to journals; and possession of appropriately qualified staff ensure that the firm is abreast of the latest developments in the field of feed production and able to choose which of these are appropriate to its needs in shrimp feed production. A new production facility specifically for shrimp feed was under construction. This was to be computer controlled and to require a minimum number of skilled operational staff. The firm's usual procedure is to buy one production unit from abroad and then to modify and copy it locally in whatever numbers required. This buy and copy process was also used by Feed 2, and it indicated a good degree of adaptive capability. The lower capability firms in this industry group appeared to assign low priority to development of technical staff and facilities.

In an attempt to determine the relationship between adaptive capability and firm characteristics in the biotechnology sector, Table 3.7 was prepared from the raw data presented in Annex 2. It compares the overall acquisitive capability of all the firms in the survey with various firm characteristics. The only characteristic that correlated with higher adaptive capability was the presence of "R&D activities". Since these activities were largely adaptive, the correlation was to be expected and it confirmed our contention that the development of technical staff and facilities would lead to improved adaptive capability. Whether a firm invests in these appears to depend upon the attitude of the management and upon the priority they assign to technological change.

Figure 3.9. Profiles of adaptive capabilities in eight industries in the biotechnology sector. See Tables 3.2 and 3.3 for an explanation of the scoring system.

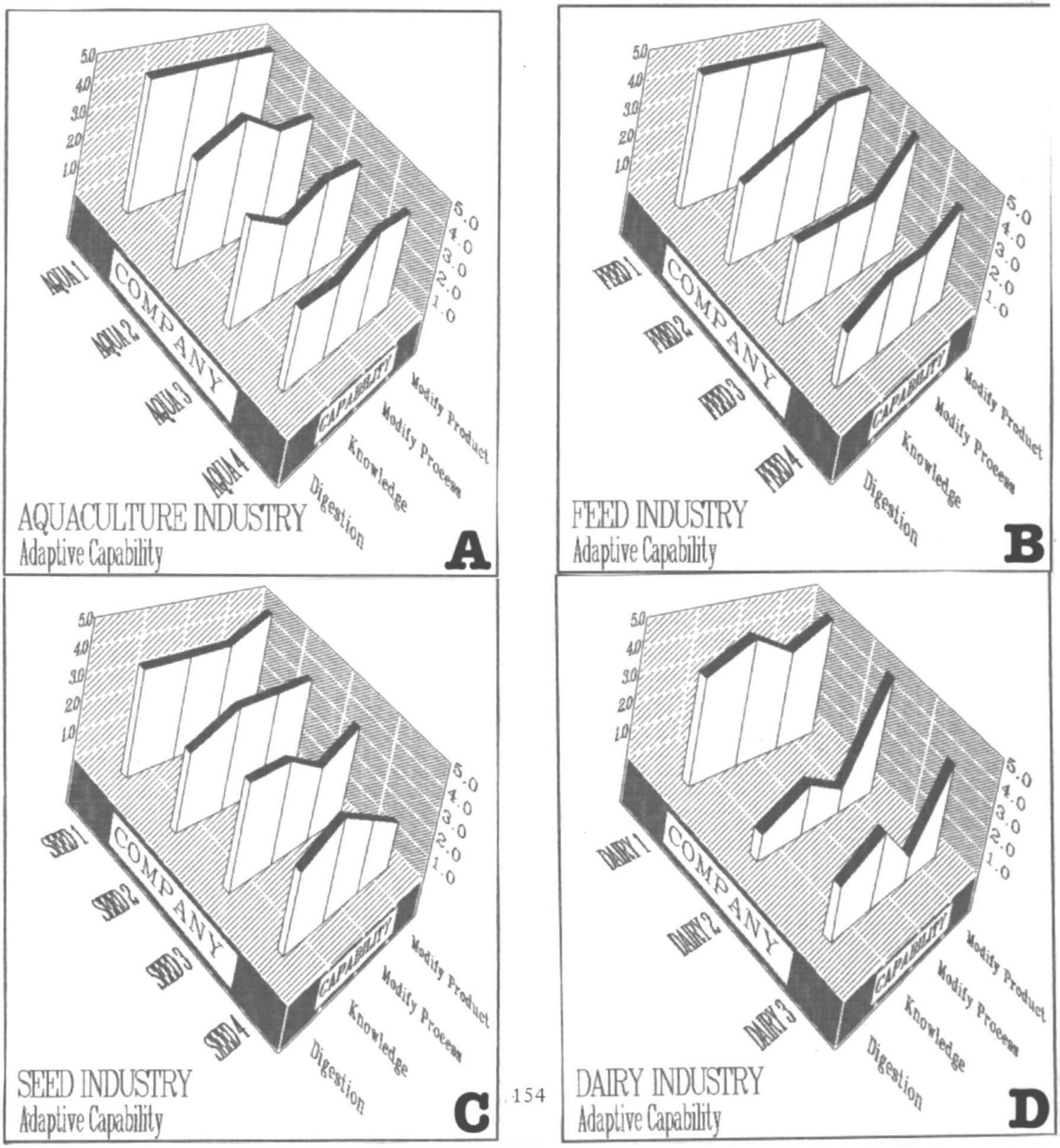


Figure 3.9. Continued

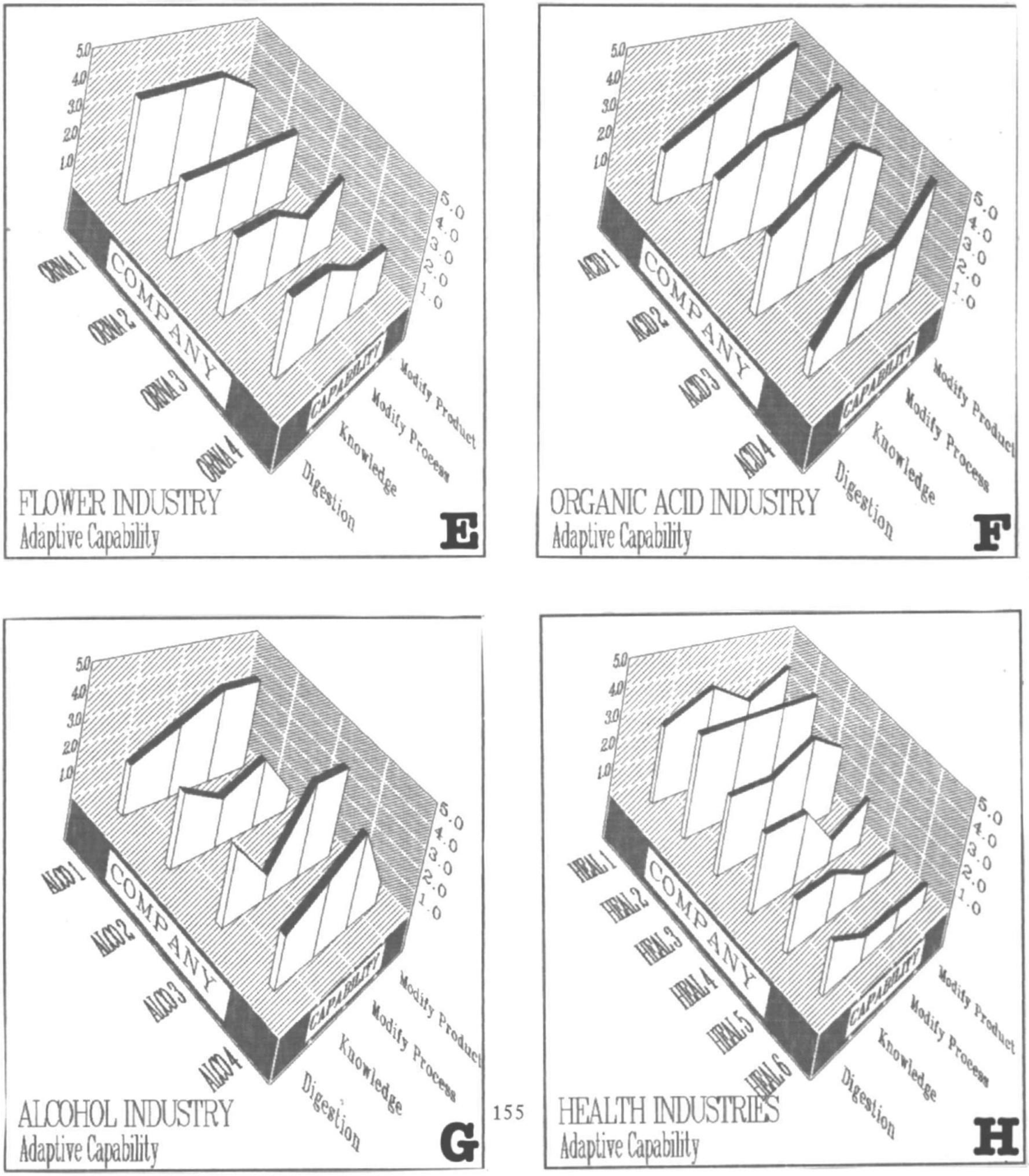


Table 3.7. Adaptive capability versus various firm characteristics.

	MEAN CAPABILITY LEVEL	STANDARD DEVIATION	N	STATISTICAL SIGNIFICANCE
SIZE OF FIRM				NS
Large	3.43	0.86	23	
Small	2.97	0.89	9	
TYPE OF INVESTMENT				NS
Thai	3.18	0.93	20	
Joint/Foreign	3.52	0.78	12	
TECHNOLOGY GROUP				NS
Upstream	3.48	0.81	14	
Downstream	3.17	0.93	18	
MARKET ORIENTATION				NS
Export	3.22	0.82	9	
Import	3.04	0.98	14	
Both	3.81	0.56	9	
PROMOTIONAL STATUS				NS
With BOI	3.22	1.04	17	
Without BOI	3.40	0.68	15	
TRAINING PROGRAM				NS
Yes	3.29	1.03	17	
No	3.32	0.71	15	
R&D				S (p = 0.01)
Yes	3.68	0.82	17	
No	2.88	0.78	15	

3.5 Profile and Assessment of Innovative Capability

Figure 3.10 graphically presents the innovative capability ratings for the eight industries included in this survey. The actual numerical data used to prepare these graphs are included in Annex 2. Unlike the profiles of adaptive capability presented above, it is clear that there is a serious problem which is sector wide with respect to innovative capability. The general trend is for a little capability to change processes and products for some firms but very little or no capability to make major innovative changes, to carry out research in new areas and to invent new products.

The range of ratings for the sector was from 1.37 for the health industry to 3.25 for the aquaculture industry and the average for the whole sector was 2.27. This corresponds to a capability well under the average for the industrialized countries and it is based on the fact that the majority of Thai firms do not carry out basic R&D work at all. Although these firms often professed to carry out R&D activities, the activities were most often very limited in nature, centered in quality control laboratories and focused on process adaptation or slight product modification rather than fundamental change. Thus, the "local average" capability rating of two virtually represents zero R&D activity.

Three firms, Aqua 1, Feed 1 and Seed 1 had rather higher innovative capabilities than the other firms in this survey. Aqua 1 had diversified its product lines into several aquatic species and had changed its process technology to accomodate these changes. The changes had required some prior, in house research and development and the preparation of feasibility studies. This firm had an ongoing research and development program but had not yet invented any new products or techniques. The firm Aqua 2 had a similar prifile, as did Aqua 5, a firm interviewed subsequent to the preparation of Fig. 3.10. These three firms realized the necessity of keeping to the forefront in shrimp culture, and the necessity of research and development in order to do this. All three have cultivated local contacts with relevant academic and governmental institutes and have qualified technical staff capable of meaningful communication with the experts therin. These firms may be contrasted with Aqua 4 which had made major changes in moving to new species (even from fresh water to salt water species), but maintained no tehnical section and had no specific R&D program.

Feed 1 is an example of the only multinational Thai company included in the biotechnology firm survey. This firm had active R&D programs to develop new and improved feeds. They had full time technical staff engaged in R&D activities, and they also maintained close contact with the academic and institutional communtity. They regularly engage in contract research with Thai adademics and they had diversified into completely different product areas by the formation of other companies. For example, they are even engaged in the manufacture of motorcycles in China. Feed 2, by contrast was less diversified, had a much more limited research staff and had less contact with the academic and institutional community. The research activity was carried out as a side line in quality control laboratories and it consisted mainly of work of an adaptive nature. Although this firm originated in much the same manner as Feed 1, it did not make the transition from a local firm to a diversified multinational. This difference appears to have resulted mainly from the attitudes and policies of the management regarding the value of research.

At the low end in innovative capability, were firms surveyed in the flower, organic acid, alcohol and health industry groups. All the firms in the ornamental plants group used plant tissue culture techniques with a high degree of skill, however none of the firms surveyed were investigating the possibilities of extending into the field of existing agricultural plants or of developing new varieties of these agricultural plants. They were completely occupied with production activities for their current market.

In the organic acid industry, the innovative capability for

Acid 1 rested entirely with the parent firm abroad, where the capability was very high. Thus, they had no need for a local R&D capability. However, the results of R&D by the parent company enabled Acid 1 to make the major change of opening a new factory for the production of lysine (an amino acid ingredient of animal feed) destined for the local and international market. Again, the capability to make this change resided with the parent company, and not with the local staff. Acid 2 was a competitor Thai firm to Acid 1 which purchased its turnkey operation from abroad. However, its production efficiency was lower than that to Acid 1 largely because of the microbial strain used in fermentation (i.e., they obtain a lower yield of MSG per unit of substrate employed). In spite of this, Acid 2 had no in house program for strain development and improvement. It had engaged in a low level of cooperative research with a local university for the development of microbial strains and processes for lysine production. However, this program was not supported for a sufficiently long period and with sufficient funds to achieve success and it was dropped. The management apparently lacked the foresight reqired for this type of long term development committment.

For the health related industries, local companies are largely engaged in formulation work and there is only one producer of antibiotics by fermentation. All of the firms which are engaged in R&D activities, including the antibiotic producer, have their R&D laboratories in other countries. None of them are located in Thailand. As with Acid 1 in the preceding section, this means that the local capability for innovation is very low.

In the alcohol industry group, Alco 1 had made some contact with the local academic community for assistance in developing a new alcoholic beverage and it had the capability to make the necessary changes changes in processing. Similarly, Alco 2 had made a major processing change for the use of enzymes in alcohol production from starch. This was accomplished by the import of a short term expert and by continued technical support from the enzyme supplier. However, neither of these companies had technical units engaged in R&D activities and even the contacts with the academic community and consultants was short term in nature. There was no long term planning for investigation into new products and processes. As stated in the preceding section, the overprotection and oligolopolistic nature of this industry group reduce cometitive drives and allow for stagnation.

In an attempt to determine any correlation between innovative capability and firm characteristics, Table 3.8 was prepared from the raw data presented in Annex 2. It compares the overall acquisitive capability of all the firms in the survey with various firm characteristics. Upstream technology group correlated significantly ($p = 0.01$) with higher innovative capability. As with acquisitive capability, this probably relates to the relatively lower degree of sophistication of the technologies in upstream industries. The lack of correlation with presence of R&D activities results because the so called R&D activities of most of the firms surveyed were really activities aimed at adapting processes to local conditions. They were not involved in fundamental or applied research aimed at developing new product lines or new processes.

We can conclude that there is nothing particularly repressive about the local policy environment with respect to carrying out R&D activities. Those companies which have the will or see the necessity to carry out R&D do so. Where there is committment and sufficient resource, all is possible. We can say, however, that the local policy environment is not conducive or stimulatory to R&D activities. Local access to information is difficult, expecially for small firms, and taxes on scientific equipment are excessive. If a large number of firms decided to begin R&D laboratories, there would not be a sufficient number of appropriately trained personnel to meet their needs.

Figure 3.10. Profiles of innovative capabilities in eight industries in the biotechnology sector. See Tables 3.2 and 3.3 for an explanation of the scoring system.

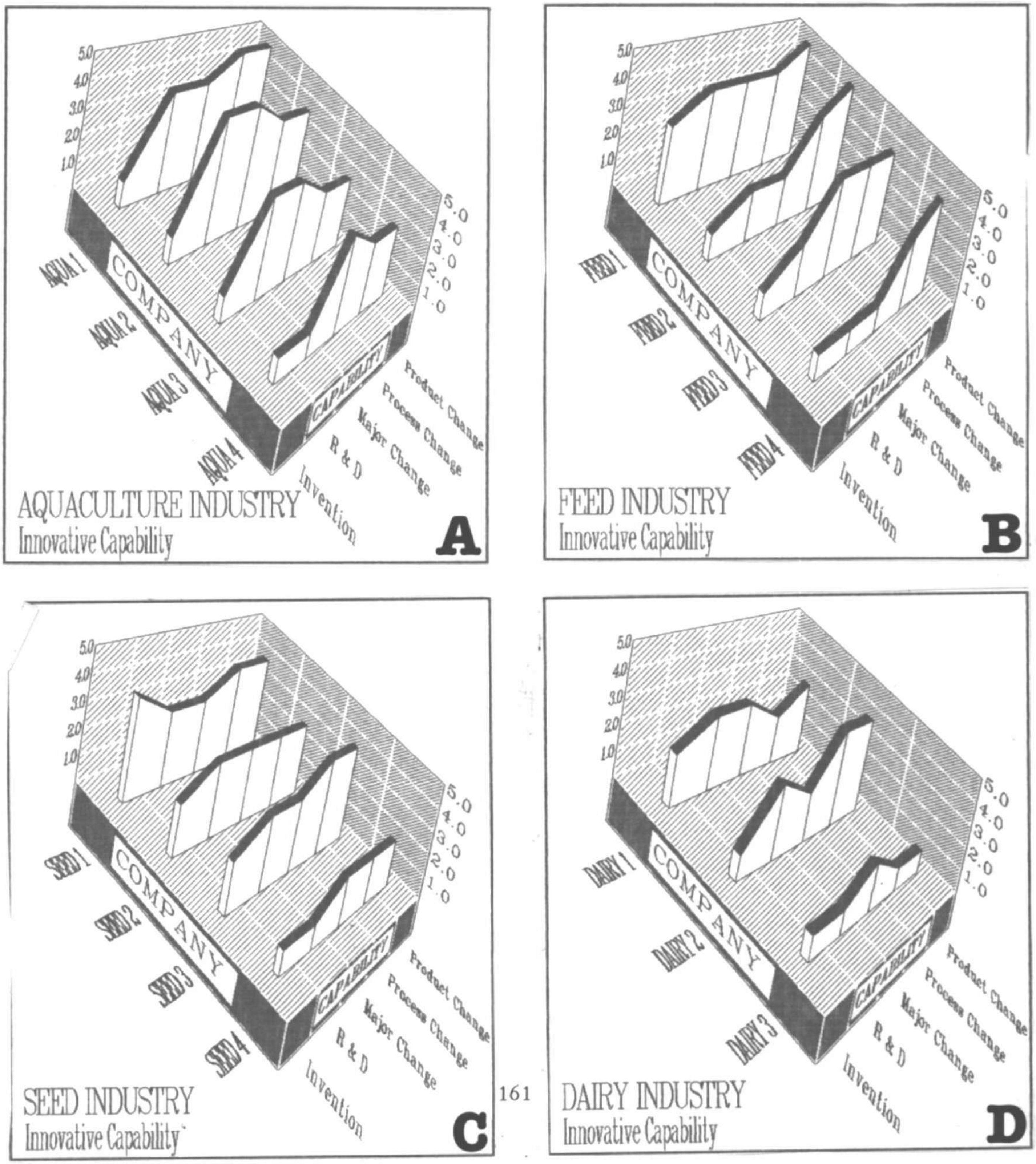


Figure 3.10. Continued

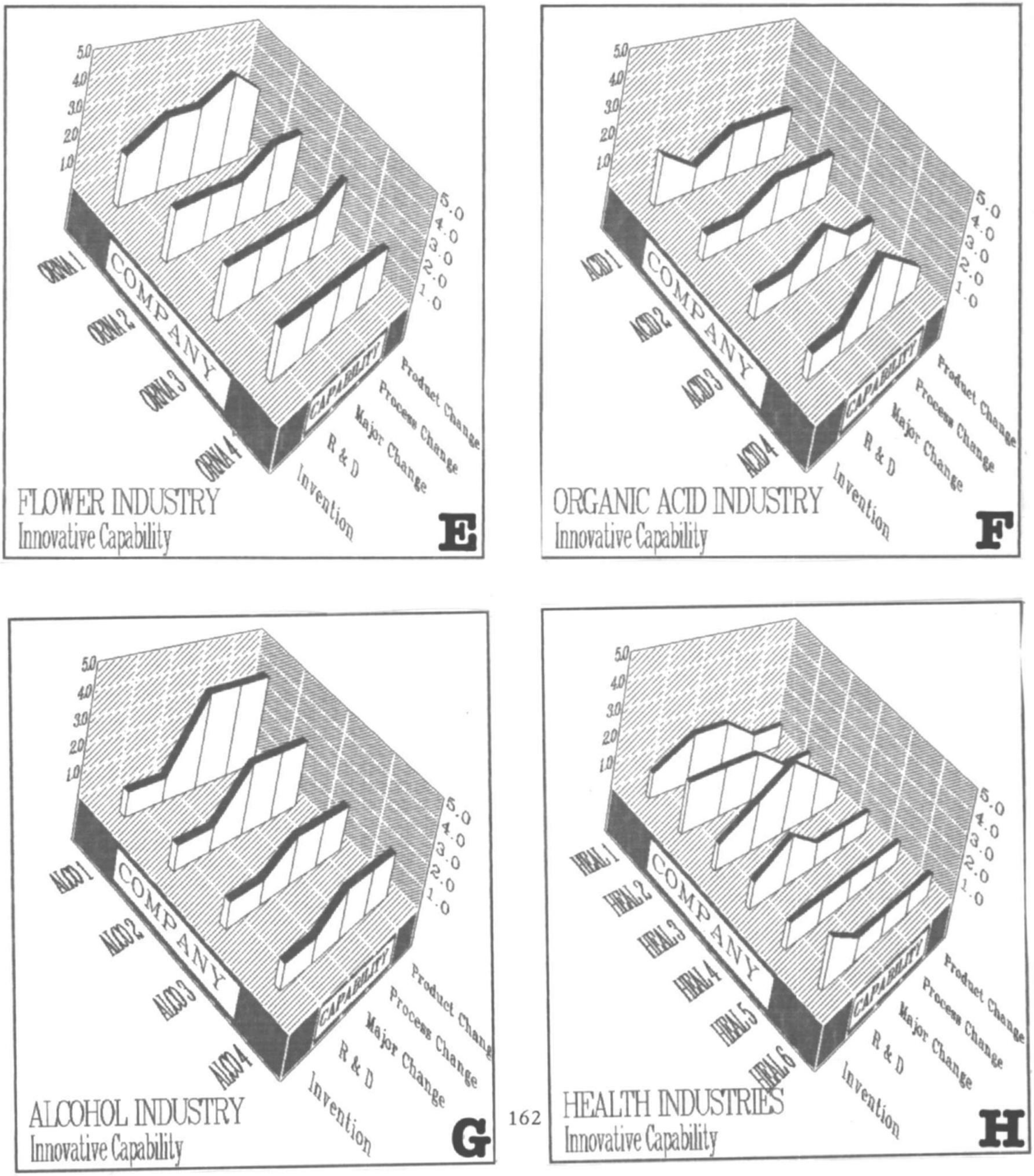


Table 3.8. Innovative capability versus various firm characteristics.

	MEAN CAPABILITY LEVEL	STANDARD DEVIATION	N	STATISTICAL SIGNIFICANCE
SIZE OF FIRM				NS
Large	2.23	0.88	23	
Small	2.27	0.72	9	
TYPE OF INVESTMENT				NS
Thai	2.16	0.83	20	
Joint/Foreign	2.38	0.84	12	
TECHNOLOGY GROUP				S (p = 0.01)
Upstream	2.67	0.75	14	
Downstream	1.91	0.76	18	
MARKET ORIENTATION				NS
Export	2.58	0.64	9	
Import	1.95	0.79	14	
Both	2.47	0.95	9	
PROMOTIONAL STATUS				NS
With BOI	2.29	0.83	17	
Without BOI	2.19	0.86	15	
TRAINING PROGRAM				NS
Yes	2.18	0.98	17	
No	2.32	0.64	15	
R&D				NS
Yes	2.24	0.84	17	
No	2.17	0.70	15	

3.6 Summary of Technological Capabilities

Fig. 3.11 is a graphic presentation of the overall technological capabilities of Thai industries in the biotechnology sector. Numerical values for these figures are given in Table 3.9. It can be seen that industries good for one particular capability also tend to be good for other capabilities. Thus, in Fig. 3.10, the firms have been ranked in descending order of overall score from left to right and the picture is one of a general decline in all capabilities in the same direction. This pattern suggests that there is nothing inherently limiting about the Thai policy environment as far as development of technological capability in Thai industry is concerned. It is probable that industries with strong leading firms such as the feed industry have high overall ratings because one or two excellent firms have the effect of pulling up their competitors.

It can also be seen from the figure and the table, that innovative capability is the poorest capability for all of the industries and that acquisitive, operative and adaptive capabilities tend to be the strongest. This is a trend that has been seen in other countries as they have made the transition to newly industrialized status (Amsden and Kim 1986). Good capability to import, copy and adapt existing technologies precedes the capability for high innovation. In order to speed the transition to higher innovative capability it is important to promote the continued acquisition of new technologies as they arise elsewhere and to lay a firm groundwork for the innovative capability that must be built for the future.

It can be seen from Fig. 3.11 that the alcohol industry and the health related industries have very low innovative capability ratings. This is perhaps surprising when one considers that these industries are amongst the leaders in biotechnological advances in the industrialized countries. With the alcohol industries in Thailand, we consider the primary cause for the lag to be overprotection. With the health industries the situation is more complex. Part of the reason for the poor rating is probably that these industries are mostly concerned with relatively simple formulation work. Also, with joint venture firms, the R&D activities and facilities are usually foreign based. This does not always mean based in the home country. For example, Lever Brothers has a very active, well equipped and modern biotechnology research facility located at Bombay, India. This center is staffed almost completely by Indian scientists.

Obviously, there are some advantages for multinationals to locate their research facilities in developing countries. We also believe that there are advantages to the developing countries. We know of one biotechnology firm (Plantek, Singapore) that considered Thailand for the location of research facilities and then rejected it because of foreseen bureaucratic complications. These included complex entry and exit procedures. This situation indicates that the Thai policy environment for R&D development in biotechnology is not optimum.

We have seen in the preceding sections that acquisition and innovation depend heavily upon easy and rapid access to information and especially to information on industrial activities at world frontiers in science and technology. Good training programs at the educational institutions and in private firms also depend heavily on up to date and easily accessible information services. The necessary infrastructure for information services is very weak in Thailand and that urgent action is required if the situation is to be rectified. What facilities do exist are badly scattered and uncoordinated. Financial support is too limited and even the funds available are not allocated wisely. These services are especially critical to small and medium sized firms which do not have the resources to maintain independent data bases.

Another critical feature concerns skilled manpower, not only for industrial firms but also for supportive agencies including information service agencies themselves. For example, it is surprising to date, that there has never been a recruitment program with the aim of training science graduates in information services.

In order for industrial development to proceed smoothly, it is essential that all the relevant technologies for the biotechnology sector are present. This includes core, auxiliary and peripheral technologies. A weakness in any of these will pull the others down to the same level. Thus, the lack of sufficient numbers of process engineers with industrial experience will retard further progress no matter how strong the core technologies may be.

Figure 3.11. Summary profiles of overall capabilities for eight industries in the biotechnology sector ranked in descending order of overall score from left to right. It can be seen that industries with high ratings for one capability tend to have high ratings for other capabilities and vice versa. See Tables 3.2 and 3.3 for an explanation of the scoring system.

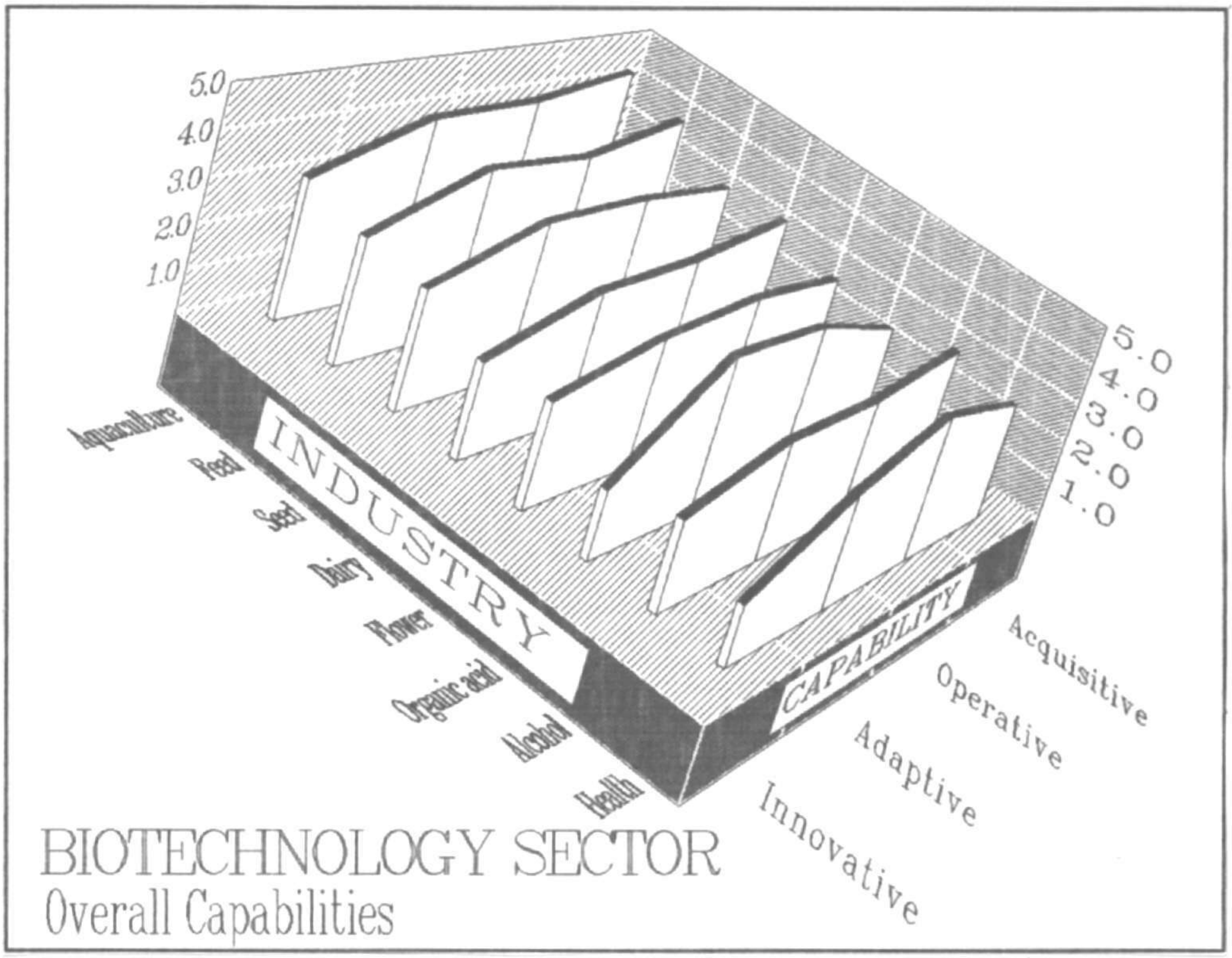


Table 3.9. Summary of capability ratings for industries in the biotechnology sector.

Industry	Acquisitive	Operative	Adaptive	Innovative	Average
Aquaculture	4.54	4.15	4.13	3.25	4.02
Feed	4.21	3.75	3.94	2.95	3.71
Seed	3.46	3.70	3.69	2.80	3.41
Dairy	3.61	3.20	3.08	2.20	3.02
Flower	3.08	3.25	3.00	2.40	2.93
Organic acid	2.79	3.55	3.63	1.55	2.88
Alcohol	3.25	2.80	2.75	2.05	2.71
Health related	2.92	3.50	2.63	1.37	2.61

Table 3.10. Overall capabilities versus various firm characteristics.

	MEAN CAPABILITY LEVEL	STANDARD ERROR OF MEANS	N	STATISTICAL SIGNIFICANCE
SIZE OF FIRM				NS.
Large	3.20	0.56	23	
Small	2.92	0.39	9	
TYPE OF INVESTMENT				NS.
Thai	2.97	0.47	20	
Joint/Foreign	3.38	0.60	12	
TECHNOLOGY GROUP				NS.
Upstream	3.37	0.41	14	
Downstream	2.95	0.62	18	
MARKET ORIENTATION				NS.
Export	3.19	0.37	9	
Import	2.93	0.59	14	
Both	3.38	0.54	9	
PROMOTIONAL STATUS				NS.
With BOI	3.16	0.52	17	
Without BOI	3.09	0.52	15	
TRAINING PROGRAM				NS.
Yes	3.09	0.54	17	
No	3.18	0.50	15	
R&D				NS.
Yes	3.17	0.66	17	
No	2.82	0.39	15	

3.7 Profile and Role of Private Sector Supportive Agents(PSSA)

3.7.1 Potential Roles of Private Sector Supportive Agents in Technological Capability Development

Private sector supportive agents in this study consisted of technical consulting firms, input agents and output agents. Capabilities in design engineering, pilot plan operation, quality control and market research are essential for the transformation of R&D results into commercial production. The essential link between R&D inventions and production & service enterprises is provided by engineering design and consulting services. Consulting firms carrying out engineering and design services are very important facilitators for utilization of indigenously developed technologies. They can make significant contributions in the process of technology development up to and including the stages of commercilalization (i.e., from feasibility studies to the promotion of technology exports). Engineering consulting firms undertake activities related to establishment of industrial units and infrastructure facilities beginning at the planning and designing stage and running through to the erection of plants and provision of services. (ESCAP, 1983; APCTT, 1986)

In developed countries, comprehensive engineering firms conduct not only engineering work but also construct plants, own process technologies and carry out intensive R&D. In the Republic of Korea, engineering services took shape in the 1970's in response to promotional laws for engineering service. These engineering firms now provide plant engineering services as well as specialized engineering services in different fields of engineering, including production management. (APCTT, 1986)

In developing countries and newly industrialized countries, consulting firms currently play more important roles in assisting transfer of foreign technologies and in disseminating technologies rather than in developing indigenous technologies. However, as more and more indigenous technologies are developed and encouraged, the shift towards the latter role will be inevitable.

Input agents consist of subcontractors and suppliers of raw materials, spare parts, and production equipment. they are themselves either producing firms (often in a different industrial sector) or, in many cases, just traders. In biotechnology related industries of the industrially developed countries, input suppliers (particularly those who supply equipment and specialty chemicals and/or materials) often play a very important role in research and development, often cooperative, with producing firms. They play an important role in technology development, particularly for technologies which are not themselves part of biotechnology but are very closely related and important to the development of the industry. Examples include firms engaged in the development of fermentors and other reactors, in the development of sensors and control equipment and in the design of specialty equipment.

In developing countries and newly industrialized countries, input agents play a role in technology development mainly as information suppliers and as agents to assist foreign technology transfer. Subcontracting, as applied to the electronics and materials based industries, does not often apply to biotechnology industries.

For biotechnological industry, output agents vary considerably, ranging from traders of consumer products and exporters & importers to very specialized agents such as diabetic patients, hospitals, and other institutions. Thus, roles of these agents vary from the simple provision of product specifications to the supply of specific technologies. In some cases, they participate directly in R&D and product development.

3.7.2 Overview of Thai Private Sector Supportive Agents

In Thailand engineering and technical consulting firms do not normally have the capabilities to carry out the full range of consulting services. There are very few consulting firms of relevance to the biotechnology industrial sector. The Engineering Institute of Thailand, at the end of 1987, published a Directory of Experienced Engineers and Thai Consulting firms (EIT, 1987). All of the listed firms were either civil, mechanical or electrical engineering consulting firms with little relevance to processing industry. The 1987 AT&T phone directories (yellow pages) listed 56 consulting firms which included architectural and water treatment consultants. None of the firms listed in either reference appeared to provide either processing or biotechnological consultants except for conventional waste treatment. In all large industrial processing projects such as the national petrochemical projects, foreign consultant companies are used throughout.

There are a few consulting companies which attempt to provide consulting service to producing firms in atleast two different capacities. Firstly, they act as advisors to investers in the selection of production technologies, and secondly, as advisors in providing technology to upgrade existing technologies. In the latter case, the clients are normally small firms with insufficient technical manpower to carry out this process on their own. Generally, producing firms have not utilized consulting firms to an appreciable extent and usually were unwilling to pay what they consider to be "high" consulting fees. Consulting firms are forced to pay very low basic salaries to their employees and to supplement the income on a per job basis, to keep the overhead expenses low. In addition to utilizing "experts" from other private sector agents and from government agencies, consulting firms also utilized free-lance engineers to fill the gap caused by occasional high demands. Invariably consulting firms in Thailand have played no role in developing indigenous technologies and have played no significant part in R&D work.

Input and output agents examined in the biotechnology sector in Thailand carried out a wide range of activities since we defined biotechnology very broadly. With regard to technology development, the industrially important input agents were materials and equipment suppliers. Some of these were producing firms themselves (e.g., seed and animal feed companies), but many were just importers and traders. Technical sales representatives provided technical information and know-how to producing firms with respect to equipment and materials. Although technical representatives were trained as engineers, scientists and technicians, they usually did not have any direct experience with producing firms. They acted only as the means for technology transfer from abroad. Foreign technicians with experience were sometimes available.

Output agents were exporters, other producing firms, traders and institutions (e.g., hospitals). Exporters usually supplied specifications and, at times, foreign experts to the producing firm. Some exporters provided quality control laboratories. Output users were invariably looking for consistency both in terms of quality and quantity. Output users could play an important role in Thai technological development since private sector motivation in generating, developing and utilizing technologies is basically market oriented.

3.7.3 Results of Survey of Private Sector Supportive Agents

a. Consulting Firms

Consulting firms surveyed in this study were selected on the basis of having activities in biotechnology based industry. Three companies were interviewed. Two were technological consulting firms that specialized in processing and quality control although they had no engineers on their full time staff. The other firm was an engineering consulting firm and its full-time staff consisted mostly of engineers. The survery results are summarized in the following paragraphs.

Sutech was the only engineering consulting firm surveyed in this study. The firm was set up in 1977 by a group of experienced engineers from sugar cane milling and sugar refining industries. Their major activities were in process improvement, process design and engineering design. Their expertise was mainly in the sugar industry. Recently they formed the Sutech Group of Companies which combined several input supplier companies, a mechanical-civil engineering consulting company (MITR) and an operational center of research and development at a govemental institute (KMITT). The combination, specifically because of the latter two components, had stronger capabilities to carry out a wider range of consulting activities. They have been hired to advise on technology selection and on broadening the base of biotechnology industries which were formerly mainly sugar based. They have advised on technology selection for fructose syrup production factories using immobilized enzyme technology, for oil extraction factories and for starch production factories. Their clients were almost totally in the private sector. This firm has recently taken on government related jobs, but these jobs represent less than 3% of their annual turn over. Because their group is listed on the ADB consulting company list, they have provided services in Nepal, Laos, the Philippines and Bangladesh. With regard to their employees, their average technical manpower experiences is over 13 years. The ten full time engineers had more than 5 years experience with one having a Master of Engineering degree, and 40% of the engineers having received their degrees from abroad. Eighty percent of the staff had experience with production firms before joining. The company also employed engineers on a part time basis mainly from other consulting firms; some from universities and other governmental agencies. They were linked formally with a university which provided highly trained staff and R&D back up. They were also strongly linked with an equipment maker. The company identified the following as being important sources of technology and know how : on the job experience, copying, foreign experts and information from input suppliers. Among their major problems for development were poor availability of technical man-power, inconsistency of demand, lack of contracts with foreign and joint venture firms which tended to use only services from abroad, and the inability to participate in major foreign funded projects due to regulations and the lack of required experience. Competition for experienced engineers was also singled out as an important problem inhibiting the development of consulting companies. Of the least concern were sources of funding and the inability to absorb technology from foreign firms joining in the same project. Suggestions for overcoming developmental problems were the following. The government should stress the importance of consulting firms in the development of technological capabilities. Government agencies and government firms should be required to use local consulting firms. The government should provide incentives in terms of soft loans to producing firms to hire consultants. Finally, the government should review its regulation requiring that foreign consulting firms be engaged for major projects. Rather, they should require subcontracting to local consulting firms to encourage their development.

A consulting company "SEAL" was set up by a large joint venture producing firm in 1985. Its major purpose was to assist small canning operators with quality control and with advice on technolgy management to improve upon product quality. The clients were usually very small firms with no trained personnel on the staff. Exporters were the usual buyers for these small producing firms. During the first three years, all of the activities involved quality testing. Only recently (less than a year) has the company expanded to cover consulting for the improvement of production technology and product development. Their three university trained staff and four technicians (all but one with a Master degree) have less than two years of experience. The manager, with a Master degree in Food Technology has less than five years experience. Seventy percent of the technical manpower is part time staff, mainly from other firms, universities, and government laboratories. The company has good linkage with universities which provide technical back up and trained manpower. There is also a link with an equipment producer. The firm identified on the job training as the most important means of staff development. They identified the same important sources of technology as identified by Sutech, with an emphasis on training programes both within and outside of the firm. Also identified as important were R&D activities at university and government labortories. The major problems obstructing development were the same as those identified by Sutech. The company suggested that government agencies and universities should support consulting agencies by allowing employees to more freely participate in private consulting firms and by making information available, conviniently and speedily, when required.

Another example of the interviewed consulting firm is the recently formed Suwannaphum Agro Consultants Co.Ltd. The company is a joint renture with 63% of the share own by Thai. Their main activities are agricultural extension plant protection and dairy consulting. Seventy percents of the clients are from the public sector mainly to manage projects. Eighty percents of the staff are employed on a partime basis, mainly from academic institutions. Important sources of their technology are the experiences of their staff and foreign experts. Availability of technical manpower was ranked as the most important obstacle for development. Among the next most important problems are the lack of confidence of the prospective clients in the usefulness of consulting firm.

b. Input suppliers

Seven input suppliers were interviewed. They supplied machinery, processing equipment and laboratory equipment. Two of the seven were themselves producing firms. Four were Thai companies and the other three were foreign firms. Table 3.11. shows profiles of these interviewed input suppliers. Except for one seed supplier, all the others suppliers were mainly importers. The equipment supplier which was itself a producing firm imported almost 100% of its raw materials. Seventy percent of its equipment was fabricated within the firm and the rest was imported as assembled equipments. This supplier formed a link between biotechnology base industries and materials based industries. The other equipment suppliers and raw materials suppliers were importers of processed raw materials and equipment. Table 3.12. shows the product types and processing sources for products handled by these suppliers.

All of these suppliers had very extensive technical and training services and considered themselves important sources of technology for producing firms.

c. Output users

The interviewed output users consisted of 2 exporters, 2 local distributers and two producers. The exporters play a more action role as technology transfer agent by providing required specifications and foreign experts for lactory inspection and give guidance on the manufactoring processes. The local distributers rely on the technological capability of producing firms which include product development capabilities, the distributers provide only the marketing efforts. The producing firm users provide only specification of products required and do not offer any other source of technology to the supply side producing firms.

3.7.4 Summary of Weaknesses and Strengths

a. Consultancy Services

The major weakness of Thai consultancy services for biotechnology based industries are listed below :

i. The lack of sufficient technical manpower with the

Table 3.11

PROFILE OF THE INTERVIEWED INPUT SUPPLIERS

	Number of firms
Total	7
Thai owned	5
Foreign owned	2
Equipment producer	1
Raw material producer	1*
Importer of equipment	1
Importer of raw materials	3*
Importer of both equipment and raw materials	2

* A firm was count twice

TABLE 3.12

TYPE AND SOURCE OF PRODUCTS HANDLED BY

INPUT SUPPLIERS (IN PERCENTAGE)

Firm no.	%Thai own	Type of product: Raw Materials	Type of product: Processed R.M.	Type of product: Equipment	Origin of products: Foreign	Origin of products: Local	Processing of processed raw materials: Foreign	Processing of processed raw materials: Local	Processing of processed raw materials: By firm	Processing of equipment: Foreign	Processing of equipment: Local
1	100	0	20	80	90	10	70	20	10	80	20
2	0	0	60	40	100	0	100	0	0	100	0
3	0	5	95	0	100	0	100	0	0	-	-
4	100	0	0	100	0	-	-	-	-	30	70
5	100	0	100	-	50	50	50	0	50	-	-
6	100	0	100	-	100	0	100	0	0	-	-
7	0	0	0	100	100	0	-	-	-	100	0

capability to provide consultancy service

ii. The inability to play the role of indeginous technology developers

iii. The lack of their own technology

iv. The lack of their own R&D activities

v. Unwillingness of producing firms to pay "high" consulting fee

vi. Lack of experience and government regulations restricting the ability to partake in large foreign funded projects.

The major strengths are :

i. The strong linkage of the consulting firms with personnel in university and government laboratories.

ii. The strong linkage with input suppliers

b) Input Suppliers

The major weaknesses are :

i. Very limited local technology development activity.

ii. Very few input suppliers who are porducing firms.

iii. Lack of truly experienced personnel with producing firm experience.

The strengths are :

i. Very good sources of technology due to good connections with foreign sources of technology

ii. Good ability to provide support to small and medium size industries.

3.8 Interaction Between Producing Firms and Infrastructure Agents

In biotechnology, interaction between producing firms and governmental infrastructure agencies is limited and much less than desirable. This is especially so in view of the fact that producing firms are week in highly trained personnel while the trained personnel of infrastructure agents are often not efficiently utilized. Table 3.13 shows the response of producing firms regarding the mode of contacts with government infrastructure agents. When analyzing the survey results, it was clear that contacts were usually made on an informal, personal basis rather than on a formal basis. Exceptions occurred when there were requirments set by various regulations.

On the other hand, the survey results of government infrastructure agents showed that they provided technical services including product testing and certification, training of manpower, and technical information. The survey results also indicated that these activities involved some producing firms. In general, it may be concluded that the interactions were mostly of a limited one way nature with the flow of technical service from the infrastructure agencies to the producing firms. Only in a very few cases there was close collaboration among the infrastructure agencies and between the infrastructure agencies and the producing firms.

The interaction between producing firms and private sector suporting agents is obviously much more intense. Attempts to utilize government infrastructure agents by the consulting firms are apparent. This was discussed in section 3.7.

4. BEHAVIOR AND ATTITUDE OF THE FIRMS TOWARD TECHNOLOGY

4.1 Past Behavior in Choosing Technology

The survey showed that firm bahavior in choosing technology varied with level of technology, staff qualifications and source of technology. It was found that 20 percent of the surveyed firms chose their technology almost completely from abroad and that the level of this chosen technology was quite sophisticated. Industries in this group were the health related industry (57 percent imported almost all their technology form abroad) the alcohol industry (33 percent) and the organic acid industry (25 percent) (Table 4.4). The reason given for choosing this sophisticated technology from abroad was that indigenous research and development in this field was not sufficiently advanced.

Of the surveyed firms, 27.50 percent had imported a majority of their technology from abroad by purchasing major production machinery while other parts were manufactured indigenously. About 50 percent of the surveyed firms fell in this category. When included with firms that acquired all of their technology from abroad, it amounted to 47.50 percent (20 + 27.50) of the to total number of firms surveyed. By contrast, 52.50 percent (15 + 37.50) of the firms acquired their technology from local sources. In this latter group, the firms with technology developed almost completely locally were in the aquaculture and ornamental plant industries, where indigenously trained staff was adequate to needs and where some research and development was underway (15 % of total surveyed). The group with a major part of their technology locally developed constituted 37.50 percent of the total firms surveyed and included dairy firms (80 percent) seed firms (75 percent) and alcohol firms (50 percent) (Table 4.1)

In cases where the technology source was largely or completely local, choice of technology was sometimes based on advice from existing or retired personnel in government agencies and semi-government enterprises. It can be concluded that the majority of the firms in the biotechnology sector had chosen their technology from local sources. However, the level of this local technology was not very sophisticated. Research and development and manpower need to be improved. The survey results concerning technology choice behavior were not far from those projected at the start of the study.

Table 4.1

SOURCES OF TECHNOLOGY OF SURVEYED FIRMS BY INDUSTRY

Industry	Sources of Technology							
	Abroad				Local			
	Almost Completely		Majority		Almost Completely		Majority	
	NO.	%	NO.	%	NO.	%	NO.	%
1. Aquaculture (6)	-	-	2	20	3	60	1	20
2. Feed (4)	1	25	2	50	-	-	1	25
3. Seeds (4)	-	-	1	25	-	-	3	75
4. Dairy (5)	-	-	1	20	-	-	4	80
5. Ornamental Plant (4)	-	-	1	25	3	75	-	-
6. Organic Acid(4)	1	25	2	50	-	-	1	25
7. Alcohol (6)	2	33	1	17	-	-	3	50
8. Pharmaceutical (7)	4	57	1	14	-	-	2	29
Overall (40)	8	20	11	27.50	6	15	15	37.50

4.1.1 Factors Affecting Technology Choice of the Surveyed Firms

The majority of the surveyed firms chose their technology on the basis of product market potential, since they declared that investment in new technology first had to be justified on the basis of product market potential. Secondary considerations were technology and/or raw material availability. This was true whether they chose technology from abroad or from local sources. Specifically, the study showed that 100 percent of the surveyed firms declared that the major factor considered in their choice of technology was product market potential. Raw material availability was a secondary consideration for 75 percent of the firms and technological advantage was a secondary or tertiary condideration for 33 % (Table 4.2). This order of priorities was to be expected. When a market and suitable raw materials for its production are available, a firm will then select the most suitable production technology whether locally developed or imported.

Criteria important in determining the suitability of optional technologies were technological raw material advantage, staff qualifications and nature of local raw materials. For example, firms with sophisticated technologies (e.g., health related and organic acid industries) gave priority to technological advantage, while firms with unsophisticated technologies (e.g., aquaculture, feed and seed) gave greater priority to raw material availability. Technology was acquired later. Ornamental plant firms gave equal significance to technological advantage and raw material availability.

When examining the relationship between technology choice and nature of business investment, market orientation, or promotional status, no differences were found in first priority, since this was market potential for all. However, small/medium Thai firms tended to give the least importance to product availability and more importance to technological advantage and staff qualifications (Table 4.3). Examples of such firms could be found in the dairy, health related and organic acid industries. For all other categories in Table 4.3 raw material availability was the second most important factor in technology choice. Example firms were found in the feed, seed, aquaculture and alcohol industries. Firms with export oriention and BOI privilege gave technological advantage equal importance to raw material availability. The degree of competition for these industries is quite high and they find a need for increased efficiency to reduce costs and to improve product quality.

Table 4.2

FACTORS AFFECTING TECHNOLOGY CHOICE OF SURVEYED FIRMS

Industry	Factors Affecting Choice					
	Product Market Potential		Raw Material Availability		Technological Advantages	
	NO.	%	NO.	%	NO.	%
1. Aquaculture	7	100	7	100	5	71
2. Feed	4	100	4	100	2	50
3. Seed	4	100	4	100	1	25
4. Dairy	5	100	2	40	3	60
5. Ornamental Plant	4	100	4	100	4	100
6. Organic Acid	1	20	1	20	3	60
7. Alcohol	7	100	7	100	4	57
8. Health related	8	100	1	13	5	63
Overall	40	100	30	75	13	33

Note: Since one firm could respond with more than one choice, the aggregated percentages are greater than 100

Table 4.3

IMPORTANCE OF FACTORS AFFECTING TECHNOLOGY CHOICE AS RELATED TO NATURE OF BUSINESS FROM THE FIRM VIEWPOINT

Firm's Characters	Factors Affecting Choice		
	Product Market Potential	Raw Material Availability	Technological Advantages
Ownership			
Thai			
Small/Medium	4	1	2
Large	4	3	3
Joint Venture/ Foreign Firm			
Small/Medium	4	3	3
Large	4	3	2
Market Orientation			
Export	4	3	3
Domestic	4	3	2
Both	4	3	2
Promotional Status			
With BOI	4	3	3
Without BOI	4	3	2

Note: 4 = most important
1 = least important

By comparing size of investment, ownership and purpose of business operation with the sources of technology, it was found that most large Thai Firms and joint venture firms with export markets had purchased technology from abroad as turn key operations. These firms also required sophisticated technology which was not locally available. Small Thai firms with domestic market orientation and firms with special protection largely selected their technology from local sources. Examples were found with alcohol and Thai Whisky producing firms. Small Thai firms which gave raw materials as their prime concern obtained their technology from retired government staff, (e.g., seed and ornamental plant businesses) or through cooperation with governmental agencies (e.g., dairy, wine and some aquaculture businesses).

4.1.2 Technology Assessment before Implementation

The study found that 62.50 percent of the surveyed firms used only their firm personnel to assess new technology, 12.50 percent used evaluation by consultant agencies and 25 percent used both (Table 4.4). Large firms with BOI promotional status always sought assestment by consultant agencies. This was followed by final analysis using firm personnel. These trends were apparent whether the source of technology was local or from abroad.

The majority of the firms surveyed were self-reliant in technology assessment, possibly because of the lack of available consultancy services, the lack of sufficient adequately trained personnel and the reluctance to spend money on technology evaluation. These firms were more progessive in economic aspects. This indicates an imbalance in the development of manpower for science and technology versus economics. The infrastructure base for investment information, including R & D, needs to be improved by both the government and private sector. The limit in R & D development also limits the availability of information and reduces the effectiveness of technology assessment.

Table 4.4

TECHNOLOGY BEHAVIOR ASSESSMENT OF FIRMS SURVEYED

Industry	Assessment Capability	Assessment Agent					
		Firm Personnel		Consultant Agency		Both	
		No.	%	No.	%	No.	%
1. Aquaculture	4.54	4	67	-	-	2	33
2. Feed	4.21	1	25	-	-	3	75
3. Seeds	3.46	3	75	-	-	1	25
4. Dairy	3.61	3	60	1	20	1	20
5. Ornamental Plant	3.08	4	100	-	-	-	-
6. Organic Acid	2.79	3	75	1	25	-	-
7. Alcohol	3.25	2	33	2	33	2	33
8. Pharmaceutical	2.92	5	72	1	14	1	14
Overall	3.48	25	62.50	5	12.50	10	25.00

Table 4.5

MODES OF TECHNOLOGY ACQUISITION

Industry	Modes of Technology Acquisition (No. of Firm)					
	Learning by Doing	Business Exchange	R & D	Diffuse from government	Short Term Expert Import	Purchasing from Abroad
1. Aquaculture	1		2		3	
2. Feed		3			1	2
3. Seeds		3		2		
4. Dairy		3		2		
5. Ornamental Plant				1		
6. Organic Acid		1				
7. Alcohol		2		3		2
8. Pharmaceutical		3				1

Note: Some firms have more than one mode of acquisition.

4.1.3 Modes of Major Past Aquisitions

The study found that there were 6 different modes of past technology acquisition. These were via:

a. learning by doing
b. diffusion from the government sector
c. R & D
d. business exchange
e. short-term import of experts
f. purchase from abroad

The first three are local modes of acquisition and the latter three are foreign modes of acquisition

a. Technology acquisition through learning by doing was the major form of acquisition found in small Thai owned businesses whose product market was domestically oriented. A good example was one aquaculture business which started by raising cat fish without any previous experience. The owners subsequently learned from neighbours, leaflets and government documents, consulted with government agency staff and participated in seminars concerned with fish. They failed for the first 3 years, unable to produce the quantity of fish fingerlings planned. However, by persistence and accumulated hands on experience, this firm has become one of the most progressive acquaculture firms, supplying almost all types of fish fingerlings and post lavea shrimp to the local market and using self developed hatchery technology.

The manager of this firm was hired by an Indonesian fishery business as a one year expert consultant in fish production. Also, some types of fish-fingerlings produced by this firm are being exported to The Republic of China. This is an example of successful technology acquisition through learning by doing.

b. Examples of technology acquisition through diffusion from government agency staff both formally and informally were found in the seed, ornamental plant, dairy, wine, alcohol and whisky industries. Sometimes this transfer was accomplished formally with a private firm, via retired government staff working with the private firm or via organized training courses. Sometime it was accomplished informally through personal contract. Technology aquisition through personal contract with government staff was found in the dairy, wine, and aquaculture industries. The qualifications and capabilities of staff for these firms were quite limited and needed to be improved.

c. Technology aquisition through R & D was found in three aquaculture firms. These firms foresaw that there was a product market potential for tiger prawns, and that the necessary new materials and environment were locally available. These large Thai firms were export oriented businesses. Their aquaculture activities were started following economic feasibility and marketing studies and pilot studies on tiger prawn hatching and raising. When a satisfactory level of production was obtained the businesses were started up. The firms generally had sufficiently qualified staff to carry out R & D activities.

d. Most of the firms in the feed, health related and brewing industries had modes of technology acquisition via business exchange. Foriegn firms wishing to export machinery, equipment, tools or parts provided new technology to the customers supported by traning courses seminars, and/or trade missions. Firms with domestic and export markets were found in this category.

Another type of business exchange occured by transfer from a parent companies abroad. The parent firms practiced business in different countries by transferring some of their technology to firms in former import markets.

e. Technology acquisition through short-term import of experts was found in only 3 aquaculture firms. One was a large Thai firm and the other two were large joint venture firms. Two of these three firms were also industrial product manufactures and the other was also an agro-industrial firm. When these businesses disversified into aquaculture, their personnel had no relevent experience. Thus, they imported experts with the needed skills to train their staff. The experts were allowed to stay for one or two years, during which time the technology was transferred to their staff. All of these firms were large export oriented frims with BOI investment privileges. Most of these firms recruited new Thai staff with limited experience in aquaculture and had them trained by the foreign experts (mostly from Taiwan) through learning by doing.

f. Technology acquisition through purchase from abroad was found in large Thai and joint venture firms with either export and/or domestic oreinted markets and with BOI privileges. Examples of this type of technology acquisition were found in the health related, animal feed, brewing and organic acid industries. Some of these were turnkey operations and others had a majority of foreign imported technology.

In conclusion, firms that acquired technology via learning by doing, R & D and government diffusion acquired their technology mainly from local sources while those that acquired it via business exchange, expert import and purchase were foreign imported. The mode of technology acquisition depended heavily on government policy and strategy. If the government policy clearly promoted self-reliant technology, then the source of technology would be predominantly local.

g. Some firms acquired their technology from combined sources. For example, one seed firm combined learning by doing with R & D. This firm diversified its business from tobacco production to include seed production. Some technology was transferred from abroad when they accepted seed production subcontracts, since the supply seed to the contractor had to meet with the contractor's requirements. This was another type of technology diffusion from abroad through business exchange.

4.1.4 Upgrading Capability in The Acquisition Process

The factors critical for upgrading a firm's acquisitive capability are discussed in the following paragraphs.

a. Firm policy. If a firm has a policy for technological self-reliance, it will upgrade the capabilities of its staff and provide some necessary facilities for this through R & D and training activities or by recruiting staff with new qualifications as they are required. Successful firms in this regard are aware of the dynamic nature of technological development. Their staff are provided with current-literature and sent to meetings and training courses, either local or abroad, in a planned maner. This pattern was found in large Thai and joint venture firms with either export and/or domestic oriented markets. The study found that most of the feed producing firms were operating by this policy. Their staff was upgraded through training and subscription technical magazines. They could keep up with the dynamic technology and acquire technology from abroad as needed.

Technological self-reliance was found in two aquaculture firms, and one ornamental plant firm. The former two firms had set up R&D units for self-reliance before starting the business, while the latter set up both together. The technology in these firms is considered to be not highly sophisticated, and thus R&D can be operated by the quailified staff of these firms without great expense. All the seed producing firms also employed well qualified staff and carried out some R&D together with staff training programs.

b. Degree of competition. A high degree of competition leads to upgrading in almost all aspects of staff capabilities between competitive firms. Examples of this were found in the feed, seed and ornamental plant industries. Feed firms have to develop feed formulas in dynamic response to raw material prices, particulaly since the prices of soybean meal, fish meal and corn are constantly changing due to the flexible supply and the high demand tiger prawn and poultry industries. The wastes from poultry slaughter houses (e.g., feathers) and the shrimp carapaces are being processed as animal feeds to substitute for some of these raw materials. Growth hormone production and development is another important activity for all feed and aquaculture firms. The competition on hormone producing technology among firms is quite high in the feed industry. A good example of competition is found in the seed industry. There is a race to develop new seeds with higher yields and better disease resistance. This activity requires specifically qualified and highly qualified staff. This stafff is upgraded constantly through training, R&D activity and subscription to technical magazines. By contrast, industries with a low degree of competition, and especially those with overprotection by the government, (e.g., the oligopoly in the alcohol industries)tended to lack programs for uppgrading staff capabilities. For firms in industries with moderate competition (i.e., where market entry was difficult), the extent of staff training was also low. Examples were found in the organic acid industry where the extent of the market was limited and where technology advantage with some products (e.g., lysine) resulted in a virtual monopoly.

c. Level of technology. Firms which employed sophisticated but mature technology purchased from abroad also had a poor record for upgrading acquisitive capability. Examples were found in the organic acid and feed industries. Since the imported turnkey technology was sophisticated, the importer was not allowed,without permission of the exporter, to develop/modify any parts/tools/machines. Because of this regulation, the degree of upgrading of the acquisitive capability of staff was quite low. These firms did not have enough time to improve/develop technology since production had to meet the planned marketing schedule. The firms also wanted to make capital recovery as soon as possible. The policy for upgrading capabilities in these firms was not clearly defined. By contrast, firms using less sophisticated but evolving technologies needed to upgrade staff capabilities to keep up with technology change. Example firms could be found in the dairy, seed, aquaculture, and alcohol industries.

d. Infrastructure. Support services from the government through R & D, information services and policy measures are important factors in determining acquisitive capability, especially for small firms with limited resources. Such companies surveyed depended upon institutional development of manpower for their staff requirements and for upgrading of staff qualifications. These firms also had limited resources to apply to acquisition of new information and therefore had to rely on these services from the public sector. Government policy is not clearly defined in this regard and consequently the process of upgrading capability for technology acquisition was poor. However, the government is trying to provide infrastructure indirectly related to upgrading the acquisitive capability of firms with biotechnology base, by establishing TISTR, STDB, NCGEB and the Technology Transfer Centre. These institutions and centers supply/ diffuse technology in various forms to the public (e.g., research training, seminar programs and publications). Informal development of acquisitive capability occured automatically via personel consultants from government staff in the alcohol, dairy, seed and aquaculture industries.

4.2 Evolution of Operative Capability

Operative capability evolution was discerned in a majority of firms which had been operating for more than 5 years. The study found that 23 percent of the surveyed firms showed significant evolution in operative capability (Table 4.6) as evidenced by changes in raw materials, processes or products. The major reason for these changes was product market potential, especially in the aquaculture, seed, feed, and organic acid industries. Another major reason was based on efficiency improvement, especially in the dairy, ornamental plant, alcohol and organic acid industries.

Some of feeds and organic acid firms, cited the degree of competition as a reason for technology change. Many firms cited more than one reason for technological change, e.g., efficiency improvement together with degree of competition. Obviously efficiency improvement toward cost reduction would improve the abiliby to compete. Some firms cited product market potential together with efficiency improvement. Others cited all 3 as causes of technological change(e.g., some firms producing organic acids, feeds and aquaculture product).

Whatever the reasons for the changes, the fact that they were made successfully by these firms indicated that they had significantly evolved their operative capability.

4.2.1 Incidences of Major Technological Events

This subject is discussed by industry type in the following paragraphs.

Aquaculture. The technology base of the firms in this group covered control of a few basic parameters such as water pH, temperature, and sodium chloride content (salinity), which varied from place to place and from season to season. Some firms evolved by diversification, e.g., starting with only tiger prawn culture and then developing hatchery technology. Some in this group are now planning to produce feed for prawns, and this requires a different more sophisticated technology.

An example of technology evolution due to market demand can be seen from the example of one aquaculture farm, which origninally produced only a few types of fish fingerlings by natural breeding, but then developed through artificial insemination to produce a few varieties of fishes such as Thai carp and cat fish. Further evolution saw production of various types of fishes according to market demand, the most recent example being tiger prawn larvae using hatchery technology. This firm is now one of the leading aquaculture companies that produces many kinds of aquaculture products in the market. In addition, the firm also produces and maintains unique father/mother stocks of endangered species seldom found in natural waters.

Feeds. Technology evolution in this area results mainly from changes in raw material prices. Feed formula technology evolution is based on the prices of the raw materials and the kinds and ages of animals. It is very dynamic, and continuously changes to suit the requirements.

Seeds. Even now Thailand has to import many types of parent seeds for production. When seed production was first initiated here only tropical seeds could be produced. Then semi-temperate seeds were produced via the influence of increasing market potential together with the advent of suitable technology. At present, some temperate seeds can be produced domestically. Chia Tai, Eastwest and Kasert Sakol are good examples of companies showing this type of technology evolution.

Dairy. Thailand has been importing increasing quantities of breed cattle from many parts of the world, including Australia, New Zealand, Denmark, U.S.A. and France. Technology evolution has occured gradually in terms of care and breeding, although many problems concerning diseases and climate adaptation remain with these animals. Technology development is more progressive at the farm level than at the factory level, since the technology is adaptive, and depends on the types of breeds, environmental factors, available concentrate feeds and available roughage. Technologies for breeding, breed improvement and breed conservation through artificial insemination and newly developed embryo transfer have been introduced and are being continuously improved.

Ornamental Plants. There are presently many varities of flowers supplied to both domestic and foreign markets. This is particularly true for flowers in the orchid family, through tissue culture and other more conventional breeding technologies. Tissue culture technology has been applied to roses, gypsophila, carnation, gladiolas, chrysanthemum, gerbera, statice, anthurium and lillies. However, technology evolution for some flowers is limited by market constraints.

Organic acids. A good example of evolution in this group of industries is diversification in monosodium glutamate (MSG) production into L-lysine production. L-lysine production requires more sophisticated technology than MSG production. Another example is technology improvement in citric acid production by using various raw materials with different specific technology to reduce the cost of production and to achieve a higher quality of product. Some of these changes resulted from indigenous research and development at universities.

Alcohol. Fluctuating raw material prices have played a significant role in technology change in this industry. Firms in this group usually adapt technology to respond to the changing prices of raw materials. Different raw materials require some change in technology. Some of the brewery firms, on the other hand, change their products quite often, e.g., Thai Amarit has produced different varieties of beer (Krathing Thong, Kloster, Ginestroud, and Siam Beer) for both domestic and export markets. Each variety requires slightly different production techniques and processing has to be adapted accordingly. Some Thai whisky producing firms can now produce brandy and whisky for export. Wine producing firms produce different types of wines from various locally available fruits.

Pharmaceutical and related industries. An example of technology evolution can be seen at the Thai Meiji Co., which produces the antibiotics Kanamycin and Gentamycin. Raw materials were initially completely imported, but were gradually changed to those from local sources. These local sources presently account for approximately 90 % of the total. Another example can be seen with the Government Pharmaceutical Organization. They cooperate with United Pharma Industries Co. Ltd. to produce Ampicillin (180 m.t/year) and Amoxycillin, and they have made changes in raw and intermediate materials towards a more completely local process. Both Thai Meiji and the Government Pharmaceutical Organization are now threatened by dumping from overseas producers such as The Republic of China, India, France and other European countries. This is a major problem which will require further technology evolution and policy measures.

4.2.2 Accumulation of Experience and Improvement of Performance Level

This was achieved through R & D and staff training programs. Most of the large Thai and joint venture firms with R & D activities significantly accumulated experience and thereby improved their performance levels. Besides R & D activities, these firms continuously upgraded their capabilities through organized internal seminars or through participation in seminars/conferences organized by both government and private agencies. Staff training programs to upgrade knowledge on technology have been organized by some companies as in-house programs, or as overseas training programs. Sometimes the overseas courses were sponsored by foreign firms which intended to sell products or technology to the local firms. Examples of these were found in some animal feed firms, seed producing firms, aquaculture firms and alcoholic beverage firms. Relevant research reports and magazines were also provided by these firms in order to improve the performance level of their personnel. Successful quality control is one of the indicators of improved performance levels and of staff experience accumulation. It can be concluded that accumulation of experience and improvement of performance level was generally achieved by large firms chiefly through R & D activities training programs, information services and quality control activities.

4.2.3 Monitoring of Local and World Standard and Practices

These activities are related to those on accumulation of experience and improvement of performance level, and constitute operative capability indicators. A majority of the large Thai owned firms and joint venture firms continuously monitored local and world technology standards and practices in order to maintain effective competition. The qualifications of the technological personnel in these firms were quite high. Examples were found in seed, ornamental flower and feed-producing firms. These firms had personnel with Master degrees or higher degrees to carry out their monitoring activities as well as their other activities which contributed to experience accumulation and performance improvement.

Table 4.6

TECHNOLOGY EVOLUTION OF BIOTECHNOLOGY FIRMS IN THAILAND

Industry	Technology Evolution*									
	Yes		No		Justification					
					Product Market Potential		Degree of Competition		Efficiency Improvement	
	No	%	No	%	No	%	No	%	No	%
1. Aquaculture	4	67	2	33	4	100	4	100	4	100
2. Feed	3	75	1	25	3	100	3	100	3	100
3. Seeds	4	100	-	-	3	75	1	25	-	-
4. Dairy	2	67	1	33	-	-	-	-	3	100
5. Ornamental Plant	3	75	1	25	-	-	-	-	3	100
6. Organic Acid	2	50	2	50	2	100	2	100	2	100
7. Alcohol	4	75	1	25	3	100	3	100	3	100
8. Pharmaceutical	5	71	2	29	2	40	3	60	3	60
Overall	27	73	10	27	22	81	16	59	21	78

Note: One firm could respond with more than one choice, so the aggregate "percentage of justification" is greater than 100.

4.3 Adaptive and Innovative Behavior of the Firms

This section discusses results form the survey of manufacturing firms on their behavior towards technological adaptation and innovation. The focal points in the discussion will be the extent and nature of these two activities. Reasons, motivation, and influencing factors behind their adaptive and innovative behavior will also be explored. Furthermore, sources and consequences of adaptation will also be addressed.

The primary objective of this section is to throw some light on the technological dynamism of the manufacturing firms, particularly with regard to their behaviour towards technological adaptation and innovation. It should be noted at the outset, however, that over generalization form the research findings and discussion should not be made without great caution because of the limited data and information obtained from the surveys of these firms. The research teams initially visited about 42 manufacturing firms which had been selected. After an introductory interview with the managers and some key personnel and an observation of the technological facilities and equipment (e.g., plant lay-out, production process, and laboratories of the (firm), a questionnaire was given to each of them for completion. Unfortunately, only a small number of completed questionnaires were returned. Because of this, a second round of visits was undertaken, and personal interviews were again conducted with the managers and key personnel of the firms. As a result, about 12 satisfactorily completed questionnaires were gathered mainly from ornamental flower firms, dairy firms and pharmaceutical firms. Therefore, the discussion below is based mainly on the data and information obtained from these manufacturing firms.

4.3.1 Technological Adaptation and Dynamism

Adaptive behavior of the manufacturing firms in the biotechnology-based industries is considered form main technological activities, namely change in plant lay-out of machinery, and adaptation or modification of machines, equipment, raw materials, or products. Table 4.7 presents intensity of adaptive activities of 12 firms of this research.

Table 4.7

INTENSITY OF ACTIVITIES ON ADAPTATION OF TECHNOLOGY

MANUFACTURING FRIMS. CLASSIFIED BY SIZE AND TYPE OF INVESTMENT.

Adaptive activity	Thai firms		Foreign-invested firms	Total (n = 12)
	Small/Medium	Large		
1. Change in plant lay-out of machinery				
Yes	2	2	1	5
No	2	2	3	7
2. Adaptation/ modification of machines of eqipment				
Yes	2	2	1	6
No	2	2	3	6
3. Adaptation/ modification of raw materials				
Yes	2	3	1	6
No	2	1	3	6
4. Adaptation/ modification of products				
Yes	2	3	0	5
No	2	1	4	7
Index of adaptiveness (%)	50.00 (8/16)	62.5 (10/16)	18.75 (3/16)	43.75 (21/48)

On the whole, the intensity of adaptive activities was rather low for these fimes. Less than half of the total number of firms carried any adaptive activities. From this table, the foreign-invested firms were less active in this respect than the Thai firms. The less adaptiveness among the foreign-invested firms may be due to the fact that they want to produce the same standard of goods produced in the parent campany. Therefore, adaptive activities, if there are any, are undertaken mainly in the parent company.

Among the Thai firms in the biotechnology-based industries, large firms were more active in technological adaptation than the small ones. As demonstrated by the index of technological adaptiveness, the large Thai firms were also the most active group of manufacturing firms in almost all areas of adaptation of technology considered in Table 4.7. Motivation for technological adaptation by the sampled manufacturing firms are outlined in Table 4.8.

Motivation for technological adaptation varied with the size and nationality of the firms. For Thai firms the main motivations were imporvement in quality (of both products and raw materials), production expansion as a result of market expansion, firm growth, and production efficiency improvement. By contrast, the foreign invested firms engaged in technologcial adaptation in order to increase production efficiency, to expand production, to meet market expansion and to reduce the cost of raw materials. Among the Thai firms, motivations for technological adaptation varied with size. Main motivations for adaptation of technology for large Thai firms were concentrated on increasing production efficiency, reduction of wage bills, quality improvement, and replacement of lod raw materials which were increasingly more scarce. Production expansion resulting form market expansion and growth of business, and improvement in the quality of products and raw materials appeared to be the most salient motivations of small Thai firms.

Table 4.8

MOTIVATIONS FOR ADAPTATION OF TECHNOLOGY OF MANUFACURING FIRMS, CLASSIFIED BY SIZE AND INVESTMENT TYPE.

Motivations	Thai firms		Foreign-invested firms	Total
	Small/Medium (n=5)	Large (n=4)	(n=3)	(n=12)
For Adaptation				
1. To increase production	1	3	1	5
2. To reduce wage bills	-	2	-	2
3. To expand production as a result of market expansion or growth of business	5	-	1	6
4. To reduce cost of raw material	1	1	1	3
5. To improve quality of product and raw materials	4	2	-	6
6. To replace old materials which are increasingly more scarce	-	2	-	2
7. To satisfy and motivate customers	1	1	-	2
8. To use progressive method	1	-	-	2
9. Others	1	2	-	3
Against adaptation				
1. The technology is still efficient	1	-	-	1
2. Present production is suitable	-	1	-	1
3. Others	-	2	-	2

From the intensity of activities and motivations with regard to technological adaptation among the Thai firms, some further observations could be made. Firstly, firms tended to change to more capital-intensive technology as size increased. The assertion here is consistent with that of Khanthachai (1987). Secondly, economic factors such as market expansion, growth of business, and production efficiency played important roles in firms behavior towards adaptation of technology.

Thirdly, as noted earlier, certain firms possessed relatively high potential capabilities for adaptation of technology, but they did not often realize this potential in practice. One of the main reasons, as reported by the firm managers, was that the market for their products was still too limited. Finally, active involvement in adaptation of technology among Thai firms is likely to be improved by a good economic environment such as that in recent years when expansion of manufactured exports and growth tates in the manufacturing sector have been very impressive.

As far as foreign-invested firms or multinational corporations (MNCS) are concerned, Santikarn (1981) and Khanthachai (1987) noted that multinational corporations in Thailand did not substantially adapt imported technologies to local requirements, particularly in product adaptation, since they wanted to maintain world-wide standards of their products. These authors futher noted that some marginal adaptation of technology occurred in the MNCS in Thailand with respect to the adaptation of raw materials. This was done in order to exploit local raw materials which were cheaper than imported ones. The findings of our research as presented in Tables 4.7 and 4.8 are fairly consistent with the observations of these former authors. Additionally, it should be noted that little adaptation of imported technology among the foreign invested firms or MNCS in Thailand was found in the areas of plant lay-out, machinery, or equipment.

Table 4.9

SOURCES OF ADAPTATION OF TECHNOLOGY OF THE MANUFACTURING FIRMS, CLASSIFIED BY SIZE AND TYPE OF INVESTMENT.

Sources of adaptation	Thai firms		Foregin-invested firms	Total
	Small/Medium (n=7)	Large (n=4)	(n=1)	(n=8)
<u>Internal source</u>				
1. Own experience	7	-	-	7
2. Managers, engineers and technicians	4	4	-	8
3. Firm's R&D	-	4	-	4
4. Other employees	-	1	-	1
<u>External source</u>				
1. Input suppliers	-	3	-	3
2. Universities	1	1	-	2
3. Foreign experts and companies	-	1	1	2
4. Output users	1	1	-	2
<u>Other sources</u>				
1. Texts, Journals and reports	1	2	-	3

Note : One firm may provide more than one answer.

As far as source of adaptated technology is concerned, Table 4.9 reveals that it varied with size of firm and type of firm investment. For foreign-invested firms, foreign experts and companies, particularly the respective parent companies, appeared to be the most obvious sources. It should also be noted, however, that there was only one foreign-invested firm that provided information on sources of technological adaptation. This is partly because most of them were not involved in such activities, and partly because only a few of them returned completed questionnaries to the research team.

Among the Thai firms, on the other hand, sources of technological adaptation were many. The large Thai firms seemed to have more sources than the small Thai firms. Important sources were managerial, engineer and technician and R&D work in the firm. Input suppliers, e.g., suppliers of raw materials and machinery, also infulenced adaptive behavior of the large Thai firms. Adaptation or modification of technology in small Thai firms was based mainly on the experience of the owners, managers, and technicians in the firms. It is clear tha the Thai firms, both small and large relied heavily on internal sources for technological adaptation whereas the foreign-invested firms relied on external sources.

It is also worthy that external sources such as universities and output users, as well as texts, journals, and reports played an important role in the adaptation of technology among the Thai firms. The large Thai firms in particular exhibited a higer level of technological adaptiveness than other types of firms. It is very likely that this resulted form the fact that they had a wider range of sources for technological adaptation.

With respect to the consequences of technological adaptation, most manufacturing firms in the survey reported that technological adaptation resulted in enhanced production efficiency and product quality as well as greater satisfaction on the part of product users.

4.3.2 A Case Study

In order to have direct access to domestic market and to respond to the import substitution industrialization policy of the Thai government, a Japanese multinational corporation in pharmaceutical industry set up its subsidiary in Thailand in 1979. With promotional status granted by the Board of Investment, the Japanese subsidiary produced various antibiotic products for both the domestic market and for export to Japan and other countries.

In the initial stages of its operation in Thailand, the Japanese subsidiary employed a number of Japanese technical experts to carry out important production, management and marketing activities of the firm. As a result of counterpart training provided to local employees, most production, management and marketing positions in the firm were later replaced by local personnel except the two top positions of general manager and production manger.

As far as production technology was concerned, the Japanese subsidiary firm employed the same production process as that used in the parent company with some modification. The scale of production, however, was reduced due to the smaller domestic market. Although the cost per unit of production was relatively higher than in Japan, the subsidiary firm was able to make profit since its operation in Thailand was subsidised in various ways under the direct foreign investment promotion scheme of the BOI, e.g., business tax exemption, and tax rebates on imported machines, raw materials, and intermediate products.

While the Japanese subsidiary firm produced the same standard of products as the parent company, technological adaptation occurred in the raw materials used for production of the antibiotics. The subsidiary firm used cassava starch as a raw material in the fermentation process whereas corn starch was used by the parent company. The major motivations for the adaptation in raw material were that cassava starch was abundant in Thailand and that it was cheaper than corn starch. Compared with the production in the parent company, the cheaper price of raw material, as well as lower wages, were countered by more expensive electricity and industrial water costs.

Experiments to test whether cassava starch could be used to replace corn starch in the fermentation process took place in the laboratory of the parent company in Japan, before it made the final decision to set up its subsidiary in Thailand. This was because the subsidiary firm in Thailand had limited facilities and equipment for carrying out experiments. A small laboratory was established in the subsidiary firm with the main aim of minor quality testing of raw materials and products. Although the quality testing was actually carried out by local personnel, it was done under close supervision of the Japanese production manager. Moreover, the quality control circle (Q.C.C.) was set up among the Thai employees, with the Japanese production manager as the Q.C.C.leader. All in all, it was evident that indigeneous adaptive capability of the Japanese subsidiary firm was rather limited.

At the time when the interview with the firm managers was conducted (1988), the Japanese antibiotics producing subsidiary in Thailand was facing operation difficulties which resulted mainly from expiration of the promotional priviledges granted by the BOI and from competition by cheaper import of antibiotics from China. Under these circumstances, the Japanese subsidiary has decided to produce baker's yeast and to apply for an extension of the BOI promotional priviledges to do so. Other policy options avaiable to the subsidiary firm included expanding its production of antibiotics in Thailand in order to exploit scale economy, and closing down production of antibiotics in the parent company in order to increase the export of antibiotics to the Japanese market.

4.3.3 Technological Innovation and Dynamism

Only a few firms in this research (mostly large Thai and foreign-invested firms) had set up research and development units for for carrying out innovative activities. From the data and from the observations of the research team, only one small Thai firm had its own R&D unit. The main purpose of the R&D units in the firms was to enhance technological skills and to conduct research on increased production efficiency. These firms considered that their R&D units were profitable for their businesses.

As for the foreign invested firms, data from the survey revealed that they had set up R&D units before their Thai counterparts. This is not surprising since the Thai economy was dominated by the agricultural sector until only a few decades ago when Thailand embarked on a program for industrial development. The R&D units in the foreign-invested firms, were not well provided with modern equipment and employed only a few research personnel. They were mostly rather small in size. This is mainly because most of their important R&D activities are carried out by their respective parent companies in other countries. For this reason, the R&D units in Thailand were mainly used for confirmatory testing of R&D rsults form the parent company, to find out whether new innovations were suitable for Thailand or not. These R&D units were also used for testing of indigenous raw materials and for product quality control.

Reasons for lack of R&D units mainly concerned policy, technical capability, and profitability of R&D investment. Among the small Thai firms, the lack of technological manpower, skills and facilities appeared to be the most important reasons for lack of R&D units. These small firms also tended to underestimate the rate of return of investment in R&D, probably because the external benefits of technolgy were not seriously assessed. Also, the cost of an R&D unit could have been unbearably high for very small firms. The large Thai firms and the foregin-invested firms that had no R&D units stated that they had no policy for the establishment of such units.

The lack of R&D units in firms does not necessarily imply that they have no R&D activities for adaptation, modification or invention of technology. Even without in house facilities for R&D, a number of the manufacturing firms in this study were involved to a varying degree in certain R&D activities. The purpose of these R&D activities was mainly to test the quality of raw materials and products, and to assess process and product changes. In most cases, these R&D activities were collaborative efforts between the firm and external R&D units, such as university laboratories, government laboratories, and private research companies. Under this type of arrangement for R&D, the manufacturing firms were able to reduce R&D costs substantially.

Table 4.10 summarizes R&D objectives of the sample firms in this study, classified by size and type of investment. The R&D objectives are presented in order of their relative importance as seen by the firms. The large Thai firms and foreign-invested firms, which were involoved more actively in R&D activities than the small Thai firms, were quite similar in their objectives. They emphasized R&D for improvement of production efficiency. This may be due to increasing competition between these two types of firms, as can be inferred from their ranking of other objectives for R&D. The two types of firms adopted fairly different patterns of business strategy. While the large Thai firms concentrated on development of new or differentiated products, on product quality control and on labour cost reduction, in that order of importance, the foreign invested firms put more emphasis on product quality, on adaptation/modification of raw materials (in order to reduce total production costs), and on product development, also in that order of importance.

As far as the small Thai firms were concerned, the most important R&D objective was adaptation or modification of raw materials. Large Thai and foreign-invested firms which were granted promotional privileges by the Board of Investment were entitled to tax rebates or reductions on imported raw materials and on parts, components, and machinery. As a consequence, they tended to import the various inputs rather than acquire them from local suppliers. On the other hand, almost all of the small and medium Thai firms did not receive promotional privileges. Imported inputs, including raw materials, were more expensive for them local raw materials. Other important objectives for R&D among the small Thai firms included product quality control and production efficiency imporvement.

Table 4.10

ROLES OF RESEARCH AND DEVELOPMENT OF THE FIRMS, CLASSIFIED BY SIZE AND NATIONALITY.

Small/Medium Thai firms	Large Thai firms	Foreign-invested firms
1. Adaptation/modification of raw materials	1. Production efficiency improvement	1. Production efficiency improvement
2. Product quality control	2. Product development	2. Product quality
3. Production efficiency improvement	3. Product quality control	3. Adaptation/modification of raw materials
4. Product development	4. Wage bill reduction	4. Product development
5. Product quality improvement	5. Other costs reduction	5. Product quality improvement
		5. Production process adaptation
		5. Wage bill reduction

Table 4.11

MAIN OBSTACLES TO RESEARCH AND DEVELOPMENT AD PERCEIVED BY THE MANUFACTURING FIRMS, CLASSIFIED BY SIZE AND TYPE OF INVESTEMENT.

Small/Medium Thai firms	Large Thai firms	Foreign-invested firms
1. Inadequate skilled-manpower	1. Not profitable	1. Insufficient instruments and equipment
2. Low capability in R&D	2. Low capability R&D	
3. Insufficient instruments and equipment	3. Inadequate skilled-manpower	
4. Insufficient funds	4. Insufficient instruments and equipment	
5. No R&D policy	5. Insufficient funds	

The main perceived obstacles to R&D in the manufacturing firms surveyed in this study also differed (Table 4.11). For the foreign-invested firms with most of their R&D capability in their parent companies, the main obstacle was insufficient instruments and equipment for R&D in the Thai subsidiary. Other R&D obstacles also mentioned by the foreign-invested firms are not presented here since there were mentioned by only a few firm.

Among the Thai firms, R&D obstacles differd for the large firms and the small and medium scale firms. However, the differences were in the perceived order of importance rather than in essense. Essentially, the R&D obstacles concerned inadequate skilled manpower, insufficient instruments and equipment, and insufficient funds. Also important was technology development policy failure, in the sense that small and medium Thai firms in particular did not have clear technology policies, and considered investment in R&D unprofitable. Unprofitability was the main obstacle to R&D for the large Thai firms.

In order to promote R&D among the manufacturing firms, fiscal measures would seem to be the most effective ones. Table 4.12 demonstrates that tax reduction on R&D instruments and equipment, and on R&D expenses were considered to be relatively more important than other policy measures. As for the foreign-invested firms, fiscal assistance form the government, particularly as tax reductions on R&D instruments and equipment, seemed to be the most important measure for them. They gave other measures very little importance. In terms of technology and skills, small Thai firms seemed to need more technological assistance including advice form experts, data and information facilitating R&D, and financial assistance.

Table 4.12

PERCEIVED EFFECTIVE POLICY MEASURES TO PROMOTE RESEARCH AND DEVELOPMENT IN THE MANUFACTURING FIRMS, CLASSIFIED BY SIZE AND INVENMENT TYPE.

Small/Medium Thai firms (n=4)	Large Thai firms (n=4)	Foreign-invested firms (n=4)
1. Tax reduction on R&D instruments	1. Advice form government	1. Tax reduction on R&D instruments
2. Government assistance on provision of data	2. Tax reduction on R&D instruments	
3. Tax reduction on R&D expenses	3. Tax reduction on R&D expenses	
4. Advice form government experts	4. Government assistance with R&D instruments	
5. Financial assistance for R&D	5. Government assistance on provision of data	

Note : One firm may provide more than one answer.

4.3.4 A Case Study

A medium-sized ornamental flower and plants-producing firm was quite active in research and development. It was a Thai company wholly owned by local entrepreneurs. Its main products were ornamental flowers and plants for export to overseas markets, mainly to Eurpoe and the US. Obviously, competition and product quality requirements in the international market forced this medium-sized Thai firm to be actively engaged in research and development of new products.

The company was established in 1974 by a group of local entrepreneurs who had been in agro-businesses for years. In order to build up its research and development capability, the company recruited a university professor by offering him a very attractive salary and fringe benefits and appointed him R&D Director of the company. The University professor had a Ph.D. degree from the University of Hawaii and extensive research experience in horticulture, particularly in orchid production. The R&D Director was responsible for establishment of a laboratory for R&D and for hiring R&D personnel for the company. According to the R&D Director, the company provided full financial support for R&D as one important activity of the company.

Main R&D activities of the company were in the area of plant breeding, plant tissue culture and plant production. To generate improved or new varieties of ornamental plants and flowers, cross-breeding techniques were employed at the experiment station of the company. For example, foreign ornamental plants and flowers were bred with local varieties by simple cross-pollination techniques. Plantlets were typically grown in tissue culture in the laboratory of the company, using appropriately adapted media.

The company provided an opportunity for the R&D Director to travel aboard to participate in various conferences and exhibitions concerning with prduction of ornamental plants and flowers. Moreover, the company also sent R&D personnel to receive further training overseas.

A linkage between the company and universities was estabished. With a prior approval of the company, the R&D Director and his R&D personnel were allowed to give lectures to students. Conversely, university students who were conducting research for partial fulfillment of their studies were allowed to use R&D facilities of the company to carry out their research activities. The student-trainees were given monthly allowance by the company, with an understanding that results of their studies would be made available to the company.

4.4 Practice in Human Capital Formation and Development

A firm's capability in technology acquisition and operation depends greatly on human qualifications. Thus, human capital should be developed continuously. This study found that firm activities in human capital formation varied depending upon size of firm and level of technology used. Most large firms tried to develop human capital through training both in-house and overseas. Firms with low capabilities engaged in fewer personnel development activities. This was particularly evident in the alcohol industries and it was probably result of the oligopolistic nature of this business which operates under government concession. The degree of technologist mobility of this group was lowest, and the technology was also less dynamic.

Other groups with low technologist mobility were the dairy and ornamental plant industries. The former was limited by the career path for technologists and by the low degree of competition in this group. The latter had a specific business operation character which differed from other groups. The marketing of ornamental flowers is horizontal through group members or company members. The technology transferred form one firm to another occurs through purchase of mother plants rather than through technologist recruitment. Similar propagation technology exists in all firms. Patents for developed varieties of plants dose not exist and therefore, plant development technology, paticularly using tissue culture techniques, is not being supported.

The industry groups with a moderate degree of technologist mobility were the fermentation, and seed industries the motivations for job changes were better/higher positions, higher salaries and greater and wider responsibilities with more challenges. This occurred mostly for young technologists seeking something new and challenging. They tended to transfer from large firms where they had limited responsibility to small/medium size firms where they were given greater responsibilities, higher positions and higher salaries. They also had better chances for continued and more rapid promotion. This was found in firms where the business was being managed/developed by young technologists. Technologist mobility in the seed industry was mostly stimulated by provision of higher salaries and/or higher positions. Many young technologists preferred to be big in small/medium firms where the potential for growth was high, rather than small in a big firm where the growth potential was limited.

The pharmaceutical industry also had a moderate degree of personnel mobility because technology level was not sophisticated. Many intermediate products were imported and then repacked and/or mixed to give products with new trade marks. Technology development was not advanced except at Thai Meiji Company which produced Kanamycin and Gentamycin using much more sophisticated technology. Technologist mobility in the pharmaceutical industry was limited by the market share of each firm and by the market system for the business. It is not a system of perfect competition, because all of the porducts imported must be approved and are controlled by the government. The highly sophisticated technological operation of Thai Meiji suffers form marketing problems as a result of dumping by overseas producers (see the previous section). The technology in this firm could not be transferred to other firms due to the constraints of huge investment, lack of required technological capability locally, and limited product market. L-lysine producing firms could also be classified into this group. It can be concluded here that industries with low or moderate .degree of technologist mobility developed human capital to the same low degree.

Of all the biotechnology-based industries, the animal feed and aquaculture industries had the highest degree of technologist mobility for the following reasons :

a. There was a shortage of experienced technologists in these two fields.

b. There was a great opportunity for product, process and technology diversification. For example, a single firm could produce feeds for poultry, livestock, fish and prawns and also engage in contract farming and in the processing industries.

c. There are multi-function businesses in this group. For example, a single company could combine the functions of an input supplier, input producer, product buyer, product processor and also as product exporter in agroindustry in agro-related industries and in non-agro-industires.

These businesses needed technologists from many different fields.

d. The degree of competition was quite high among these industry groups.

e. Production was both export and domestic market oriented.

f. The firms in this group were big Thai or joint venture firms with secure personnel. The degree of human capital formation in this group was quite high.

Aquaculture, a relatively newly developed industry, has a serious problem in human capital formation. Foreign experts from Taiwan, under government authority, have been unavoidably imported, on short-term contracts. Human capital formation has occured through staff learning from these foreign experts during the contract period. Examples were found with AQUA 4 (5 experts imprted), AQUA 3 (3 experts imported) and AQUA 2 (one expert imported).

In addition to the import of experts form overseas, Thailand also exported experts, particularly in the field of horticulture. This is should serve as an indicator for manpower planning for concerned parties.

When technologists moved, some firms gained, some lost. The gaining firms were usually ones offering higher salaries and higher positions during a period of expansion. They did not do this as part of a long-term personnel development program but rather to expand in response to product market potential (i.e., for technological advantage). Technology was thus gained through purchase or import of knowhow or expert. The biggest losers were those firms who had invested in human capital formation especially by investment in overseas training. Some of these losing firms even claimed that they were essentially training schools for technologists for other firms. Two such of examples were FEED 5 (not included in the profiles in Section 3.). The high degree of mobility reflects the present low hunman capital formation through educational and training systems, and is now severely restricting the technical innovative capability.

4.4.1 Approaches and Practices in Acquisiton of Technical Manpower.

This section is divided into two subsections, one concerning staff recruitment and the other concerning staff promotion and fringe benefits. Recruitment practices fell into three catagories :

a. Public advertisement. This process was applied for personnel of all levels of skill and experience and it was generally practised by almost types of firms.

b. Personal contact. Head hunting was practiced only with highly experienced technologists. Examples were found mostly in the feed industry and aquaculture industry where the number of available skilled technologists was low.

c. Imported experts. A good example was the aquaculture industry where highly experienced local technologists were in very low supply. The imported experts were mostly Taiwanese. Human capital development took place by staff learning side-by side with the experts.

Observations regarding staff promotion planning and fringe benefits were as followers :

a. Tranining took place both in-house and overseas for large feed producing firms. The overseas training was mostly for relatives of the company owner on a business exchange basis. One alcoholic firm (ALCO 2) and one alcoholic beverage firm (ALCO 5, not included in the profiles in section 3) were examples of companies who had developed personnel through this process. Training was offered by the technology supplier overseas.

b. Promotion with higher salaries and higher positions was practised by all firms.

c. Fringe benefits were provided by some firms to encourage personnel to stay longer with the firm.

However, in-firm career paths fer technologists were found to be limited, and out-mobility to other promissing firms was often found in large firms with multi-product business operations. By contrast, the degree of mobility in single product firms was quite low, e.g., in alcoholic, ornamental plant, and pharmaceutical industries.

4.4.2 Apporaches and Practices in Upgrading Skill Levels.

Many firms tried to reduce production costs and saw technology improvement via skilled technologists as the only was to achieve this goal. These firms were seeking alternative means to upgrade their personnel to a satisfactory skill level. The means practised by the firms in this study were :

a. Training in-house for lower level personnel and training overseas for the higher level personnel (i.e., heads of sections and higher).

b. Sending personnel to participate in seminars/workshops organized by other agencies. This has been practised by firms in the aquaculture, ornamental plant, dairy, feed and seed industries.

c. Periodic invitation of experts from overseas to meet with the highly experienced technologists of the firm. This method has been employed by FEED 1.

d. Providing information on technology and science through domestic and overseas subscriptions to jounals. This practice was common for feed producing firms, aquaculture firms and seed producing firms.

e. Getting the staff to meet unofficially with government officers to exchange knowledge. This was particularly the case with university staff. The method has been practised by firms in the wine, alcohol, beer, dairy, seed and aquaculture industries.

f. Sending staff to observe similar operations in the foreign parent firm.

The study that firm policy on upgrading skills through higher education was very weak, except for those which were family operated/owned businesses where promotion was limited to family members. Since this training was costly and time consuming and since there was a high degree of mobility in some industries, most firms did not want to take the risk of training those who were not family members.

With respect to practise in human capital formation, it canbe concluded that there was high mobility in large firms with multi-product business operations but low mobility in small/medium firms with single product operations. The degree of technologist mobility affected technology acquisition and operation. The factors affecting mobility and human capital upgrading were firm size, nature of business, business dynamism, cost, and time required. Short tranining periods were preferred by the majority of firms. There was a limited career path for technologists. If firm policy were adjusted to give equal promotional chances to all personnel, the degree of mobility would decline. The government should ensure that the educational system produces a sufficient number of technologists to supply the market demad.

Table 4.13

MODES OF TECHNOLOGY AQUISITION

	Modes of Technology Acquisition					
	Learning by Doing	Business Exchange	R&D	Diffusion from Government	Short Term Export Import	Purchasing from Abroad
1. Aquaculture	1		2		3	
2. Feed		3			1	2
3. Seeds		3		3		
4. Dairy		3		2		
5. Ornamental Plant				1		
6. Organic Acid		1				
7. Alochol		2		3		2
8. Pharmaceutical		3				1

Note : Some firms have more than one mode of acquisiton

4.5 Managerial Capability, Entrepreneurial Attitude and Business Strategy

Entrepreneurs and managerial staff in manufacturing establishments play indispensable roles in the process of the enhancement of industrial technology and skills. For example, the capability in technological adaptation of the small and medium scale manufacturing firms in this survey, as demonstrated above, lay heavily with the experience of the firm owners, managers, and technological staff. Moreover, experience in some countries, particularly South Korea, indicates that the entrepreneurs and/or managers of a manufacturing firm with past technological orientation tend to play aggressive roles as orchestrators of a firm's technological strategy (Amsden and Kim, 1986).

In this section the focus will be on the association between entrepreneurial background adn attitude toward technology, business strategy, and technological dynamism of the firms. For analytical purposes, comparison between different types of firm ownership and different firm sizes will also be made.

4.5.1 Entrepreneurial Background and Attitude Toward Technology

The entrepreneurs in the manufacturing firms in this study were in the age range of 36-70. Those in the small and medium Thai firms were 36.64 years old and those in the foreign-invested firms were older, with ages ranging from 53 to 70. In the large Thai firms, the entrepreneurs seemed to be in the same generation as those in the small and medium Thai firms. In terms of educational attainment, the entrepreneurs in the small and medium Thai firms had lower levels of formal education than those in the large Thai and foreign-invested firms. A substantial number of the small and medium Thai entrepreneurs had only secondary or Mathayom 6 formal training. Almost all of the entrepreneurs in the large and foreign-invested firms had completed university studies.

Most small and medium Thai manufacturing firms in this survey were owned and managed by members of the same family. In the large Thai firms, on the other hand, family members tended to occupy only certain key positions, and additional managerial staff were recruited from the general popular to take up other less important positions. As far as the foreign-invested firms were concerned, key positions such as general manager, finance manager and chief-engineer tended to be held by foreigners while less important business functions were allocated to their Thai counterparts. Under these arrangements, managerial styles varied among these three groups of the manufacturing firms.

With respect to past work experience, a singificant portion of entrepreneurs had previous occupations in commerce or industrial enterprises either as owners, family workers or employees. Most who set up their own businesses had had parents who had been businessmen and they used to work for this family business. Those whose parents had been farmers or government officials were in the minority. There was obviously some advantage to the possession of knowledge and experience in the same line of business and to the acquisition of technical or marketing knowledge while employed as family wokers. This knowledge and experience in production, management and marketing was acquired mainly through self-study.

Since these entrepreneurs acquired their knowledge and skills (both technical and managemet) mainly through former employment rather than formal education, it was interesting to see the relative importance which they placed on technology. Thus, they were asked to consider various factors which they considered important for their sustained business growth. The factors presented were market and marketing management, finance, labour and skills, and development of technological capability and they were asked to rank them in order of importance with 1 denoting highest importantce and 5 denoting the least importance, The results are presented in Table 4.14

Table 4.14

FACTORS AFFECTING SUSTAINED GROWTH OF BUSINESS, RANKED IN THEIR PERCEIVED ORDER OF IMPORTANCE AND CLASSIFIED BY FIRM SIZE AND INVESTMENT TYPE.

Growth factor	Thai firms		Foregin-invested firms
	Small/Medium (n=4)	Large (n=4)	(n=4)
Development of technological capability	4	1	2
Labour and skills	5	2	4
Finance	2	2	5
Management	3	4	2
Market and Marketing	1	5	1

It is worth nothing than the large Thai firms appeared to attach the most importance to development of technological capability. Labour and skills, which are closely related to technological capability, ranked second in importance. This result sheds more light on the technological behavior of this group of firms which were shown above to be the most dynamic group, particularly in adaptation of technology.

The small and medium Thai appeared to attach little importantce to technology and skills. They relied more heavily on relatively unsophisticated technology and they were less influenced by imported technology as compared to larger firms. For this particular group of manufacturing firms market, marketing and financial factors were perceived as relatively more important than technology and skills.

For the foreign-invested firms, market and marketing, technological capability and management, in that order, were considered the important factors for sustained growth of the firm. Foreign-invested firms in this study were either joint-venture firms or subsidiaries of MNCs. Their products and production and management technologies were oriented towards international markets and standards.

Most firms in this survey had experienced business expansion since their inception in terms of manpower employment, types and quantity of products, market shares, and values of products. Compared with the large Thai firms and foreign-invested firms, the small and medium Thai firms seemed to have experienced a more impressive rate of expansion. Under these circumstances, the expansion of small and medium scale industires in Thailand can be attribued to changes in the economic environment (e.g., reduced energy costs, lower rates of interest and higher export demand) rather than changes in development of technology and skills. This is particularly true of the expansions that have taken place in recent years. However, these better economic prospects, having provided much of the impetus for firm expansion, have also resulted in production and technology improvement.

4.5.2 Business Strategy and Marketing

The products of the manufacturing firms in the biotechnology-based industires in this study were oriented mainly towards the domestic market, except for most of the firms in the ornamental flowers industry and for shrimp producers. The main reasons for low exports varied with size and ownership of the firms. For small and medium Thai firms, reasons were that few were entitled to promotional privileges offered by BOI, that products were not of staisfactory quality for export, that existing production was not adequate for export, that the entrepreneurs involved lacked knowledge on exporting, or that market prospects for domestic were still good.

For the large Thai and foreign-invested firms in the biotechnology-based industries, a number had been granted promotional status by the BOI to produce mainly for the domestic market (e.g., animal feed, seed, dairy, aquaculture, alcohol, pharmaceutical and organic acid industries). This was partly because of the import-substitution industrialization policy of the government which has been persued since the 1960s, especially for pharmaceutical products and dairy products.

Another reason for low exports among this group of manufacturing firms, particularly the large Thai firm, was that prospects in the domestic market were still good (e.g., aquaculture products, dairy products, animal feeds, and seeds), that trade restrictions were imposed on Thai goods in overseas markets (e.g., animal feeds) or that overseas customers did not pay import bills in good time.

Large Thai fims also mentioned problems with respct to designs and standards of products which did not meet export requirements. As for foreign-invested firms in particular, the main motivation for investing in Thailand was to produce goods for the domestic market (e.g., pharmaceutical firms), in line with the foreign investment policy of the BOI. However, because of an adjustment in the industrialization and foreign investment policies since the second half of the 1970s, some of these foreign-invested firms have started to export their products to overseas markets. Frequent complaints among this gorup of firms were that the prices of Thai manufactured goods were not competitive due to such factors as high cost of electricity and raw materials, inadequate protective measures, and lack of adequate export promotion measures and facilities.

Although most products of the manufacturing firms in the biotechnology-based industries were oriented toward the domestic market in value and volume terms, 18 out of 42 firms in the study were involved to varying extents in exporting. The small and medium Thai firms in the ornamental plants industry, in particular, were quite active in exporting. Changes in both the internal and external economic environment in recent years have resulted in export expansion in almost all sectors of Thai industry. Devaluation of the baht, determination of exchange rate, on the basis of a basket of currencies, re-alignment of the major currencies of the world, and more stable oil prices have resulted in lower costs of production for Thai manufactures. These major changes have boosted the comparative advantage in favour of Thai goods and export expansion.

Apart from these macro-economic factors, there were also several motivations for exporting at the firm level. Main motivations for exporting which were common to firms of all types were saturation of the domestic demand for certain products, (e.g., ornamental flowers and monosodium glutamate) expansion of sales, and higher profits. Another motivation worth noting, particularly for small, medium and large Thai firms was that export sales were more easily liquidifiable. This was due to the fact that letters of credit or other documents related to exporting could be discounted with commercial banks for necessary financing by the exporting firm.

It is also interesting to note that among the small and medium Thai firms the first export sales were initiated in many cases, by contact form foreign customers, from customers introduced by relatives and friends or from international trading companies. After the first export sale was made, the Thai entrepreneures involved tried to expand their export sales by various measn. Some of these entrepreneurs traveled yearly to meet their foreign counterparts in order to discuss overseas market prospects for their goods and to introduce new products to their overseas customers. New machines and production facilities were installed to meet the new demands and there was an improvement in packaging technology as well.

It should be noted further that some subcontracting arrangements have been observed among the firms in the biotechnology-based industries. Subcontracting arrangements are broadly defined here to include contracts requiring the subcontractors to supply raw materials and/or intermediate products to a contractor. Under this broad definition of subcontracting arrangements, some small and medium scale firms in the biotechnology-based industries (e.g., feeds, aquaculture, seed, organic acid and ornamental flower industies) were subcontractors. For example, a number of small ornamental flower producers received contracts form large producers and exporters of ornamental flowers to supply the latter, of specified quality and amount and at agreed prices. Under the contractural arrangement the contractor agreed to provide the subcontractors with necessary technical and financial assistance. As another illustrative example, a contractural arrangement was made between a larval prawn producer and a prawn raiser in the manner that the former would supply the latter with a quantity of larval shrimps of specified quality and at an agreed price. In this case, the contractor also provided the subcontractor with an example of the larval prawns that he wanted. Since these subcontracting arrangements are quite a new phenomenon in Thai industry, their role in the enhancement of technology and skills as well as in industrialization should be carefully observed and further strengthened.

4.5.3 Effects of Ownership, Firm Size and Business Strategy on Technological Capability

Table 4.15 presents the levels of technological capability of the manufacturing firms in the biotechnology-based industries in this study as classified by ownership of the firms. In the assessment of acquisitve, operative, adaptive and innovative capabilities, the capability scores range from 0 to 5, 0 denoting the lowest level and 5 denoting the highest level. On the whole, the results from the assessment suggested that foreign or joint-venture firms possessed higher levels technological capability in all aspects. This finding is confirmed by serveral previous studies indicating that the level of technology employed in foreign-invested firms tends to be higher than that employed in local firms (Pancharoen, 1983; and Khanthachai, 1986). The difference in the level of operative capability between these two types of firms is quite marked.

The higher level of technological capabilities in the foreign-invested firms may be attributable to the inflow of foreign technology that accompanied foreign direct investment into Thai industry. This can be used to support the argument that the policy on foreign investment promotion has been successful in bringing foreign technology into Thai industry. However, the extent to which the foreign technology is transferred to local manpower and local manufacturing extablishments remains unclears. In fact, several studies on foreign technology transfer in Thai industry have suggested that insignificant transfer of technology has taken place (Santikarn, 1982; Khanthachai, 1986). Nevertheless, the data in Table 4.15 indicate that there is a technological gap between Thai and foreign-invested firms in Thai industry, particularly in the operative capability. It should also be noted, however, that the non-statistical significances ($p < 0.05$) between means as presented in Table 4.15 are probably due to small size of samples.

Table 4.15

EFFECT OF OWNERSHIP ON TECHNOLOGICAL CAPABILITY

Technological capability	Thai firms (n = 20)	Foreign-invest firms (n = 12)	t
1. Acquisitive capability			
Mean	3.34	3.65	NS
S.D.	0.84	0.74	
2. Operative capability			
Mean	3.20	3.98	S (p<0.01)
S.D.	0.74	0.54	
3. Adaptive capability			
Mean	3.18	3.52	NS
S.D.	0.93	0.78	
4. Innovative capability			
Mean	2.16	2.38	NS
S.D.	0.83	0.84	

Table 4.16 compares the levels of technological capability between different sizes of firms. Although statistical tests do not indicate significant differences, ($p \nless 0.05$), large manufacturing firms in the biotechnology-based industries tended to exhibit higher levels of technological capability than the small and medium firms in almost all aspects except innovative capability.

Previous studies on small and medium scale industries pointed out that most SMIs in Thailand employed redimentary technology. Some of them evenemployed second hand machines. One explanation to such technological practices is that the SMIs have financial difficulty for the purchase of new machines and equipment (IMC, 1985; and Khanthachai, 1986). On the other hand, large firms tended to have fewer problems in acquisition of machines and equipment. While the SMIs rarely received promotional privileges from the government, the large scale industries were often granted promotional status and could purchase machines and equipment at subsidised prices.

Additionally, SMIs (mostly without any foreign participation) also tended to have limited skilled-manpower and hence limited technological capabilities both in terms of equity and manpower. Furthermore, lower levels of formal educational and limited experience in the field of modern technology for the entrepreneurs in the SMIs hindered the development of technology and skills in this firms.

Table 4.16

EFFECT OF FIRM SIZE ON TECHNOLOGICAL CAPABILITY

Technological Capability	Small/Medium firms (n = 9)	Large firms (n = 23)	t
1. Acquisitive capability			
Mean	3.17	3.57	NS
S.D.	0.74	0.84	
2. Operative capability			
Mean	3.27	3.58	NS
S.D.	0.71	0.77	
3. Adaptive capability			
Mean	2.97	3.43	NS
S.D.	0.89	0.86	
4. Innovative capability			
Mean	2.27	2.23	NS
S.D.	0.72	0.88	

Table 4.17 presents the difference in technological capabilities between manufacturing firms that have different business strategies. The firms were classified into three types, namely wholly exporting firms, wholly importing firms, and firms involved in both activities. As demonstrated in Table 4.17, it is evident that technological capability tended to vary with business strategy, and particularly with market orientation. The wholly importing firms, which imported raw materials, and/or intermediate goods, and/or finished products and did not export, exhibited the lowest levels of technological capability in all aspects. A higher degree of competition in the international market was a major factor contributing to the relatively higher technological capabilities among the firms involved in exporting.

Moreover, exporting firms also tended to have more exposure to modern technologies. As mentioned earlier, overseas customers as output users usually provided the producers with specifications of the products that they wanted. They also occasionally recommended new production and marketing technologies to Thai entrepreneurs, particularly at the initial stages of the export business. Their purpose in so doing was quite obvious. With improved production, product, and packaging technologies, the Thai products had better access to the foreign markets and a more competitive edge over other similar goods in those markets.

Table 4.17

EFFECT OF BUSINESS STRATEGY ON TECHNOLOGICAL CAPABILITY

Technological capability	Wholly exporting firms (n = 9)	Wholly importing firms (n = 14)	Both (n = 9)	F
1. Acquisitive capability				
Mean	3.55	3.39	3.45	NS
S.D.	0.73	0.86	0.83	
2. Operative capability				
Mean	3.42	3.36	3.77	NS
S.D.	0.64	0.82	0.74	
3. Adaptive capability				
Mean	3.22	3.04	3.81	NS
S.D.	0.82	0.98	0.56	
4. Innovative capability				
Mean	2.58	1.95	2.47	NS
S.D.	0.64	0.79	0.95	

4.5.4 Entrepreneurs's Responses to Government Measures

In principle, government policies and measures aim to facilitate the working of market mechanisms so that allocation of resources is efficient. In certain circumstances, market failures cannot be alleviated despite various policy interventions of the government, due mainly to gaps in implementation of policy measures or so-called implementation failures. Table 4.18 below presents entrepreneurs's opinions on the government policies which they considered beneficial to them.

Obviously, the entrepreneurs attitude varied with the size and ownership of the firms. Small and medium Thai firms seemed to put more emphasis on financial and technical assistance from the government. The large Thai firms emphasized technical advice, finance and deregulation. As for the foreign-invested firm, fiscal measures, administrative mechanisms and regulations seemed to be their important concerns.

With respect to the various government organizations that delivered services to manufacturing industry, most entrepreneurs were of the general opinion that the services were limited and that they had used them little. Nevertheless, they agreed that the Export Promotion Centre had recently played an increasingly important role and that the Universities had played an indispensable role in supplying skilled manpower to the manufacturing sector.

Table 4.18

BENEFIT OF CERTAIN GOVERNMENT POLICIES AS CONSIDERED BY ENTREPRENEURS

Small/Medium Thai firms (n=4)	Large Thai firms (n=4)	Foreign-invested firms (n=4)
1. Credit provision	1. Technical advice	1. Tax reduction on imported raw materials and inter-mediate goods
2. Electricity price reduction	2. Credit provision	2. Product standards testing services
3. Technical advice	3. Electricity price reduction	3. Improvement in administration
4. Training	4. Technical information services	4. Deregulation
5. Technical information services	5. Deregulation	5. Electricity price reduction
6. Trade information services	6. Tax reduction on imported machinery	6. Trade infromation services
7. Product standards testing services		

5. BRIDGING THE PRESENT CAPABILITY GAPS AND BUILDING FUTURE CAPABILITY

The existence of capability gaps can be viewed from many different perspectives. The fact that scores of technological capabilities presented in Chapter 3 are all lower than five indicates, obviously, that there are gaps between the present capabilities and that of the world frontier. The degree or the extent of the gaps varies depending upon the type of capability. It was determined that all capabilities except for innovative capability are at the same level as those of most developing countries. Innovative capability was low for all of the sub-industrial sectors of this study. Section 5.1 deals with the strengths and weaknesses in technological capabilities of Thai biotechnology-based industry. A more difficult task lies in the attempt to evaluate the needed technological capabilities. The review in Chapter 1 indicated that there are many new biotechnologies which are not currently utilized in the Thai biotechnology sector. This represents one kind of technology gap. For example, there is no firm in Thailand with any activity in genetic engineering. The results presented in Chapter 3 also indicated that there was no firm with research and development for the improvement of processing equipment.

There are at least two types of need which must be addressed. Firstly, the need of capabilities to improve the existing technology and industry and secondly, the need of capabilities to venture into new industry and new technology. Section 5.2 and 5.3 attempt to adress both these needs. The support needed to bridge these gaps are proposed in section 5.4

5.1 Strengths and Weaknesses in Technological Capability in Biotechnology-based Industry.

Survey results summarized in Chapter 3 indicated that, when viewed sub-sectorialy within the biotechnology-based industry, there was no apparent difference in the technological capability scores. This result implied that there was no serious disadvantages for any particular sub-sector. When comparing the capabilities of different firms, government owned or operated firms stood out as being at the lower end of the spectrum in all of the technological capabilities. Also apprent was the low innovative capability of the downstream industries as compared to upstream industries, and of the import substitution market oriented firms as compared to the export oriented firms.

Results presented in Chapter 4 showed that very few firms were carrying out research and development as a distinct activities separately from quality control activities. The results also revealed the fact that firms with "real" research and development activities scored higher in the innovative capability category. Upon a closer examination of the individual firm survey results, the lack of personel for research and development was apparent. Also apparent was the low ratio of scientists and engineers in the producing firms. There was also no systematic means for the accumulation of know how within the firms. Another major weakness was the lack of linkage between the producing firms and the supportive agents.

The main strength of private sector supportive agents was in their role as technology transfer agents. Input suppliers, particularly equipment suppliers, were the most active foreign technology transfer agents, whereas local consulting firm strength was in the dissemination of local technology. The major role of output users was in supplying specifications and quality control. Major weakness were the lack of or the inefficacy in the utilization of consulting firms by producing firms, the lack of consulting firms for the processing industry and the foreseeable lack of qualified manpower. The consulting firms had high potential in the role of linking private firms and various supportive agents.

For the government sector supportive agents, education and training are adequate in certain specific areas but severely lacking in others. The imbalance between the demand and supply.

5.2 The Gaps Between Present Capabilities and Needed Capabilities

5.2.1 Gap in Acquisitive Capability

From section 3, it can be seen that the overall acquisitive capability of industries in the biotechnology sector is 3.48 and that this is under the average capability for industries in developed countries. It is our opinion that a target of 5 is necessary for acquisitive capability in the biotechnology sector, even if Thai industries are only to catch up to foreign competition, let alone surpass it. The cause for this overall low acquisitive capability in the biotechnology sector may be attributed largely to substantial deficiencies in infrastructural agents (including their manpower), to the existence of barriers to technology transfer and to deficiencies in technical manpower for industry. The following paragraphs give details on the nature and the extent of these deficiencies.

With respect to infrastructural agents, we would like to focus first upon information services. Our survey has revealed a serious deficiency and even a trend to deterioration in information services that is in need of urgent rectification, not only to obtain the industrial capability target cited above, but to stop a potential decrease in capability. The problem is particularly serious for medium and small sized industrial firms, entrepreneurs and local consultants. These firms and individuals do not have the resources to maintain adequate information bases necessary for assessment of new technology and for carrying out feasibility studies. They will perpetually require government support in this area.

To overcome these problems, we recommend that steps be taken towards the formation of a Thai centralized national information center for science and technology (TICST) that is partly staffed by librarians with previous training in science and technology. This recommendation is in keeping with the results of the study by Shigihara and Manunapichu (1983), concerning the development of information services for science and technology in Thailand. This center need not be constructed de novo. It can evolve out of existing facilities of the Ministry of Science, Technology and Energy by reorganization and consolidation.

Another important infrastructural agent is The Technology Transfer Center of the Ministry of Science, Technology and Energy which was established in 1979 as a part of MOSTE to assist industries in the assessment and selection of foreign technology and to recommend favourable terms in transfer contracts. The services of this division have been utilized by approximately 10 firms per year in the past three years and the frequency of consultation has remained relatively constant over that period. This suggests that the Center is underutilized and this likely results from insufficient publicity and lack of soliciting. As recommended by Shigihara and Manunapichu (1983) for TICST, we feel that this Center should be active rather than passive in establishing contacts with industry. Certainly, the activities of this center should receive continued support and since its function is, in part, to provide information, it would be good to have the division situated in the same building as the nationally centralized information center (TICST) proposed in the preceding paragraph.

Universities and governmental agencies are also important infrastructural agents with qualified personnel that can assist Thai industrial frims in the assessment of technological options and with the installation of new equipment. However, our survey has shown that the linkage between these institutions and industry is not yet strong. However, the recent informal governmental policy that encourages universities to establish self sustaining technological service centers with a mandate to develop university - industry contacts has shown increasing success as evidenced by their rising nation wide income. At Mahidol University, for example, income at the Institute for Technical and Scientific Services has risen from approximately 1 million baht in 1984 to over 20 million baht in the first 8 months of 1988. These programs and others like them should receive continued encouragement and support. Promotion of these linkages will make the institutional expertise more accessible to industry and it will concurrently give Thai academics more experience with industrial operations. However, we foresee some difficulties as the income from these centers rises. Without formal governmental sanctioning of these operations by legislation, particularly with respect to taxation, it is likely that a dispute will eventually arise with the Finance Ministry.

The Thailand Institute for Scientific and Technological Research (TISTR) functions much like the University service centers, but it was instituted to provide research services to industry by formal legislation. The original intent was for this institute to function as a key science and technology resource like KAIST in Korea. However, the Institute has not prospered as well as was hoped. It has had difficulty in attracting and retaining high quality staff, in spite of higher than normal government service salaries, and the majority of its income is still derived from Government sources; not from contracts with the private sector. Perhaps the rather low number of contracts can be attributed, in part, to the lack of "sales" personnel with the task of actively soliciting industry contracts.

Our study has shown that the source of the much of the technology used by industries in the biotechnology sector has been from abroad (see section 4). This is particularly true for the more sophisticated of the technologies (i.e., high tech options) which will become more prevalent as the country progresses towards further industrialization. This implies a need for the presence of further industrialization. This implies a need for the presence of foreign technologists, since effective transfer of technology often requires a period of training with them. Although, permission for such experts is not a problem for promoted industries such as those of the BOI, it is a problem for non promoted industries. We have found examples of biotechnology firms that have chosen other Southeast Asian countries for location of regional offices because of the difficult entry and exit procedures for their foreign staff.

Although restriction of experts can be an impediment to rapid technological development it is also true that a completely free policy could result in the use of specialists to prevent the transfer of specific technologies to Thais. A balance must be struck whereby such abuses are prevented. However, the situations that could arise are not straight forward and a set of inflexible regulations would be an unlikely solution. We recommend the adoption of more streamlined entry and exit procedures that would closely match those of competitor countries in the region. In the event of disputes or appeals, it would be better if rulings were handed down by a group which included scientists and technologists capable of evaluating the scientific and technological issues involved.

In industrialized countries, consulting firms play an important role in assisting industries with the acquisition of new technology, particularly in assessing technology options and in carrying out feasibility studies. Our study has shown that there are very few consulting firms with capabilities to advise biotechnology industries in Thailand, although it is possible that they could obtain part time assistance from specialists at the universities or governmental institutes, if the need for them arose.

5.2.2 Gap in Operative Capability

The average operative capability score of the surveyed Thai industries in the biotechnology sector was 3.49, a score similar to that for acquisitive capability. As with acquisitive capability, this score indicates a capability which is under the average for the industrialized countries. The reason for the capability gap is not so much concerned with inadequate ability to operate and manage technological activities as with inadequate ability to maintain facilities, with weaknesses in manpower training and with weaknesses in manpower skills. The remedy for these weaknesses is to strengthen infrastructural agents particularly with respect to training of new graduates and to upgrading the skills of current manpower.

Amongst the firms surveyed, the large firms which could afford good quality control laboratories and qualified technical manpower had higher capability ratings than smaller firms which could not. The larger firms also tended to regularly subscribe to technical and trade journals and to plan training activities for their staff, both locally and abroad. Thus, their success could be related, in part, to strengths in technical manpower resources, information access and manpower training.

A further problem for small firms in the biotechnology sector is the lack of resources for proper quality control analysis. This is partially alleviated by contractual services available at laboratories of universities and some governmental institutes. However, there is a complete absence of independent, but government certified testing agencies which could help to speed up the process of product validation.

In the biotechnology sector, the most significant portion of the production cost is very often the raw material cost, and it can be the key factor for ultimate competitiveness on the world market. So long as Thailand maintains a large surplus of efficiently produced agricultural raw materials, Thai biotechnology firms will enjoy the advantage of lower cost raw materials than those of their world competitors that import these materials. This should not be taken to infer that efforts to improve operative capability are not important and should be neglected. On the contrary, poor quality control and production inefficiencies can quickly eliminate competitive advantages gained by lower costs for raw materials. That is the why we believe that the target for operative capability in Thai industry should be set at five.

According to our results, the large Thai firms and joint venture firms surveyed had better operational capability scores than the small Thai firms surveyed. The reason for this difference lies largely in the inability of the small firms to carry out training programs and to obtain or retain sufficiently skilled manpower for process operation and maintenance. As with acquisitive capability, these small firms with limited resources will always depend upon governmental agencies for assistance in making up these deficiencies.

The output of graduates pertinent to industries in the biotechnology sector has been presented in section 2.2 of this report. However, this does not include graduates in engineering fields associated with auxiliary and peripheral technologies important for the sector, even though such graduates are essential for industrial operations. As reported in a very recent STDB study conducted by TDRI (TDRI 1988), the current supply of engineers already lags well behind the demand, and the projections show that demand is rising sharply. In the coming years, this study projected a slight excess over demand for agriculturally related graduates, but a deficit for graduates in more specialized fields of biotechnology. It is clear that the educational system must be strengthened if the demands for new graduates are to be met. This requires strengthening not only for higher numbers, but also for higher quality.

Strengthening the educational system, in turn, infers a concomitant strengthening of information services in science and technology, and this has already been addressed in the preceding section.

In order to upgrade the skills of manpower already on the job, greater linkage between government scientific and technological institutions should be sought. Training activities in the form of organized seminars and workshops are already a common practice, but greater orientation towards the needs of industry and greater participation by industry would be desirable. Again, these activities should be coordinated out of an information service center (TICST).

Because of the importance of information services in training, it would be worthwhile considering a close linkage, perhaps even physical, between seminar and workshop training facilities and the network of the national information center for science and technology proposed above (TICST).

Our survey has also revealed that there is an underutilized opportunity within current regulations, for industrial personnel to undergo contractual training on an individual basis at governmental laboratories. These activities should be further encouraged and expanded.

5.2.3 Gap in Adaptive Capability

Of the four major capability types examined, adaptive capability ranked third from the top, with an overall score of 3.36 for industries surveyed in the biotechnology sector. Again, this capability level is lower than the average for firms in industrialized countries. On the other hand, the level of capability was higher than that which we projected at the outset of the study. We found numerous examples of local industries that would purchase one module of a production unit from abroad, adapt it to local requirements and then locally manufacture copies of the remainder needed. This copying and modifying indicates the burgeoning of a manufacturing capability that is a prelude to true innovative capability. We believe that this adaptive trend should be encouraged and we therefore recommend a target capability of five.

As with operative capability, our survey showed that large firms which could afford good quality control laboratories and offer competitive salaries to qualified technical manpower had higher capability ratings than those which could not. Their regular subscription to technical and trade journals and their regular training activities for staff, both locally and abroad, appeared to be important factors contributing to their high adaptive capability.

Again, we found that small firms depended more heavily on governmental institutions for informational, technical and training support than did the large firms. Therefore, to meet the target set, informational services, educational services and training services (upgrading of staff) must be strongly supported.

5.2.4 Gap in Innovative Capability

At 2.32, the innovative capability rating for firms in the biotechnology sector was the lowest of all the capabilities examined in our survey. Perhaps the single most important factor in the poor rating was the lack of interest in real research and development activities by the majority of the firms surveyed, even though they claimed to have R&D laboratories. These laboratories were, in fact, largely used for quality control activities. What was touted as R&D work was usually associated with solving minor production problems. An examination of Table 3.4 will show that many new biotechnologies are not being explored by R&D units in Thai firms. Usually, the reasons cited for lack of interest were that the cost of R&D was unwarranted in terms of the potential economic return and that new technology could be purchased from abroad whenever required.

Our survey has shown that there was a considerable R&D capability in the public sector, especially at the universities, in the form of both manpower and equipment. A major problem was under utilization of this R&D potential by industry. There were three major reasons for this. First, some industry managers were unwilling to accept that the available expertise was of high quality. Second, some did not know the services were available under contract. Third, some feared the leaking of proprietary information.

Current deficiencies which need to be addressed concern poor informational services, poor knowledge of available services at public institutions, lack of confidence in institutional support, lack of incentives and insufficient funding for R&D, lack of sufficient technical manpower (especially in biochemical engineering and process engineering), lack of protection for intellectual property, and existence of tax barriers to purchase of scientific and technical equipment that are not available in Thailand. Since it is likely that there will be an ongoing need for contribution from foreign experts in innovative activities, barriers to exit and entry should be eased.

It is our opinion that lack of support for innovative activities and neglect to improve innovative capability in the biotechnology sector would be very short sighted. At the same time, a high priority national drive to reach a capability target of 5 within the near future would neither be feasible nor particularly desirable since the operative capabilities that must complement this innovative capability will take several years even to catch up to the current level found in the developed countries. We believe, rather that an immediate move to reinforce institutional-industrial linkages and to steadily improve the R&D facilities as an adjunct to educational and training activities would be a more appropriate focus. Also, any effort on the part of industry to build up private R&D facilities should be encouraged. The program of support should be such that as the capabilities for acquisitive, operative and adaptive capability approach their targets, more and more resources will be turned towards support for high innovate capability.

5.3 Future Industries and Future Technologies

In the industrially developed countries, the biotechnology industrial sector is evolving from technology segmentation toward market segmentation. The forefront technologies will continue to be employed in conjunction with traditional technologies in most segments and the ability to integrate forefront and traditional technical capabilities will become increasingly important. It has been predicted that within the next 20 years, biotechnologies will contibute significantly to nearly every growth industry. The commercialization of biotechnologies such as genetic engineeing, hybridoma, protein/cell immobilization, and biospecific separations has already begun and will accelerate. Full commercialization of biotechnology based products such as synthetic peptides engineered molecules and biosensors will require up to 20 years, although a small fraction are already in the market. It has been further predicted that within five years, the affected market segments will be agriculture, environmental quality monitoring and control, specialty chemicals and waste treatments. In the next ten to fifteen years, biotechnology will contribute to the commercialization of products in commodity markets such as mining, chemicals, electronics and pulp and paper. The current efforts are focused on laboratory research, biomedical equipnemt, animal vaccines, pharmaceutical products and bioprocessing equipment (ref.)

For Thailand, the low level of research and development activity in industry means that development of the biotechnology industrial sector by technological segmentation is highly unlikely. Although the Natioal Center for Genetic Engineering and Biotechnology and the STDB have been established with the specific aims to enhance R&D activities of Thailand in the field of biotecnology (see Table 2.6 and 2.7), the amount of money and the total effort expended are still very low in comparison to that in developed countries. Thus, there is a very low probability that technology developed in research laboratories will drive the Thai biotechnology industries as is happening in the west. Moreover, none of the producing firms are engaged in R&D with the aim of becoming a technological leader or for advancing the technology they utilize. Thus, for the next ten years, it is logical to conclude that most, if not all, industries that develop will still rely on the input of foreign technology. In other words, it is unlikely that the Thai scientific and technological society (including that in the producing firms) will be mature enough to significantly contribute to the development of new technology, within the next ten years.

5.3.1 Future Industries

From the above argument, we feel that Thai industries in the future 10-15 years will be resource based rather than technology driven. These future industries will result from diversification of the current industries. There will be only a few new industries. However, the technolgogy level will be improved, mostly by import from abroad. The following is an example of how biotechnology will affect future industry :

Biotechnology, and especially the "new" biotechnology, will have important impacts on the development of new crops, plants, and animal species. It has been estimated that the first new generation crops with resistance to specific herbicides will be marketed in the 1990's. Prospects are brighter for development of insect and disease resistance plants by way of genetic engineering. Thus, many genetically engineered products from the west will probably have a dramatic impact on Thai agricultural products within the next 10-15 years. Rice, maize and legumes, which are receiving attention in the West, will probably be among the first crops to show the effect partly due to the large plantation areas. Cassava and rubber have received less attention in the West and thus, effects for these products will probably come somewhat later. For this example, the industries most likely to be affected are the seed industry and the agriculture industry. Local plant breeding technology will obviously continue to have an impact on the industry, as it has over the past decades. For example, sufficient effort put towards successful local R&D development of varieties of disease resistant plants over the next 5-10 years, could have an impact on the industry.

The most likely scenario is that Thailand will continue to import technology to improve its present industries, a selected list of which is shown in Table 1.12. The industries will likely expand to cover a wider range of poducts as dictated by market demand. It is likely that the industries listed in Table 5.1 will recieve special attention.

Table 5.1

LIST OF INDUSTRIES LIKELY TO BE GIVEN SPECIAL ATTENTION IN THE NEAR FUTURE

Sector	Industry
Agriculture	Seed/Seedling
	Aquaculture
	Livestocks
	Biofertilizers/Mycorrhizae (*)
	Biopesticides (*) (**)
	Plant growth promotors
Agro-industry	Dairy
	Animal feed
	Biopolymers (including modified starch)
	Aquaculture
Food, Beverages and Special Chemicals	Organic acid
	Modified starch (*) for food ingredient)
	Other starch/sucro based
	Food flavours and Coloring
	Preserved foods
Helth and Health-related	Antibiotics
	Specific antigens (*)
	Vaccines
	Diagnostic
	Plant medicines
	Toileteries
	Vitamins (*)
	Hormones (*)

Energy & Environment and others	Methane Production Waste Treatment Biosensors. (*)

The (*) on the above list indicate industries which were not on the selected present industries list of Table 1.12 but came up during the course of this survey.

(**) including compounds which modify insert behavior.

5.3.2 Future Technology

Besides improving current technology in order to bridge the existing capability gaps, Thailand will also have to master the "new" biotechnology, and must carry out enough basic R&D to lead technology in some chosen technology areas. This can only be achieved by active R&D activities both by the private sector and the public sector. Table 5.2 shows the technologies which the surveyed firms selected as their likely future technologies. Enzyme and packaging technologies stand out as being the most popular. For the biotechnology based industries the "new" technologies which need be mastered while improving currently utilized technologies are :

Genetic engineering
Cell/Tissue culture
Hybridoma (Cell Fusions)
Immobilization/Enzyme Engineering
Cell culture scale up
Down stream processing (Biospecfic separation)
Biosensors
DNA/RNA probes

There are of course many technologies which are currently being used by firms which do not have the capability to improve upon them in order to closely follow world leaders. The consequence is that new improved technology must continuously be brought into renovate old equipment or to start up new factories.

The development of the above "new" technologies is a must if Thailand is to bridge the gap between its present technological state to that of the developing countries. Ralph Landou (Scientific American June 88,258 (6)) pointed out clearly the importance of technologies development to economic growth. For Thailand however, participation in these "new" technologies alone will not be effective enough, the conventional technologies which are required for effective utilization of the "new" technologies will have to be greatly beefed up. The commitment needed are presented in section 5.4.

Table 5.2

TECHNOLOGY CHOSEN AS THE LIKELY FUTURE TECHNOLOGIES BY THE SURVEYED FIRMS

	Frequency
Animal breeding technology	1
Chemical engineering technology	2
Chemical and biochemical technology	2
Chemical and biochemical analysis	2
Control and measurement technology	3
Computer-aided production technology	1
Consumer testing	2
Dehydration (Drying) technology	2
Enzyme technology	7
Fermentation and reactor technology	1
Genetic engineering technology	2
Industrial engineering technology	1
Plant tissue culture cell fusion technology	4
Plant breeding technology	3
Packaging technology	6
Preservation technology (including refrigeration)	2
Pollution control technology	1
Separation and purification technology	2
Sterilization and pasteurization technology	2
Water purification technology	2

5.4 Commitment Needed to Bridge Technology Gaps and Build Future Technology

5.4.1 Types of Firms and Their Different Needs

In this survey, there were two broad types of firms that could be divided roughly on the basis of being near or far from the world technological frontier with respect to their particular industries. In general, those near the world frontier were in relatively new fields best exemplified by aquaculture, where the degree of technological sophistication was not currently very high. Those firms far from the frontier tended to be in industries which required much more sophisticated technology (e.g., firms in the fermentation and health related industries).

For these two types of firms, the needs for future development are different. Those near the frontier need strong reinforcement in the R&D infrastructure in order to maintain their position at the frontier. Those far from the frontier need first to "catch up" by upgrading of acquisitive, operative and adaptive capabilities, before they could properly consider launching R&D programs.

In the Thai biotechnology sector, firms in the shrimp hatchery and farming industry are good examples of firms near the world frontier in technological capability. However, this should be no invitation to rest on laurels. The basic competitive advantages of a large coastline and a full year growing season are not unique. Technological advance is continuous and there are many upcoming competitors in this field. In order to maintain a position at the forefront of this industry, it is imperative to invest in the necessary R&D to increase the efficiency and reliability of production.

With shrimp, there are great potential areas for improvement in disease analysis and control, in feed formulation and feeding regimes, in full domestication and in strain development.

All of these bear directly on long term increases in production efficiency. Research to solve these problems alone requires sophisticated biotechnology. Applying the results of this research to stay at the forefront of the field will necessitate evolution of more sophisticated production technology as well. Only those countries that succeed in originating these relevant technologies will survive as leaders in the industry.

Some relevantly trained scientists for R&D work with shrimp are already on hand and working on these problems in Thailand. However, they are currently too few in numbers, underfunded and lack a conducive environment for highly productive research.

Firms in the industrial alcohol and alcoholic beverage industries in Thailand are examples of firms at the other end of the spectrum. They are far from the world frontier. By in large, they are using outdated technology and none are engaged in true R&D activities aimed at new product development and diversification. This is a sharp contrast to their counterparts in the developed countries. As pointed out previously, this is because of oligolopolistic practices and overprotection. Should this industry be regulated by the government to increase the degree of competition, the first task of the relevant firms would be to "catch up" to the world frontier, before any thought could be given to basic R&D.

5.4.2 Information Services

It can be seen from the discussion in sections 5.2 and 5.3 that information services are in urgent need of strengthening if all the industrial capabilities discussed are to reach the capability targets set. In the following paragraphs, library services (only one aspect of information servies) is used as an example to define the current situation and the needs.

We recommend an interim measure of immediate restoration of 1983 value to science and technology library service budgets in order to rectify the damage done by cuts at that time, by subsequent inflation, by subsequent changes in currency value, and by static budgets in real terms since that time. There has been a slight increase in the most recent budget, but one must realize that the cost of books and journals has risen on average between 10 and 30% per year in the past four years so that the required increase would now be more than double the old budget, just to keep pace with the changes. For example, the budget for the library at the Faculty of Science of Mahidol University was approximately 4 million baht in 1983, and just to keep pace with the changes, the 1988 budget should be not less than 9.9 million baht! Because the budget has not, in fact, kept pace, this library has gradually cut its journal subscription by over 60 titles and it has not purchased any new books (excluding continued series) for more than two years. There has been a marked deterioration in the available services. This is only one example.

The restoration of budgets would only be an interim measure. It must be followed by a longer term plan for centralization of information in science and technology, concurrent with development of rapid access electronic services via linked institutions scattered throughout the country. Half measures will not suffice.

In addition to higher budget allocations, the budget utilization regulations need to be modified. The current system of surface mail delivery results in minimum delays in journal delivery of three months and sometimes much longer. The current system of delayed payment increases both book cost and delivery time. The budgetary rules necessitate purchase of books though local agents rather than directly from publishers. This regularly results book costs of more than double, in spite of the fact that there is no import tax on these items. This could be solved if the university libraries handled their budgets directly.

The existing library facilities (e.g., the Thai National Documentation Center and the Division of Scientific and Technological Information) at the Ministry of Science, Technology and Energy could be consolidated and reinforced as the initiating step and focus of a national information service center for science and technology. In addition to buildings, hardware and software requirements, there would be a need for science and engineering graduates (including computer science graduates) with further training in library science. Shigihara and Manunapichu (1983) recommend a total initial staff of approximately 34 including a Director with a rank equivalent to a permanent secretary. We recommend an attractive scholarship program for science graduates to undertake post graduate study in library science and that the scholarship recipients be committed to join TICST following graduation. This should suffice to draw bright science and computer graduates into this field.

Shigihara and Manunapichu (1983) recommend that the first step in establishing TICST be the formation of a coordinating committee for consolidation of information services chaired by the Permanent Secretary of MOSTE. They recommend that this committee be set up by Royal Decree or by Cabinet special order. They suggested an initial cost of approximately $200,000 US in 1983 for journals alone (a target of approximately 2,000 titles). They also suggested salaries 20% above current government scales to attract and retain high quality staff. These costs do not include the capital costs.

We concur with the recommendations in this report, and would even go further than its recommendations in empowering the consolidation committee to gradually commandeer the holdings of all the scientific and technical libraries in the government system.

As pointed out in the report (Shigihara and Manunapichu 1983), it is vital to realize that TICST would not be a mere passive library but an active service, requiring that its staff make regular visits to users all over Thailand to conduct seminars, conduct guided tours and advertise services.

After the initial decision to go ahead with the steps in setting up TICST, it would take at least three years to assume even partial operations, because of material requirements and because of the training requirements. Thus, it is urgent that the recommendations in their report be followed up immediately.

5.4.3 Education and Training

The recent manpower report by TDRI (1988) has projected a slight deficit for B.Sc. graduates in specific areas of biotechnology and a large deficit in the number of engineering graduates in the coming years. However, the shortage of manpower at the post graduate level is more extreme. This points out the necessity of strengthening the education system. Changes required are not only increased budgets for higher numbers of S&T graduates. The quality of the graduates must also be high, and this requires a strong and healthy university research environment.

A report by le Pair (1988) points out many problems with the post secondary education system which should be solved. Among these are an antiquated promotional system, low salaries and a cumbersome bureaucracy. We concur with the author's recommendations that the situation be rectified.

Promotion in the university system should be decided by each university and the academic ranks so allocated should be tied to the specific granting institution. Ranks should not be absolute. Allocation of academic ranks should not require the wasteful preparation of lengthy applications; they should be granted by each university, as it decides, to recognize excellence in academic achievement of its staff. In this regard, the recently introduced practice of assigning percentage contributions to authors of scientific papers is deplorable. A more effective vehicle for the stifling cooperation between scientists could not have been devised. This type of diabolical regulation is typical of decisions made by "far-away civil servants who do not have the knowledge" (le Pair 1988), rather than those who possess the relevant knowledge.

The low salaries of academics cannot be raised if there is not a concomitant change to insure productivity and excellence. Thus, tenure should be abolished and individual universities should be left to weed out their "dead wood".

A greater level of autonomy and trust is required in the university system such that university budgets, once granted, can be more flexibly utilized to meet changing exigencies. The amount of useless paper work must be reduced. "The time spent by good people on mediocre routine work is a tremendous waste; such people should be occupied with the advancement of knowledge," (le Pair, 1988).

One requirement not mentioned in the le Pair report is the necessity of reclassification for highly skilled technicians. The current governmental regulations group all "technicians" at the level of technical school graduates. This is an example of another antiquated regulation made by people without knowledge. There are many highly sophisticated pieces of scientific equipment that require the skills of university trained personnel, sometimes to the level of Ph.D. (e.g., electron microscopes, sophisticated computers and sophisticated analytical equipment). Such "technicians" are required to spend full time maintaining and operating this extremely expensive equipment if it is to be efficiently utilized. However, salary scales and promotional regulations make it impossible to find and retain sufficiently qualified personnel. Academics sacrifice their chances of promotion if they devote the required time as a service to the university. This is another example of where the universities should be left to make their own promotional decisions.

5.4.4 Support for the Technology Transfer Center

The services of this center should be consolidated with the Thai National Center for Science and Technology (TICST) (see 5.4.2) and services should be augmented by having the staff make regular visits to potential users all over Thailand to conduct seminars and advertise services.

5.4.5 Linkage between Industry and Infrastructural Agents

From section 3 of this report, it is clear that there is a great need for improved information services. Needs for the system are outlined in 5.4.2, particularly with respect to TICST, and this includes requirements for stimulation of usage by the industrial sector.

From section 3, it is also clear that there is a great underutilized R&D manpower and equipment base at the universities and governmental laboratories. Current programs to stimulate contractual usage of these by industry should be further promoted and, where necessary, formalized by legislation. It would also be useful for these institutions to engage in individual laboratory training by contract for industry staff. Again, the TICST could act as a coordination center for advertising the nature and availability of these services. Increasing the number of these contacts will give Thai scientists more experience with industry and it will also help to improve their image for Thai industrialists.

The TICST should also act as a one stop center for advertisement and convening of technical and scientific seminars and workshops held by various governmental institutions.

5.4.6 Foreign Experts

Current barriers to the entry and exit of foreign scientific and technical experts include cumbersome work permit, visa and tax clearance procedures. For example, 'excessive scrutiny and tiresome prying interviews often regarding private matters (Where did you meet your Thai wife?) are sometimes conducted by the tax clearance division. These are superfluous when a guarantee has been provided. Such procedures are unnecessary, unfruitful, annoying and intimidating. Such procedures should be streamlined and sped up in keeping with the regulations of more progressive competing nations in the region (e.g., Singapore).

Decisions regarding residence of specialists and disputes regarding the same should be made by a committee with contains relevant specialists. Needed scientists and technologists who wish to immigrate should be facilitated.

In certain fields were there is need, special concessions should be given to retired technologists from industrialized countries if they wish to work in Thailand.

The work permit and visa procedures for scientists and technologists in the private sector should be eased equally, whether firms in question have BOI privileges, or not.

The procedure to issue work permits and visas should not be interlinked. In current practice, a work permit candidate must apply for a permit in coordination with his or her visa. Visa applications and extensions usually require two or three short extensions during a consideration period at the Inmigration Division. Each short extension for consideration requires a similar short extension of the work permit and this must be accomplished before the expiry of the previous work permit extension. Even a one day delay results in the necessity of reapplication for a new work permit and all the related paper work and cost. The result is an inconvenient and stressful period of running back and forth between agencies. There is no need for this requirement. The labour department can decide on whether an applicant may work and for how long. The Immigration Division can decide whether an applicant may stay and for how long. Each can police its own permit holders, as they already do Aliens are responsible for having a valid visa and work permit.

5.4.7 Support for Local Consulting Firms

The development of consulting firms with expertise in biotechnological fields will act as a stimulus to the more rapid development of relevant industries. Government policies should favour the creation of such firms.

5.4.8 Independent Government Certified Testing Agencies

Small industry owners in the biotechnology sector often have difficulty getting their products certified by government laboratories. Although they would like to improve the quality of their products, they are fearful that some unexpected analytical result may result in the closing of their factory for some interval. Private, government certified testing agencies which could provide confidential reports to industry and advice on how to upgrade products would be beneficial in upgrading the quality of Thai products, especially for export markets.

As with consulting firms, government policies should favour the creation of such firms.

5.4.9 Publicity for Scientific and Technical Achievements

A planned publicity program for successes from institutional and industrial linkage in biotechnology would improve confidence in the expertise available at public institutions. This publicity would also assist in advertising the availability of the services and could act as a device to attract bright students to the field.

5.4.10 Advertisement of Available Government Services

Wider advertisement to industry of services available at government institutions would help to improve their utilization by the private sector. Again, TICST could take an active role in this.

5.4.11 Protection of Intellectual Property Rights

The absence of this protection in Thailand for many pharmaceutical and agricultural products is a barrier for transfer of technology from abroad.

5.4.12 Removal of Tax on Analytical and R&D Equipment

The high tax on scientific equipment and materials and on analytical equipment used in quality control should be reduced or eliminated to stimulate research and development activities. This would also help the governmental institutions obtain better value from their research budgets.

5.4.13 Removal of Over Protection

Non progressive industries enjoying high protection should be exposed to higher competitive pressures. This can be accomplished by removal of protection, either immediately or after a fixed interval.

5.4.14 Stimulation of R&D

Fiscal measures should be invoked to stimulate R&D activities in industry.

DTEC should not interfere with non quota, non bilateral research grants from competitive international agencies. Their jurisdiction should be confined to Thai allocated funds only. If they reject a proposal from a competitive, non quota agency, the funds will not be given automatically to another Thai applicant in their program. The rejected grant aid will simply be lost.

5.4.15 Govemment Regulatory Agencies.

Agencies such as the Public Health Ministry should take an active and constructive role in improving manufacturing practice in the biotechnology industries. By readjusting policy they could support advances and become regarded as an ally rather than an enemy by manufacturers. For example, a change in Ministry policy to reduce Bacillus content in traditional Thai soy bean paste should be announced ahead of time and producers allowed to bring samples of their products for inspection. If they fail the inspection, they should be advised on how to rectify the situation and be given a grace period to do so. This would result in a general upgrading in quality stimulated by a governmental agency. Surprise aids to collect samples followed by newspaper announcements are not constructive activities.

5.5 Development Strategies

As stated previously, the firms in this survey could be divided on the basis of whether they were near of far from the world frontier in their particular industry (5.4.1). Development strategies and choices for these two types of firms would be different.

In Thailand, firms near the world technology frontier in the biotechnology industrial sector tended to be downstream industries currently using rather unsophisticated technologies. Examples were in the aquaculture, ornamental plant and seed industries. However, there were some exceptions like very progressive feed companies, in the upstream industries. These firms should be given every assistance and incentive to remain at the frontier and to attain a leading world position there. Since the sophistication of these technologies is evolving, Thai firms should be encouraged to become creative leaders in this evolutionary process. Any alternative strategy would lead to a decline in competitive position.

Of the firms surveyed, those far from the world technology frontier tended to be in somewhat older industries or in over protected industries using more sophisticated and sometimes mature technologies. Radical innovation in these industries may not be feasible, especially for firms with high capital investment in existing facilities. Such firms would probably find it more fruitful to diversify by investment in new areas where they can purchase world frontier technology. They could then strive to remain at the frontier by innovative R&D activities. Potential fields for these firms are the promising new technologies such as those outlined in Section 5.3.

6. MAJOR STRATEGIES FOR GAINING NEEDED FUTURE CAPABILITIES FOR THAI INDUSTRIES

Our study has pointed to a number of strategies to be followed in order that Thailand will gain needed future capabilities in the biotechnology-based industries. The results in ch.3 amd 4 and analysis in ch.5 indicate that Thai firms can undergo technological change, and that many of them have considerable technological capability, especially at the operative level. However, the results also show a general weakness of the firms in technological efforts which will enable them to acquire and retain robustness in general, and to have innovative capability in particular. The technological efforts need to be made by the firms themselves, but will require strong support from the goverment in provision of infrastructure and manpower. In addition, since most firms, and especially those of small and medium sizes, would not have the financial strength to exert the needed technological effort, financial resources must be made available by provision of credit, grants and tax incentives. The most important strategies are therefore

- Promotion of technological efforts by firms.
- Targeted science and technology manpower training.
- Available financial and tax incentives for firms.

In addition, other strategies also need to be considered. These include both the strategies to strengthen the technology itself and those to promote the biotechnology-based industries. The former strategies include selective strengthening of key institutions, measures on legal issues and positioning on utilization and conservation of genetic resources. The latter strategies include promotion of biotechnolgy-based manufactured exports, protection and promotion measures for domestic markets, and promotion of subcontracting production and procurement measures.

Table 6.1 gives a summary of the strategies of highest importance and those of medium importance.

Table 6.1
IMPORTANT STRATEGIES FOR ATTAINMENT OF NEEDED CAPABILITIES

Strategies of highest importance:

- Promotion of technological efforts by the firms.
- Targeted science and technology manpower training.
- Financial and tax incentives for firms.

Strategies of moderate importance (technology strengthening):

- Selective strengthening of key institutions.
- Measures on legal issues.
- Positioning on utilization and conservation of genetic resources.

Strategies of moderate importance (industrial promotion)

- Promotion of biotechnolgy-based manufactured exports.
- Protection and promotion measures for domestic markets.
- Promotion of subcontracting production and procurement measures.

6.1 Promotion of Technological Efforts by Firms

In order to increase the industrial technological capabilities to the set targets discussed in ch. 5, technological efforts by firms need to be greatly improved. Our study has shown that the greatest need is for the firms to embark upon real research and development activities and that one of the bottlenecks to increasing overall capabilities is poor information services. Moreover, since most of the technology to be used by Thai firms in the near future (5-10 years) will be foreign technology, measures to improve absorbtion of foreign technology will quicken the process of closing the technological gap. Recommended strategies for improving these three important areas of technological efforts by firms are described below.

6.1.1 Promoting R&D

The survey results indicated that the poorest capability of the producing firms was innovative capability. The lack of activities in R&D is no doubt the major cause. By R&D we mean the systematic activities for the improvement of final products and improvement of the production processes, and not necessarily academic activities. It is thus apparent that strategies for promtion of R&D must be seriously considered. The major obstacles to R&D activity in the private sector are lack of funds and lack of qualified personnel. For the public sector one needs to add the obstacle of excessive bureaucracy in the agencies with the responsibility to carry out R&D activities. It has been concluded elsewhere in this report that the major R&D strength and activity lie currently with the public sector. Various studies have also pointed out that firms without in-house research do not have the capability to effectively utilize R&D potential at academic institutions. Private sector participation in R&D will in turn strengthen the public sector R&D activities. By carefully selecting R&D activities which will benefit firms, these public institutions would find certain types of R&D more economical to carry out. This would foster closer links between the private-public sector R&D. Moreover, R&D activities in firms will create academic career paths for scientists and technologists. This will create a needed interest to draw good students into scientific programes of the higher education system. Thus, it is a major concern to make sure that the private sector is involved in R&D. To do this, one must tackle the problems of their lack of funds and lack of qualified manpower. To improve public sector capabilities in R&D, one must additionally solve the problems of excessive bureaucracy.

To tackle the problems of lack of fund in R&D, the government should provide subsidies so that the private sector will find it benficial to undertake R&D activities. These subsidies could be provided for limited times and be subjected to periodic review. Possible actions are (see also section 6.3) :

a. To provide tax incentive schemes for firms or groups of firms to spend money on R&D. The Australian government has been successful with such a programme. It allows firms to claim 150 percent expense on real R&D spending. The same measure could be as effective in Thailand since our corperate tax is relatively high. Using the current 35% corporate tax a 150% claim would be equivalent to a 17.5% subsidy on R&D spending and a 200% claim would be equivalent to a 35% subsidy on R&D spending. However, this measure would benefit only the established firms which are already making profit.

b. To provide grants for private sector firms to carry out R & D. This measure would be effective for new firms which are not yet making profit. The grants should be on a competitive basis and on a matching fund basis where the firms are prepared to spend up to 25 percent on the R & D project.

Furthermore, measures to reduce cost in carrying out R & D activities can be affected by a tax exemption scheme for R & D equipment similar to the current tax exemption scheme for equipment to be used for educational purposes. Joint R & D programmes between firms can reduce costs and strengthen R & D capabilitics. It was noted elsewhere in this report that Thailand has been a major exporter of canned goods, particularly pineapple and sea food, for the last decade. However, it has been unable to join the leaders in developing technology associated with the processing industry. Research institutes with funding based on the sale of particular products such as cassava or canned foods should be set up with the sole purpose of carring out R & D to improve the relevant industries. These research institutes could be run by the respective industrial associations, and they would be similar to the Malaysian Rubber Research Institute and the Palm Oil Research Institute of Malaysia. In Thailand, for example, the following research institutes could be set up :The Starch Research Institute, The Food Processing Research Institute and the Fermentation Research Institute. The policy direction and management should be determined by the industrial association concerned. The government should provide the initial infrastructure such as land and buildings, which should be within or closely associated with a university or public sector institute in order to maximize the utilization of available qualified manpower and related infrastructure such as instruments and libraries.

For the public sector, the promotion of R&D activities at research institutions including universities requires major structural changes. Currently, there is no institution where advancement and job security of employees (researchers) depends mainly on research work and its useful output. A major reason is that all government infrastructure does not lead to a healthy R&D almosphere. Funding and staffing are heavily regulated and subject to exess bureaucracy. Incentives for doing research are essentially non existant. As suggested by le Pair (1988) the following measured should be taken:

a. Funds should be considered as funds in the broadest sense and not as personnel funds, equipment funds etc. The scientific community should be able to re-allocate funds among the line items of the budget.

b. A budget should be considered as a plan and not as a rigid grid.

c. Income generated by R&D institutions should, as a rule, not be recycled back to the treasury.

We further feel that salary levels should be competitive to retain good people at all levels. If it is not possible to remove research institutions from the current government infrastructure, perhaps multi-tier systems could be devised which would accomodate higher paid non "permanent" positions.

With regard to grant-awarding agencies, measures should be sought to provide more scholarships for students and funds to hire research personnel that aid in graduate research programmes. The numbers of scholarships and fellowships for graduate school need to be increased significantly. Post doctoral fellowships for foreigners as well as Thais should be made available with enough incentives to attract good quality researchers into research laboratories.

Another measure which would effectively help promote R&D in firms would be for the BOI to make a definite requirement that foreign investors or multi national firms who seek BOI privilege to set up active R&D units locally.

6.1.2 Absorbing Foreign Technology

Having adequate level of R&D activities is an important asset to the absorption capability. However, we have chosen to deal with the issue separately since it is the weakest area. A few other issues needs to be discussed here as they may serve to significantly improve the absorbing capabilities.

In section 5.2 we have stated that information services are in urgent need of strengthening . The establishment of Thailand Information Center on Science and Technology TICST as outlined in the section is recommended. To be effective TICST must provide active service rather than acts as a passive library. This would require highly qualily personnel.

An effective technology transfer mechanism is also very important to absorbtive capability. We have pointed out in section 5.2.1 that the Technology Transfer Center (TTC) of the Ministry of Science, Technology and Energy is under utilized. Perhapas due to lack of funding and adequate manpower, the Center has played a passive role rather than the preferred active role in contacting industry. Since TTC can not be held wholly responsible for all of the technology transfer activities due to the diversification of technologies. More technology transfer organizations similar to the TPA should be encouraged. Moreover, TTC can be a very important liaison office between the industry and the NCGEB and other public research organizations.

The lacking consulting firms in biotechnology also inhibits Thai abilities to absorb technology effectively. Since most available manpower resources for consulting are with universities, encourging universities to play a role in consulting firms may help to partially solve this problem. However, this will pull scarce manpower resources away from active R&D activities. By careful management university consulting can serve as a necessary stop gap measure to the development of technical consulting businesses. Meanwhile, measures should be developed to encourage the establishment of private consulting firms.

Another possible measure to utilize technical manpower in the academic sector, which also would bring about closer cooperation between public, university and private sectors, would be to set up an industrial (or science) park with proximity to an active research organization or university. An industrial park will act to catalyze high technology industrial development and bring about effective usage of technical resources of the country.

6.2 Targeted S&T Manpower Training

Section 2. 2 summarized the present biotechnology related manpower production capacity of the Thai higher education system. In terms of numbers of scientists and engineers, the current acute shortage is in the engineering discipline. However, the fact that the number of the Thai scientists and engineers per capita is very low (10/10,000)(MOSTE, HRI 1986) when compared to the number in developed and newly industrialized countries (150/10,000) has been well documented. Besides the need to increase the numbers, attention must also be focused on balancing of types and levels of education. Table 2.3 shows that out of approximately 2,000 annual Bachelor's degree graduates related to biotechnology, 75% are in agriculture and medicine. Very few are in the basic science areas. Moreover, when one examines the individual program curricula such as those for chemical engineers, one finds that there are practically no courses related to biology. This is because the curricula are aimed at serving firms in the chemical and petrochemical sectors rather than those in the biotechnology sector. Thus, several issues must be addressed.

a. The need to expand post graduate programmes. Section 2.2 also revealed the limited production capacity for doctoral degree and master degree graduates in biotechnology related areas. Although the situation for biotechnology is somewhat better than for most other sectors, it is still far from adequate if we are to develop meaningful R&D activities. We are convinced that the purpose of science and technology development is not just economic but also social. As put forward by le Pair (1988), R&D constitutes "reliable knowledge" which affects almost all aspects of life. Having a large part of the educational system engaged in research is necessary for the maintenance of high educational standards which are characteristic of all developed and newly industrialized countries. Training of scientists and technologists to participate in R&D work can not be done by undergraduate education alone;post graduate studies are also required. It is important to stress that graduate programmes in process engineering are particularly weak. This is partly due to the shortage of engineering graduates and partly to the practically complete absence of research in engineering science.

b. The need to increase undergraduate training. Although, the demand for graduates in the basic sciences is currently very low, the rational put forward in section 6.7 and 6.8 (a) requires measures to improve undergraduate enrollment in basic sciences, if we are to succeed in promoting R&D in the private and public sectors. Most acute is the shortage of engineers, for which various measures are being implemented. Of particular concern to the biotechnology sector is the lack of process engineers with a relevant background in biological science. Current engineering curricula have practically no biology related content. This lack of manpower and the limited training will severely hamper the development of biotechnology. The imbalance must be quickly resolved in order to avoid a bottleneck in future technological development. One possible measure would be to moderately change the stress in the current chemical engineering programmes to accommodate some courses in biochemistry and microbiology.

c. Special training in infrastructural institutions. In order to improve the levelof technological capabilities in private firms, short courses on specialized subject should be regularly provided by teaching institutions. Examples would be courses on fermenter operation, handling of microbes, sanitation, good manufacturing practices, process equipment operation, and equipment maintenance, instrumentation and control. These courses would also provide a mechanism for university - industry linkage. Although some courses are currently provided, they are too few and too infrequent. This is particularly true for those specifically geared to inprovement of technological capabilities rather than managerial capabilities. For the public sector, workshops or short courses should be provided on specific skills such as genetic engineering and downstream processing. Most of the "new skills" are practiced only in one or two laboratories. The NCGEB has organized a few courses in an attempt to disseminate the technology and encourage more R&D activity in various "new" biotechnologies, but stronger pursuance and possibly more regular programmes would be useful.

d. Training within firms. Although our survey has shown that some firms have their own training programmes, these are usually not very effective nor extensive and cannot generate the expertise needed by the personnel to generate technological changes for optimum benefits of the firms. This conclusion was previously made in a study of Thai industries about twenty years ago (Bell and Scott-Kemmis,1987). Another study (Chantramonklasri, 1987) showed a correlation between higher learning activity of the firms and their performance efficiencies and technological advancement. Intra-firm training beyond the basic level required for day-to-day operation, therefore, is an important activity which should be encouraged for achievement of technological capability. This can be done in conjunction with other training and educational activities.

6.3 Financial and Tax Incentives for Firms

The development of many technology based industries depends heavily on financial resource allocation. It is anticipated that more financial resources will be required to support technological capability development targeted in section 5. Here is presented a discussion on credit availabity for future investment, financial resource allocation policy and the roles of the related implementing organizations, particularly IFCT, BOT, BOI and TTC. These are the indicators for development of future technological capability.

6.3.1 Credit Availability for Strategic Industries

The sources of credit for strategic industries in biotechnology through R&D are STDB, TISTR, NRC, MOSTE and other government agencies. As previously mentioned, the budget allocated to R&D is only 0.34 percent of total GNP, while the request is 1 percent. It is obvious that the present allocation of financial resources is not sufficient. If the budget allocation is not adjusted, it can be foreseen that development of technological capability in the future will drop even further behind tnat in the developed countries. Technological capability will advance according to the allocated budget, and not according to the need.

The research study found that credit available to strategic industries was for export promotion rather than development of technological capability. Many private financing agencies including the state owned organizations credit mainly on economic, engineering and marketing feasibility without any consideration for future technological capability development. This is party because R&D activities for future self reliance, are not regulated in the established industries. Nor are regulations on budget allocation for R&D to improve future capability of each firm mentioned in the conditions of investment.

Credit available from local sources is not suitable in termsof quantity, and interest rates are high when compared with loans available from abroad. This is due to the low degree of competition and to low exit/entry to the banking system. If loans with suitable conditions from abroad are allowed and/or if foreign banks are allowed to establish/accommodate the local need, costs of credit allocation will be lower due to a greater supply. The banking system will more closely approach pure competition. At that stage, the cost of loaning would be cheaper, and this would pave the way for future capability development.

We realise that banking operation, through nearly pure competition, is limited by many factors, which we need not identify. However, greater supply, particularly from overseas where loans are available at low interest, should be considered by the concerned agencies, for the sake of industrial investment with more emphasis on future capability development.

Financial assistance from the concerned agencies should be provided for the following types of activities :

a. Development of R&D laboratories and technological institutes.

b. Development of indigenous technology or upgrading of conventional technology.

c. Development of new products or processes.

d. Commercialization of R, D & E projects.

e. Improvement or development of physical and human resources.

If these recommendations are followed, credit availability for investment will accelerate along with the develpment of technological capability.

6.3.2 Financial Resource Allocation Policy

The study found that policies on private and public financial sources for technological development were not being formulated. To enable future capability development, the following policy recommendations are made.

a. Financial institutions both private and public should design a scheme for promoting development of future technological capabilities. Under this scheme, they should offer the types of financial support described in the following paragraphs.

Long term loans at low interest rates should be granted to finance the development of laboratories in private companies. The activities of these R&D facilities may focus on improving product quality, on increasing resource productivity (especially human resources), on energy conservation, on import and raw material substitution and on pollution control.

Soft loans of different types should be made available for technological improvements in various industrial subsections in order to enable modernization, replacement and deversification of plants.

Government financial institutions should provide soft loans for the commercialization of indigenous technologies.

Conventional loans provided by IFCT and the Bank of Thailand to small and medium scale enterprises in order to supplement financing available from the private sector should be encouraged, since these firms tend to develop appropriate indigenous technology in the country.

Since R D & E projects generally involve substantial risks, government institutions like IFCT should share the risk of failure in projects with expected high returns. Schemes designed for sharing both risks and substantial returns may be of the following types.

i. Conventional loans : Regular loans repaid in accordance with ageeed conditions concerning interest rate, grace period, and repayment period.

ii. Conditional loans : Financial instruments that allow profit and risk sharing with project sponsors. These loans would be paid back in the form of royalty payments from sales revenues if the projects are successful. This should include a reasonable return on the loan. If the project fails in terms of sales revenues, the loan provider would recover only a portion of the principal.

iii. Equity investment in and support to industry by the government for companies set up to commercialize R D & E results.

b. A Research Revolving Fund should be set up by the government to actively provide financial relief for firms to purchase or adopt appropriate technology or to generate new technology indigenously. To effectively utilize this revolving fund to promote future technological capabilities, present obstacles and drawbacks to such funds should be taken into consideration. The condition that firms have to reveal their confidential technological development or R D & E projects is a major drawback resulting in underutilization of these revolving funds and it needs to be reconciled. Enterprises wishing to undertake R&D or to adopt appropriate technology should be able to obtain loans from this revoloving fund without revealing all of their confidential information. After the technology or R&D unit became operational and began to draw revenue, the firms could retire their debts at reasonable interest rates.

c. For the government sector, the possibilities for encouraging future technological development may be discussed under two categories.

The first concerns government expenditures. These should take into consideration the optimum amount of

i. government budget for R&D as a portin of total government expenditure,

ii. public expenditure on S&T human capital investment and

iii. financial support for technological or research institutes

The second category concerns revenue. Fiscal incentives in the form of tax exemption for a certain amount of a firm's capital investment in R&D laboratories may be granted. Import tariffs on R&D equipment should also be lowered.

6.3.3 Roles of Related Organizations

The present role of related organizations that provide credit to firms is too insubstantial to boost technological capability to the the levels targeted in section 5. In addition to the constraints as previously mentioned, we must consider that the functions and objectives of IFCT, BOT and BOI are different. In addition, none of them have regulations or specific guidelines concerning technological development and cooperation in support of R&D. In order to support future technological development, the roles of IFCT, BOT and BOI could be coordinated as described in the following paragraphs.

a. Roles in crediting
   i. Conditions for credit approval should include requirements for indigenous R&D laboratories.
   ii. Priorities for soft loans from overseas, through BOT approval, should be given to firms with a self-potential for capability development.
b. Roles in future capability development for strategic industries.

i. Provide technical information on science and technology as a periodical to firms associated with these agencies.

ii. Stimulate the firms associated with these agencies to upgrade their personnel by requiring that a planned training program be attached to the application for credit or previleges.

iii. Organize workshops/seminars to promote exchange and transfer of technology to personnel of strategic industries.

iv. Support and promote R&D activities in strategic industries by providing funds.

v. Support coordination of R&D between firms and government agencies, (e.g., acdemic institutes) through soft loan allocations.

vi. Seek cooperation on technology development with foreign agencies.

6.4 Selective Strengthening of Key Institutions

a. Universities. The current policy of NCGEB to selectively foster development of research units with relatively strong existing foundations as "centers of excellence" is a good one, but this measure must be expanded and, more importantly, accelerated. More funds, in the broadest sense (see 6.6), should be channeled to these centers and more centers should be set up. The NCGEB or an equivalent agency should be entrusted with the task of allocating the funds and selecting new centers, to ensure more effective coordination among the scarce human resources of the biotech community scattered amongst the academic institutions. Funds could be used to initiate the multi-tier system mentioned in section 6.6. To be successful, however, current governmental restrictions on the use of NCGEB funds must be removed.

b. Other public research institutions. TISTR can be used as an example here. Major restructuring is required. A major weakness is the lack of qualified human resources. Research institutions should attempt to utilize available resources in academic institutions. Promotin criteria must be changed to include incentives for carrying out quality research. A large number of positions should be less permanent, and a major proportion of research grants should be earned through competition with other R&D organizations.

c. Grant awarding agencies. In biotechnology, the most relevant grant awarding agencies are STDB and NCGEB. These two agencies share the same goals and concepts as related to grant awarding policy. The only difference is in the sources of funds. Having been active only during the last few years, the main criticism of the STDB awarding scheme is the difficulty in spending the awarded funds. Apparently, here again, the inhibiting factor is bureaucracy. The situation must be improved if STDB is to continue to draw high quality proposals.

For the NCGEB to continue to be effective, its status must be seriously reconsidered. We feel that the center should not be a government unit subject to excessive bureaucracy which inhibits healthy R&D activities. However, the government should continue to provide major funding, while any income generated by R&D activities should be recycled through the Center.

d. Information services. As disscussed in section 5.4, a plan for centralization of information in S&T, concurrent with the development of rapid access electronic services via linked institutions scattered throughout the country is necessary. This is to accomodate the access to available information which is necessary if industrial capabilities are to reach the targets set.

6.5 Measures on Legal Issues

6.5.1 Laws for Promotion of Science and Technology

Promotion of future capabilities for biotechnology-based industries requires enactment of new laws and regulations or strengthening of existing ones. The rapid advance in technological capability in countries like the Republic of Korea and Singapore can, to a significant degree, be attributed to the enactment of specific laws to promote technological development in the industrial sector, and to promote science and technology development in the university and public sectors. Such laws are non-existent in Thailand, although there have been periodic attempts to promulgate them during the past decade (for a review, see TDRI, 1985). As examples, the three following draft laws were prepared in the early eighties. These were never submitted to Parliament, although some positive action regarding their content was subsequently taken in the form of substitute measures.

a. Law for Establishment of a Science and Technology Council. The council was to comprise the Prime Minister as chairman, the Minister of Science, Technology and Energy as the deputy chairman, Mininsters of Agriculture, Industry, Education, and University Affairs, as members, private sector representative members and the MOSTE permanent secretary as secretary. This draft law aimed to achieve a more effective policy and planning mechanism, ensuring that implementation would be carried out from coordination between MOSTE and other ministries and agencies concerned. This draft law was accepted in principle by the cabinet, but was then referred to a high-level committee which eventually made a negative recommendation. In the light of the outstanding issues, however, the Sixth Plan specified the formation of a " high-level mechanism " for formulation and coordination of science and technology policy.

b. Law for Promotion and Development of Science and

Technology. This law called for the establishment of a Science and Technology Fund to provide R&D grants to public and private agencies, and an incentive backed Technology Development Fund (TDF) to be financed by private companies for their own R&D. This draft law was referred to the Ministry of Finance which agreed with certain measures such as increased depreciation for R&D equipment but, opposed other tax incentives for the private companies to do R&D. However, subsequent developments resulted in the establishment of the National Center for Genetic Engineering and Biotechnology (NCGEB), the Science and Technolgy Development Board (STDB) (which both provide R&D funding to public and private agencies) and R&D loan schemes for industries operated by MOSTE and STDB.

c. Law for National Technical Qualification. This called for the establishment of a high-level inter-ministerial committee with minister of MOSTE as the chairman. The purpose was to develop a scheme for recognition of technical qualifications in various fields of science and technology. Also included were provisions for testing of skills and knowledge, and for increasing incentives for techincal personnel both in the public and private sectors.

In addition to these three draft laws, another law is being prepared by the BOI on technology and investment, which will consider technology transfer as a form of investment to be promoted in a similar way to financial investment (see also 6.4). These laws are examples of legal measures to promote technological capability in industry. Various countries at a similar stage of development, and even a few more industrially developed countries, have adopted similar measures. In the light of recent developments, suitable should be made so as to produce optimal results. For example, the establishment of a Science and Technology Fund as stipulated in b) should take into consideration the fact that these new funding agencies have been formed. The Technology Development Fund incentive package may need to be provided by the Ministry of Finance rather than MOSTE, since it involves tax measures normally under the jurisdiction of the former.

6.5.2 Patenting System and Protection of Intellectual Property

As the patenting system in industrially developed countries is rapidly undergoing adjustment with respect to protection of biotechnological inventions, a striking contrast is seen with Thailand, where the first patent law was passed in 1979. The present law in Thailand, not surprisingly, reflects the status of industrial development. The law does not specifically accommodate protection of biotechnological inventions, with which Thailand is still unfamiliar. Furthermore, national policies dictate against patenting in certain areas such as drugs, microorganisms and plant varieties. Although the main purpose of the patenting system is to foster the early disclosure and wide dissemination of technical knowledge embodied in an invention, there is a reluctance in Thailand to strengthen the system so as to enable a more effective protection of an inventor's intellectual property. This is due to fear that the enhanced protection would hamper endogenous technological and industrial development. This fear is reinforced by the fact that the great majority of patents in Thaialnd have been granted to foreign inventors.

Biotechnological inventions present unique problems concerning protection both for developed and developing countries like Thailand. These problems arise mainly from questions concerning products and processes that use living organisms; whether they constitute patentable inventions, and whether the living organisms themselves are subject to patent protection. As commercial biotechnology continues to make an increasingly greater impact, these problems are being answered through landmark court decisions, and through national and international measures. There are however, still numerous legal differences among various industrially developed countries concerning protection of biotechnology. The interests of developing countries like Thailand should also be taken into account in the attempt to achieve international harmony on biotechnology protection. For example, the fear that local genetic resources in Thailand may, after some modification by inventors in developed countries, be protected from use by Thai entrepreneurs should be taken into account. National upgrading of patent protection in biotechnology, as well as in other industrial fields in general, should serve the interest of Thailand in the long run, since history has shown that an efficient patent system is favorable to technological and industrial development. A gradual approach to the upgrading of protection may be necessary, so as to achieve maximum benefits in line with the existing infrastructure.

6.5.3 Regulations on Biosafety

Just as questions of public safety in laboratory experiments, in field experiments, or in environmental release of new biotechnology products are seriously considered in developed countries, so also should be considered in Thailand, even though such questions are presently not very significant. Thailand is fortunate in that it can learn from the experience of developed countries. The safety of genetic engineering experiments and genetically engineered microorganisms, for example, has been subject to scientific tests and public debate for over a decade now, and the conclusions reached so far should be useful to Thailand in devising safety guidelines. Ensurance of safety for commercial genetic engineering products is a necessary part of a firm's development work, and firms should meet rigorous criteria before their products are released. The issue of environmental impact of released biotechnology products should be actively examined. The Food and Drug Administration, the National Environment Board and other regulatory agencies should take an active interest in these issues to formulate necessary regulations and to take necessary precautionary measures.

6.6 Positioning on Utilization and Conservation of Genetic Resources

Thailand is rich in genetic resources on which new biotechnological proesses are based. An important policy target, therefore, should concern the utilization and conservation of these resources. As discussed in 6.10, new developments in protection of intellectual properties in industrialized countries, including protection of micro-organisms and plants originally occurring in Thailand but isolated or modified by foreign inventors, pose an important dilemma. Opening these resources to the international industrial community would, on the one hand, encourage more effective utilization through biotechnology. On the other hand, such an open policy might in the long run inadvertently lead to restricted use of our own indigenous resoures. In addition, unchecked export of unique genetic resources may lead to loss of Thailand's comparative advantage. Optimum measures have to be found which will allow both the growth of technology and the retention of ownership of these indigenous resources. In the short run, selective protective measures may need to be adopted. In the long run, strengthening of our own capabilities would be more effective.

The use of a few superior resources such as genetically improved plant species, has another effect which must not be ignored. As the extent of its use grows, the survival of the various original genetic resources from which it was generated is threatened. Conservation of the original genetic resources should be an important target in addition to development and utilization of improved resources. Conservation is not only for the passive purpose of maintaining the original gene pool. The active purpose is to safeguard against inadvertent loss of genetic characters which might be needed in unforeseen stress situations or in further improvement of resources.

6.7 Promotion of Biotechnology-Based Manufactured Exports

Export promotion for Thai biotechnology-based manufacturers can lead to enhancement of indigenous technology and skills in the manufacturing industries in the Thai economy. There are several reasons for this. There will be an expansion of manufacturing production since the export market is larger than the domestic market. For this reason, underutilised productive capacities which have been found in several manufacturing establishments, e.g. those in the agro-based, alcoholic, and organic acid industries could be fully utilised. Another short run effect of the expanded market, will be pressure on entrepreneurs to acquire more machines and manpower and to improve the operative capability of their firms. The enlarged market will also result in production economies of scale so that manufacturing firms can operate at the most efficient scale.

Moreover, competition, which is more tense at the global level than at the domestic level, will exert more pressure on entrepreneurs to improve price competitiveness, designs and quality of their products. Under these circumstances, new technologies which increase labour productivity will have to be acquired or invented. Adaptive and innovative capabilities of the manufacturing firms will have to be improved so that new or modified raw materials, new product designs, and continually improved product quality are introduced into the production and marketing processes. For example, many new varieties of ornamental flowers have been produced since they have been exported to international markets. Moreover, there have been concomitant improvement for post-harvest technologies and packaging in this industry as well.

Furthermore, participation in international businesses will create an opportunity for Thai manufacturers to learn new management practices and technologies and to have better access to information on design, quality, and sources of technology. The knowledge and experience gained from exporting will enhance their technological capabilities.

Finally, the export promotion of biotechnology-based products can generate subcontracting arrangements between firms. For example, large ornamental flower exporters could expand their exporting capacity by offering subcontracting to small and medium growers who supply them with flowers for export. Under such subcontracting arrangements, the small and medium entrepreneurs in turn would receive technical assistance from the large exporting firms.

Biotechnology-based products that are worth considering for export promotion are listed below :

- Fresh vegetables, fruits, and flowers
- Preserved vegetables and fruits
- Meat and fish products, e.g., ham, sausages, and meat and fish balls
- Fermented food, e.g., soy sauce, pickles, vinegar and alcoholic beverages
- Monosodium Glutamate
- Natural products, e.g., health and health related products which are plant - based.
- Canned seafoods
- Frozen foods
- Other food products

As a natural resource-rich country, Thailand enjoys comparative advantage for the production of the above-mentioned products. Although these products are rather traditional and Thailand has been exporting them to the world (e.g., canned seafoods and frozen foods) there is still a wide scope for export promotion since the international markets are enormous. More important, improved technology, particularly in the areas of post-havest technology, design, quality control, and packaging need to be acquired and put into operation.

Some new biotechnology-based products such as engineered foods, e.g., modified starches, crab meat and seafish meat have good prospects in certain overseas markets (e.g., Japan).

In recent years, several attempts have been made to promote manfactured exports (section 1.2). Although these export promotion measures were not aimed specifically at bio-technology-based industries, those industries also benefit to some extents from the measures. Additional measures and instruments aimed specifically at the promotion of biotechnology-based exports will be given special attention here. Moreover, mesures and instruments to improve the implementation of export promotion policy measures will be underlined. The recommended measures are as follows:

a. Improve export infrastructure, particularly export transportation facilities at the ports and airports. More space should be provided for air transportation of ornamental flowers to overseas customers. Improvement in the ringroad systems will result in transportation of goods between manufacturing firms and ports and airports. Not having to pass central Bangkok, the products could be carried by trucks at any time.

b. Streamlining of export and export tax rebate procedures so that the procedures will take less time and involve fewer activities. The format of export documents should conform to international standards.

c. Improvements in the trade data system would help in monitoring and evaluating trade policies and targets. Manufacturers, exporters, and trading companies should be provided with current trade statistics, news, and prospects in overseas markets.

d. Long-term loans for exporters should be offered at the same rates of interest as those in the world capital market, in order to facilitate investment in exports. Long-term loans should also be extended to finance investment in technology-intensive production of exports.

e. Fair trade practices should be established between trading partners. For example, Thai monosodium glutamate should be given direct access to the Japanese market. At present, Thai manufacturers of monosodium glutamate have to sell their products through a Japanese monosodium glutamate producing company who holds the patent right for this product in the Japanese market.

6.8 Protection and Promotion Measures for the Domestic Market

6.8.1 Promotion of Import-Competing Biotechnology-Based Industries

As demonstrated in section 1.2, Thailand is still importing annually a substantial amount of biotechnology-based products. Moreover, the import value of these biotechnology-based products has increased in recent years. This clearly indicates an expansion in domestic demand for the products. Lack of technological capability is partly responsible for the inadequate domestic supply of these biotechnology-based products. For these reasons, it is desirable to promote more domestic production of such biotechnology-based products.

Protection and promotion measures are necessary for the development of indigenous industries and of industrial technological capabilities, particularly at the initial stages of development. As a late commer in industrialization, Thai industry could face fierce competition from imports, or even from dumping. Without assistance from the govenment, it would be difficult for firms to obtain the necessary financing from commercial banks in their learning period, a period required for building up goodwill with customers and a period during which loss tends to occur. Protection against imports and new entry ensures infant industries of an adequate domestic market for their products and a viable scale of production. Encouraged by government promotional measures and by market prospects for their products, entrepreneurs will respond rapidly. Other arguements for the promotion and protection of import competing industries can be put forward in terms of so-called "infant industry protection", employment and skills enhancement, and benefits to the country's balance of payments. From a general equilibrium consideration, however, protection and promotion should be provided only for a limited period of time.

The following represents a selective list of biotechnology-based products each with annual import values in recent years, of more than 50 million baht. Thus they are worth considering for local production to compete against imports. These include :

Powdered milk for infants,

Soya bean oil (crude, refined or purified),

Whole milk powder containing not less than 2.6% by weight of fat,

Mushrooms and truffles dried,

Palm oil (crude, refined or purified),

Skimmed milk powder

Butterfat

Wheat or mestin food

Malt

Agar-agar

Fatty alcohol,

Cocoa powder unsweetened,

Chocolate,

Preparations of flour starch malt extract with cocoa less than 50%,

Concentrated extract for making beverages,

Sweetened forage and other preparations of a kind used in aminal feeding,

Infant milk foods

Vitamins and hormones

Citric acid,

Enzymes,

Penicillins,

Food colour, and

Varnishes and lacquers

To encourage local production of import-competing biotechnology-based products, the following policy measures and instruments are proposed :

a. Financial measures : long-term cheap production credit, and exchange facilities.
b. Fiscal measures : tax exemption on imported capital equipment and raw materials, and business tax exemption for limited periods of time.
c. Tariff protection for limited periods of time.
d. Promotion of foreign capital participation in the form of joint ventures with local investors.
e. Promotion of development and application of new biotechnologies, particularly, those for food industry such as recombinant DNA technology, tissue and cell diffusion technology, bioreactor, and mass cultivation of cells, biosensors, and artificial enzymes.

6.9 Promotion of Subcontracting Production and Procurement Measures

Subcontracting is an important means for diffusion of technology from contractors to subcontractors. It usually results in the enhancement of technology and skills on the part of the subcontractors. For example, contractors dictate product specifications in terms of design and quality. In addition, they often provide subcontractors with technical assistance. With a substantial degree of market certainty, the subcontractors start to acquire needed technology and enhance their operative capability. As competition increases in later stages, adaptations and innovations occur with both the contractors and subcontractors.

Subcontracting production can be arranged in the biotechnology-based industries both for exports and for import-competing products. For instance, the production of citric acid, and food colours could be arranged under such a subcontracting system.

To promote subcontracting arrangements, the following measures are proposed :

a. VAT regulations should be implemented and the present business tax system should be abandoned as it tends to hamper the development of subcontacting arrangements. This will result in enhancement of technology and skills as a result of specialization in seperate production lines and business activities.

b. For technological capability development purposes, subcontractors should be entitled to promotional priviledges offered by BOI, e.g., tax exemption on imported capital goods and raw materials,accessibility to long term loans with low rates of interest, and tax holidays.

These two measures will not only strengthen the subcontracting system and technological capabilities but also promote the role and technological modernization of small and medium Thai firms. Moreover, production deepening into upstream and downstream industries could also be encouraged.

c. As regards institutional arrangements, a Manufacturer's Subcontracting Development Office should be established in the Ministry of Industry to promote sub-contracting arrangement between large contractors and a number of small producers by identifying opportunities and prospects and organizing sub-contracting projects that will complement large industries.

d. To avoid possible disputes that might occur between subcontractors and contractors, the government authorities concerned (e.g., the Thailand Institute of Industrial Standards (TISI)) should be prepared to provide necessary assistance on such matter as product standards and testing and quality control facilities. There should be regulations governing practices in the subcontracting system. Disputes between two parties (e.g., on the quality of products manufactured by subcontracting arrangement) that could not be settled satisfactorily and fairly would destroy the whole system of subcontracting arrangements.

Apart from subcontracting arrangements which are a form of procurement whereby large firms obtain needed parts and intermediate goods from small firms, or subcontractors, one more type of procurement arrangements is considered below as a measure for the enhancement of technological capabilities in Thai industry.

Small manufacturing biotechnology-based firms should be encouraged to jointly procure facilities, equipment and materials for research and development purposes in order to reduce costs of such activities. The proposed joint undertaking among small firms includes joint construction and use of laboratories and equipment for research and development of new technology and for testing and quality control.

In support of these undertakings, the government should provide long-term loans at lower interest rates and tax incentives for jointly used facilities. Moreover, adequate space in industrial estates should be allocated for the construction and use of such laboratories and equipment by small collaborating firms.

7. CONCLUSION AND POLICY RECOMMENDATIONS

In conclusion, an attempt has been made to test some hypotheses and answer some questions concerning technological capability of the biotechnology-based industries (see 1.4.3). Information gained from this attempt has pointed to strategies to upgrade this capability. Many of these strategies require upgrading of the capability of the infrastructural system and government sector institutions. However, the strategies can only be successful if the firms themselves can continuously improve their own technological capability. In this respect, it is worthwhile to summarise the main points of conclusion gained from the present study.

Our results have shown that large Thai firms tend to assign higher priority to development of technological capability than foreign-invested firms or small Thai firms. Owing to the small number of firms surveyed, however, this conclusion is only tentative, and we did find a few examples quite to the contrary. The main policy implication from this study is that, based on the assumption that technology dynamism is an important factor in the firms' performance, many firms, especially foreign-invested and small Thai firms, still need to assign greater importance to such technology dynamism.

As expected, most firms are using conventional technologies in the production processes and very few firms are planning to use new technologies which are the hallmark of the present global importance of biotechnology. Significantly, there appears to be an inverse relationship between the level of technology sophistication and level of technological capability in the industries. Hence, a high capability was found for upstream industries, e.g., aquaculture, which are relatively unsophisticated, while a low capability was found for such downstream industries as organic acids and health-related industries with relatively higher sophistication. The policy implication is that measures need to be taken to increase the capability of the firms in more sophisticated technology, provided that it will improve their products and processes which have to meet stiffer competition in the future. At present, while the firms are not inclined to upgrade the technology level, it may be necessary for the public sector institutions to build up capabilities in new biotechnology for long-term development purpose, and to try to achieve a greater linkage with the industries.

The firms are generally weak in innovative capability and have various problems albeit less severe in acquisitive, operative and adaptive capability. This can be further linked to lack of technological efforts of the firms, lack of manpower supply and training, both within the industries and the training institutions. A policy is needed to promote the technological efforts and active manpower training. Tax and other incentives may be required by the firms in order for them to invest in these efforts.

The list below gives policy recommendations mainly addressed to the public scetor and infrastructural agencies.

7.1 On Industrial Planning (NESDB, BOI)

a. Establishment of an SIT subcommittee under the Joint Public Private Sector Consultative Group Committee (JPPSCGC).

b. Establishment of Science and Industrial Parks.

c. Establishment of a National S&T council.

d. Encouragement and coordination in establishment of cooperative R&D programmes between firms.

7.2 On Investment Promotion (BOI)

a. Encouragement should be given to industries based on locally developed and indigenous technology.

b. An important criterion for promotion of joint ventures should be provision for technology transfer, in addition to capital investment.

c. Bureaucratic problems in investment approval should be reduced, especially for technology-based industries.

d. More personnel in science and technology should be encouraged and recruited to serve functions in technology consultancy, selection, planning and negotiation.

e. Tax exemption policy should be revised, with incentives given to technology development in promoted industies.

f. R & D facilities should be encouraged as an important feature of industies seeking BOI privileges.

7.3 On Tariff, Taxes and Budget (MOF)

a. Increased budget should be provided for R&D activities in the public sector : the target of 0.5% of GNP in the 6^{th} plan should be attained.

b. Tariffs should be imposed on imported products which can be produced by locally developed technology; however, overprotection should be avoided.

e. Tax restructuring should be made by introducing tax exemption on necessary equipment imported for R & D of both company and university laboratories.

f. Increased depreciation allowance should be made to the firms investing in R&D facilities. Export subsidy should be given to products produced by adaptive or locally developed technology, especially to enable competition with other countries.

g. Soft loans with long term credit and long grace periods should be provided to firms engaged in technology-based production.

h. Tax benefits should be given to firms undertaking R&D activities. This can replace dirict subsidy on production which invites retaliation from trading partners.

7.4 On Financial Instruments (BOI, IFCT, STDB)

a. Monetary buffering for technology licensing should be implemented in the case of highly fluctuating exchange rates.

b. Promotion should be given to formation of venture capital for technology-based industries which require a relatively long payback period, but provide high margins in the long run.

c. Local financing sources for R & D and technology such as government bonds under the authority of Bank of Thailand should be provided.

7.5 On Private - Public Cooperation. (NESDB, FTI, Universities)

a. Establisment of Science and Industrial Parks.

b. Establishment of privately run research centers on specific subjects and in close proximity to universities.

c. Establishment of Continuing Education Centers aimed at upgrading the technological capability of private firms.

7.6 On Manpower Development. (MUA, MOE)

a. Reorient and restructure Universities to encourage R&D activities, especially with regard to competitiveness in hiring staff and to flexibility in funding.

b. Establishment of a Pilot Plant Training Institute.

c. Encourage establisment of graduate research programmes in multi disciplinary areas as well as in conventional areas.

d. Establishment of Continuing Education Centers for upgrading and retraining of private sector technical manpower in areas such as process engineering and applied microbiology.

e. Foster training of high technology skills (e.g., genetic engineering, biospecific separation) for staff of both public and private institutions.

f. Introduce biological science into various engineering curricula.

7.7 On Research and Development. (MOSTE, TISTR, NRC)

a. Increase competitive R&D funding for both the private and the public sectors. Total R&D funding should be at least 0.5% of GNP annually.

b. Restructure public sector research liboratories with respect to funding and promotional schemes, to encourage healthy R&D activity.

c. Income generated by R&D institutions should be recycled into R&D activities.

d. Increase the number of scholarships and fellowships for post doctoral and post graduate research.

e. Establish and accelerate the development of centers of exellence in chosen technological areas.

f. Establish, on a national basis, electronic linkages of libraries and information centers.

g. Establish national research laboratories in chosen areas.

7.8 On Industrial Support. (DIP, TISI, MIDI)

a. Encourage the establishment of privately run laboratory services and establish a national system for laboratory certification.

b. Promote the use of technical consulting services.

7.9 On Technical Assistance. (DIP, DTEC, STDB)

a. Increase research grants for private sector R&D.

b. Establish grants for subsidizing the use of technical consulting companies.

7.10 On Trade Policy (MOC, NESDB)

a. Technology transfer should be included in trade negotiation, agreement and marketing development.

b. JPPSCAC and NESDB should contribute as technology networking agencies.

c. MOC should function as a technology watching agency as well as trade information providing agency, if trade is negotiated on a technology transfer basis.

d. MOC should seek technological information through the cooperation of UNCTAD.

7.11 On Legal Issues

7.11.1 Laws and Regulations for Promotion of Science and Technology (MOSTE, MOF, BOI)

a. A Law for Establishment of a National Council on Science and Technology should be promulgated (for content, see 6.10.1). In the interim period, a high level interministerial committee should be formed to formulate and coordinate support measures for science and technology.

b. A law for establishment of a flexible funding agency should be promulgated. This agency should take over the present role of the Science and Technology Development Board, and encompass the funding role of the National Center for Genetic Enginerring and Biotechnology, and other national centers for specific technologies.

c. Provisions should be made to encourage industries to set up technology development funds for R & D purposes in their own companies. These should be support by with tax incentives, and other incentives such as reduced custom fees for equipment, and increased depreciation for equipment bought. A law should be set up for this purpose, although a decree or an announcement from the Ministry of

Finance might be a possible interim measure.

d. A law and/or civil service regulation should be set up to recognize the value of technical skills and to devise incentive packages for technical personnel both in the public and private sectors.

e. Measures should be devised to offer incentives to investors to transfer technology to Thailand as a part of investment. This can be achieved by modification of the present Law for Investment Promotion.

7.11.2 Patenting System and Protection of Intellectual Properties (MOC, MOSTE, NCGEB, STDB, MOE)

a. Assessment should be made of the need and the time scale for upgrading of the present patent system and other measures for protection of intellectual properties. With regard to the biotechnology - based industries, protection in the areas of pharmaceuticals, microorganisms and plant varieties deserves thorough study. A stepwise programme should be evolved, taking into consideration optimum measures for future development of industry.

b. Supportive actions should be taken for implementation of new protection measures, such as establishment of the national collection system for deposit of novel microorganisms, plant germplasm, genetic materials, etc. (see also 7.12 b)

7.11.3 Regulations on Biosafety (FDA, NEB, MPH, MOSTE, NCGEB)

a. Present FDA regulations should be revised to take into account the production and marketing of new biotechnology products affecting consumers.

b. Regulations for field trials and environmental release of new biotechnology products should be devised to take into account both short and long-term eological consequences

c. Regulations should be devised for laboratory and pilot scale experimentation involving genetic engineering, taking into account international standards and practice.

7.12 Utilization and Conservation of Genetic Resources (MOA, MOSTE, NCGEB)

a. Establishument of reserve lands which contain valuable genetic resources.

b. Establishment of national collection systems and conservation measures for microorganisms, plant germplasm, genetic materials, etc. (see also 7.11.2 b).

c. Participation in international efforts to conserve and exchange genetic materials, taking care that the interests of the country are served in such conservation and exchange activities.

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Annex 1

LIST OF FIRMS INCLUDED IN THE SURVEY

Aquaculture Industry

1.	World Aquaculture Co. Ltd.	606 Luang Rd. Pomprab, Bangkok.
2.	Thai Prawn Culture Center Co. Ltd.	36 Soi Yenchit Chand Rd., Bangkok.
3.	Premier International Co. Ltd.	62 Soi Lang Suan Ploenchit, Bangkok.
4.	Thai Luxe Enterprises Co. Ltd.	101/3 Nares Rd. Bangkok.
5.	AQUA Star	103/1 Moo2 (Km.64) Tambol Paktrae, Amphoe Ranod Songkhla 90140
6.	Wang Matcha	Wong Noi Ayuthaya

Animal Feed Industy

7.	Star Feedmill Co., Ltd.	29/29-31 Sukhumvit 22 Bangkok. 10110
8.	P. Charoenpan	69/10-13 Suksawadi Rd. Ratburana, Bangkok.
9.	Thai Wah Co., Ltd.	21 Sathon Tai Rd. Thung Mahamek, Yannava Bangkok.

10. Sahapatana Kaset Co., Ltd.	51/515-8 Drive In Sq. Lard-Prao, Bangkapi Bangkok.

Seed Industy

11. Chia Tai Seed. Agr. Co., Ltd.	393/2 Soi Tonglau Sukhumvit Rd., Bangkok.
12. Kaset Sakol	1168 Soi Phahonyothin 22 Phahonyothin Rd., Bangkhen
and	Bangkok.
Adams International Co., Ltd.	5/26-29 Saladaeng Rd. Silom, Bangkok.
13. East West Seed	50/1 Moo 2, Sai Noi-Bang Bua Thong Rd. Amphoe Sai Noi, Nonthaburi. 11150.

Dairy Industry

14. Thai Dairy Industry Co., Ltd.	30 Sukumvit, Pak Nam
15. Nong-Po Ratchaburi Dairy Co-op.	119 Moo 3, Tambol Nong Po Amphoe Photharam, Ratchaburi.
16. Udom Wang Tal Farm	Amphoe Ban Pong Ratchaburi.

17. Kasiratharn Co.	Amphoe Nakhorn Chaisri Nakhorn Pathom

Ornamental Plant Industry

18. Bangkok Flower Center Co.	34/19 Moo 7 Petchkasem Rd. Nong Kang Plu, Nong Khaem Bangkok.
19. Excel Orchids	63/3 Moo 1 Petchkasem Rd. Bangkok.
20. Tropical Flora	Opposite Mahidol University. Salaya Campus, Budhamonthon 4 Rd. Salaya, Nakhon Pathom.
21. Chao Phraya Orchids	Pakkret, Nonthaburi.

Organic Acids Industry

22. Ajinomoto (Thailand) Co. Ltd.	Soi Sukhabhibal 1 Suksawasdis Rd., Phrapaadaeng Samutprakarn
23. Thai Churos Ltd.	48 Suksawasdi Rd., Phrapadaeng, Samutprakarn.
24. Thai Theparos	28 Moo 6, Tambol Thai Ban Amphoe Muang, Samutprakarn.
25. Thai Fermentation Industry	186/1-4 Siam Squares Rama I Rd., Bangkok.

Alcohol Industry

26.	TCC COSMO CORP.	TCC Building 290 Surawongse Rd. Bangkok 10500
27.	Eastern Chemicals	Chonburi
28.	Sura Ayudthaya	1448 Nakhon Chaisri Rd. Dusit, Bangkok.
29.	Thai Alcohol Ltd.	31-35 Chalermkhet 1. Bangkok.
30.	Thai Amarit Brewery Ltd.	369/1 Pracharat 1 Bang Sue, Bangkok.
31.	Pramualphol Co. Ltd.	56 Sukhaphiban Nakhon Chaisri, Nakhon Pathom

Heath and Related Industry

32.	Lever Brothers (Thailand) Co.Ltd.	1037 Ploenchit Rd. Bangkok.
33.	BM Lab. Co. Ltd.	2/19 Phahonyothen Rd. Victory Monument Circle. Bangkok.
34.	Thai Meiji Pharmaceutical Co.	183 Ratchadamri Rd. (Back of Reagent House) Bangkok.

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35.	Hoechst Pharmaceutical Industries Co.	302 Silom Rd. Bangkok.
36.	The Government Pharmaceutical Organization	Rama IV Rd. Bangkok.
37.	Department of Livestocks Development	Phyathai Rd. Bangkok.

Annex 2

Raw data

BIOTECHNOLOGY INDUSTRY CAPABILITY

Overall Capabilities	Acquisitive	Operative	Adaptive	Innovative	Average
Aquaculture	4.54	4.15	4.13	3.25	4.02
Feed	4.21	3.75	3.94	2.95	3.71
Seeds	3.46	3.70	3.69	2.80	3.41
Dairy	3.61	3.20	3.08	2.20	3.02
Flowers	3.08	3.25	3.00	2.40	2.93
Organic acid	2.79	3.55	3.63	1.55	2.88
Alcohol	3.25	2.80	2.75	2.05	2.71
Health	2.92	3.50	2.63	1.37	2.61

AQUACULTURE

Acquisitive Capability

	Install	Transfer	Procure	Negotiate	Assess	Search
AQUA 1	5.00	5.00	5.00	5.00	4.00	5.00
AQUA 2	4.00	5.00	4.00	5.00	5.00	5.00
AQUA 3	4.00	5.00	4.00	5.00	4.00	5.00
AQUA 4	5.00	4.00	4.00	5.00	4.00	3.00

Operative Capability

	Operate	Maintain	Skills	Manage	Train
AQUA 1	5.00	4.00	4.00	4.00	5.00
AQUA 2	5.00	5.00	4.00	4.00	5.00
AQUA 3	5.00	5.00	4.00	5.00	1.00
AQUA 4	5.00	5.00	4.00	3.00	1.00

Adaptive Capability

	Modify Product	Modify Process	Knowledge	Digestion
AQUA 1	5.00	5.00	5.00	5.00
AQUA 2	4.00	4.00	5.00	4.00
AQUA 3	4.00	4.00	3.00	4.00
AQUA 4	4.00	4.00	3.00	3.00

Innovative Capibility

	Product Change	Process Change	Major Change	R & D	Invention
AQUA 1	5.00	5.00	4.00	4.00	1.00
AQUA 2	4.00	4.00	5.00	5.00	1.00
AQUA 3	3.00	3.00	4.00	4.00	1.00
AQUA 4	3.00	3.00	4.00	1.00	1.00

Overall Capabilities

	Aquisitive	Operative	Adaptive	Innovative	Average
AQUA 1	4.83	4.40	5.00	3.80	4.51
AQUA 2	4.67	4.60	4.25	3.80	4.33
AQUA 3	4.50	4.00	3.75	3.00	3.81
AQUA 4	4.17	3.60	3.50	2.40	3.42

OVERALL

AQUA	4.54	4.15	4.13	3.25

FEED

Acquisitive Capability

	Install	Transfer	Procure	Negotiate	Assess	Search
FEED 1	4.00	5.00	5.00	5.00	5.00	5.00
FEED 2	4.00	4.00	5.00	5.00	5.00	5.00
FEED 3	5.00	4.00	5.00	4.00	2.00	3.00
FEED 4	3.00	4.00	4.00	3.00	4.00	3.00

Operative Capability

	Operate	Maintain	Skills	Manage	Train
FEED 1	5.00	5.00	5.00	5.00	5.00
FEED 2	4.00	4.00	5.00	4.00	2.00
FEED 3	4.00	4.00	4.00	4.00	1.00
FEED 4	3.00	3.00	4.00	3.00	1.00

Adaptive Capability

	Modify Product	Modify Process	Knowledge	Digestion
FEED 1	5.00	5.00	5.00	5.00
FEED 2	5.00	5.00	4.00	3.00
FEED 3	5.00	3.00	3.00	3.00
FEED 4	4.00	3.00	3.00	2.00

Innovative Capibility

	Product Change	Process Change	Major Change	R & D	Invention
FEED 1	5.00	4.00	4.00	4.00	3.00
FEED 2	5.00	4.00	2.00	2.00	1.00
FEED 3	4.00	4.00	4.00	2.00	1.00
FEED 4	4.00	3.00	1.00	1.00	1.00

Overall Capabilities

	Aquisitive	Operative	Adaptive	Innovative	Average
FEED 1	4.83	5.00	5.00	4.00	4.71
FEED 2	4.67	3.80	4.25	2.80	3.88
FEED 3	3.83	3.40	3.50	3.00	3.43
FEED 4	3.50	2.80	3.00	2.00	2.83

OVERALL

FEED	4.21	3.75	3.94	2.95

DAIRY

Acquisitive Capability

	Install	Transfer	Procure	Negotiate	Assess	Search
DAIRY 1	3.00	5.00	4.00	5.00	4.00	5.00
DAIRY 2	4.00	5.00	5.00	1.00	3.00	3.00
DAIRY 3	3.00	3.00	4.00	4.00	1.00	3.00

Operative Capability

	Operate	Maintain	Skills	Manage	Train
DAIRY 1	5.00	4.00	4.00	4.00	4.00
DAIRY 2	3.00	5.00	3.00	3.00	3.00
DAIRY 3	4.00	1.00	3.00	1.00	1.00

Adaptive Capability

	Modify Product	Modify Process	Knowledge	Digestion
DAIRY 1	5.00	4.00	5.00	4.00
DAIRY 2	5.00	1.00	2.00	1.00
DAIRY 3	4.00	1.00	3.00	2.00

Innovative Capibility

	Product Change	Process Change	Major Change	R & D	Invention
DAIRY 1	3.00	2.00	3.00	3.00	2.00
DAIRY 2	4.00	4.00	2.00	3.00	1.00
DAIRY 3	1.00	1.00	2.00	1.00	1.00

Overall Capabilities

	Aquisitive	Operative	Adaptive	Innovative	Average
DAIRY 1	4.33	4.20	4.50	2.60	3.91
DAIRY 2	3.50	3.40	2.25	2.80	2.99
DAIRY 3	3.00	2.00	2.50	1.20	2.18

OVERALL				
DAIRY	3.61	3.20	3.08	2.20

SEED

Acquisitive Capability

	Install	Transfer	Procure	Negotiate	Assess	Search
SEED 1	4.00	5.00	4.00	5.00	4.00	5.00
SEED 2	2.00	4.00	3.00	3.00	3.00	4.00
SEED 3	3.00	3.00	3.00	2.00	3.00	4.00
SEED 4	3.00	3.00	3.00	3.00	3.00	4.00

Operative Capability

	Operate	Maintain	Skills	Manage	Train
SEED 1	5.00	4.00	4.00	4.00	4.00
SEED 2	4.00	3.00	4.00	4.00	4.00
SEED 3	4.00	3.00	4.00	4.00	3.00
SEED 4	4.00	3.00	3.00	3.00	3.00

Adaptive Capability

	Modify Product	Modify Process	Knowledge	Digestion
SEED 1	5.00	4.00	4.00	4.00
SEED 2	4.00	4.00	4.00	3.00
SEED 3	4.00	3.00	4.00	4.00
SEED 4	2.00	3.00	4.00	3.00

Innovative Capibility

	Product Change	Process Change	Major Change	R & D	Invention
SEED 1	4.00	4.00	3.00	3.00	4.00
SEED 2	3.00	3.00	3.00	3.00	2.00
SEED 3	4.00	4.00	3.00	3.00	2.00
SEED 4	2.00	2.00	2.00	1.00	1.00

Overall Capabilities

	Aquisitive	Operative	Adaptive	Innovative	Average
SEED 1	4.50	4.20	4.25	3.60	4.14
SEED 2	3.17	3.80	3.75	2.80	3.38
SEED 3	3.00	3.60	3.75	3.20	3.39
SEED 4	3.17	3.20	3.00	1.60	2.74

OVERALL SEED	3.46	3.70	3.69	2.80

ORGANIC ACIDS

Acquisitive Capability

	Install	Transfer	Procure	Negotiate	Assess	Search
ACID 1	2.00	3.00	3.00	2.00	2.00	2.00
ACID 2	2.00	4.00	3.00	2.00	3.00	3.00
ACID 3	3.00	4.00	3.00	3.00	3.00	3.00
ACID 4	2.00	4.00	3.00	2.00	3.00	3.00

Operative Capability

	Operate	Maintain	Skills	Manage	Train
ACID 1	5.00	4.00	5.00	4.00	5.00
ACID 2	4.00	3.00	4.00	4.00	2.00
ACID 3	3.00	2.00	3.00	3.00	4.00
ACID 4	4.00	3.00	4.00	3.00	2.00

Adaptive Capability

	Modify Product	Modify Process	Knowledge	Digestion
ACID 1	5.00	4.00	3.00	2.00
ACID 2	5.00	4.00	4.00	3.00
ACID 3	4.00	5.00	4.00	3.00
ACID 4	5.00	3.00	3.00	1.00

Innovative Capibility

	Product Change	Process Change	Major Change	R & D	Invention
ACID 1	2.00	2.00	2.00	1.00	2.00
ACID 2	2.00	2.00	2.00	1.00	1.00
ACID 3	1.00	1.00	2.00	1.00	1.00
ACID 4	1.00	2.00	3.00	1.00	1.00

Overall Capabilities

	Aquisitive	Operative	Adaptive	Innovative	Average
ACID 1	2.33	4.60	3.50	1.80	3.06
ACID 2	2.83	3.40	4.00	1.60	2.96
ACID 3	3.17	3.00	4.00	1.20	2.84
ACID 4	2.83	3.20	3.00	1.60	2.66
OVERALL ACID	2.79	3.55	3.63	1.55	

ORNAMENTAL PLANTS

Acquisitive Capability

	Install	Transfer	Procure	Negotiate	Assess	Search
ORNA 1	5.00	4.00	5.00	1.00	4.00	4.00
ORNA 2	5.00	3.00	4.00	1.00	3.00	3.00
ORNA 3	4.00	3.00	3.00	1.00	3.00	3.00
ORNA 4	3.00	2.00	3.00	1.00	3.00	3.00

Operative Capability

	Operate	Maintain	Skills	Manage	Train
ORNA 1	4.00	4.00	4.00	4.00	4.00
ORNA 2	4.00	3.00	4.00	4.00	3.00
ORNA 3	4.00	4.00	3.00	3.00	2.00
ORNA 4	3.00	2.00	3.00	1.00	2.00

Adaptive Capability

	Modify Product	Modify Process	Knowledge	Digestion
ORNA 1	3.00	4.00	4.00	4.00
ORNA 2	3.00	3.00	3.00	3.00
ORNA 3	3.00	2.00	3.00	3.00
ORNA 4	2.00	2.00	3.00	3.00

Innovative Capibility

	Product Change	Process Change	Major Change	R & D	Invention
ORNA 1	3.00	4.00	3.00	3.00	2.00
ORNA 2	3.00	3.00	2.00	2.00	2.00
ORNA 3	3.00	2.00	2.00	2.00	2.00
ORNA 4	2.00	2.00	2.00	2.00	2.00

Overall Capabilities

	Aquisitive	Operative	Adaptive	Innovative	Average
ORNA 1	3.83	4.00	3.75	3.00	3.65
ORNA 2	3.17	3.60	3.00	2.40	3.04
ORNA 3	2.83	3.20	2.75	2.20	2.75
ORNA 4	2.50	2.20	2.50	2.00	2.30

OVERALL				
ORNA	3.08	3.25	3.00	2.40

HEALTH & RELATED

Acquisitive Capability

	Install	Transfer	Procure	Negotiate	Assess	Search
HEAL 1	4.00	4.00	4.00	3.00	4.00	4.00
HEAL 2	3.00	4.00	4.00	3.00	3.00	4.00
HEAL 3	4.00	3.00	3.00	2.00	4.00	3.00
HEAL 4	5.00	4.00	3.00	2.00	4.00	4.00
HEAL 5	2.00	2.00	2.00	1.00	2.00	2.00
HEAL 6	2.00	1.00	1.00	1.00	2.00	2.00

Operative Capability

	Operate	Maintain	Skills	Manage	Train
HEAL 1	5.00	5.00	4.00	5.00	5.00
HEAL 2	3.00	4.00	4.00	3.00	3.00
HEAL 3	4.00	4.00	4.00	4.00	4.00
HEAL 4	4.00	4.00	4.00	4.00	4.00
HEAL 5	3.00	2.00	3.00	3.00	1.00
HEAL 6	3.00	2.00	2.00	3.00	2.00

Adaptive Capability

	Modify Product	Modify Process	Knowledge	Digestion
HEAL 1	4.00	3.00	4.00	3.00
HEAL 2	4.00	4.00	4.00	4.00
HEAL 3	3.00	4.00	3.00	3.00
HEAL 4	2.00	1.00	3.00	3.00
HEAL 5	1.00	1.00	2.00	2.00
HEAL 6	1.00	1.00	1.00	2.00

Innovative Capibility

	Product Change	Process Change	Major Change	R & D	Invention
HEAL 1	1.00	1.00	2.00	2.00	1.00
HEAL 2	1.00	1.00	2.00	2.00	2.00
HEAL 3	1.00	2.00	3.00	2.00	1.00
HEAL 4	1.00	1.00	1.00	2.00	1.00
HEAL 5	1.00	1.00	1.00	1.00	1.00
HEAL 6	1.00	1.00	1.00	1.00	2.00

Overall Capabilities

	Aquisitive	Operative	Adaptive	Innovative	Average
HEAL 1	3.83	4.80	3.50	1.40	3.38
HEAL 2	3.50	3.40	4.00	1.60	3.13
HEAL 3	3.17	4.00	3.25	1.80	3.05
HEAL 4	3.67	4.00	2.25	1.20	2.78
HEAL 5	1.83	2.40	1.50	1.00	1.68
HEAL 6	1.50	2.40	1.25	1.20	1.59

OVERALL				
HEALTH	2.92	3.50	2.63	1.37

ALCOHOL

Acquisitive Capability

	Install	Transfer	Procure	Negotiate	Assess	Search
ALCO 1	4.00	3.00	4.00	3.00	2.00	3.00
ALCO 2	3.00	2.00	4.00	3.00	3.00	3.00
ALCO 3	5.00	4.00	4.00	1.00	2.00	4.00
ALCO 4	5.00	4.00	3.00	3.00	3.00	3.00

Operative Capability

	Operate	Maintain	Skills	Manage	Train
ALCO 1	4.00	3.00	3.00	3.00	1.00
ALCO 2	4.00	4.00	4.00	3.00	1.00
ALCO 3	3.00	2.00	3.00	3.00	1.00
ALCO 4	4.00	4.00	3.00	2.00	1.00

Adaptive Capability

	Modify Product	Modify Process	Knowledge	Digestion
ALCO 1	4.00	4.00	3.00	2.00
ALCO 2	1.00	3.00	2.00	3.00
ALCO 3	4.00	4.00	1.00	3.00
ALCO 4	1.00	4.00	3.00	2.00

Innovative Capibility

	Product Change	Process Change	Major Change	R & D	Invention
ALCO 1	4.00	4.00	4.00	1.00	1.00
ALCO 2	3.00	3.00	3.00	1.00	1.00
ALCO 3	2.00	2.00	2.00	1.00	1.00
ALCO 4	2.00	2.00	2.00	1.00	1.00

Overall Capabilities

	Aquisitive	Operative	Adaptive	Innovative	Average
ALCO 1	3.17	2.80	3.25	2.80	3.00
ALCO 2	3.00	3.20	2.25	2.20	2.66
ALCO 3	3.33	2.40	3.00	1.60	2.58
ALCO 4	3.50	2.80	2.50	1.60	2.60

OVERALL

ALCO	3.25	2.80	2.75	2.05

Annex 3

LIST OF ABBREVIATIONS

BOI	Board of Investment
DIP	Department of Industrial Promotion
DTEC	Department of Technical and Economic Cooperation
FDA	Food and Drug Administration
FTI	Federation of Thai Industries
IFCT	Industrial Finance Cooporation of Thailand
JPPSCGC	Joint Public Private Sector Consultative Group Coommittee
MOA	Ministry of Agriculture and Cooperative
MOC	Ministry of Commerce
MOF	Ministry of Finance
MOI	Ministry of Industry
MOSTE	Ministry of Science, Technology and Energy
MPA	Ministry of Public Health
MUA	Ministry of University Affairs
MIDI	The Metal Working and Machinery Industry Development Institute

NCGEB	National Center for Genetic Engineering and Biotechnology
NEB	National Environment Board
NESDB	National Economic and Social Development Board
NRC	National Research Council
TICST	Thai Information Center for Science and Technology
TISTR	Thailand Institute of Scientific and Technological Research
TISI	Thailand Industrial Standard Institute
STDB	Science and Technology Development Board