Comparison of Bioinformatics Industry between Malaysia and India: An Overview

Kingsley Chow[1]
Eng Piew Kok[2]
Agan Adun Shashi Mohan[3]
Wei Huo So[4]

Bioinformatics Division, Institute of Biological Science
University of Malaya 50603 Kuala Lumpur, Malaysia.[1 2 3 4]
E-mail: kingsley.chow109@gmail.com[1], engpiewkok@gmail.com[2]
shashi_mohan@hotmail.com[3], so.wei.huo@gmail.com[4]

Abdul Rahman Ahmad Dahlan[5], (Corresponding author)
Department of Information Systems
Kulliyyah of Information and Communication Technology
International Islamic University
E-mail: arad@kict.iiu.edu.my[5] , Phone: +60192202032[+]

Abstract

The amount of information being churned out by the field of biology has jumped manifold and now requires the extensive use of computers of the management of this information. The field of bioinformatics that addresses this need of biology has become an industry in its own right with the pharmaceutical and biotechnology industries being dependent on it for their growth. The bursting of the dotcom bubble in 2000 saw investors and venture capitalists flocking to the biotechnology industry in general and bioinformatics in particular. This work gives an analytical comparison of the bioinformatics industry in Malaysia and India. We examined government policy, education and economic aspects that are faced by the industry of each country. We also examined the difference in the development for the Bioinformatics industry between each country.

Key words: Bioinformatics, Economy, Education, Government, Malaysia, India

1.0 Introduction

Bioinformatics is a newly emerging interdisciplinary research area, which may be defined as the "interface between biological and computational sciences". Although the term 'Bioinformatics' is not really well-defined, it can be said that this scientific field deals with all kinds of biological information, whether it is about genes and their products, whole organisms or even ecological systems or anything related to biology. Most of the Bioinformatics work that is done can be described as analyzing biological data, although a growing number of projects deal with the organization of biological information. The global Bioinformatics industry has grown at a double-digit growth rate in the past and is expected to follow the same pattern in the next four years. US remains the largest market in the world, but Asia-Pacific countries, particularly India and China, are witnessing the fastest growth and are anticipated to emerge as the dominating forces in future. The content database market, with revenues of over US$ 800 Million in 2006, represents the largest segment in the market; however, it is the analytical software segment that is posting the fastest growth rate. Bioinformatics is full of opportunities. The sector is poised to open new avenues for the other related sectors also. But the biggest opportunity area in the Bioinformatics market will be in the drug discovery sector. Reduction of both the cost and time taken to discover a new drug due to fast development in the Bioinformatics tools and software zone is also making drug discovery an attractive field to venture in.

2.0 Government Bioinformatics Policies

2.1 Government of India's Bioinformatics Policies

Bioinformatics is publicly known to be emerged in India and it thanks the rapid growth of Information Technology (IT) based industry which provides invaluable support for bioinformatics development (14,29). Currently, there are more than 200 bioinformatics- related companies and over 300 institutions offering bioinformatics program. The Government of India is the major contributor to the establishment of the industry in the country.

Besides the main support the federal government gives to the industry, the state governments such as the Government of Karnataka and Government of Andhra Pradesh have also created their own biotechnology policies to promote the biotechnology development and indirectly involve the bioinformatics development (5,10). Thus, the role played by the government becomes the study model to understand the necessary strategies and work to be performed in order to build up an internationally-recognized bioinformatics industry. The bioinformatics development was initiated by the Department of Biotechnology (DBT) was set up by the Ministry of Science and Technology, Government of India in 1986 (9). DBT has foreseen the potential of bioinformatics industry and its development was also initiated in the same year. The initial objectives for setting up the bioinformatics program were (3):

1. To make the Indian bioinformatics industry being internationally famous.
2. To strengthen the fields of other biotechnological sciences particularly medical, agricultural, animal and environmental biotechnology with strong and advanced bioinformatics support.
3. To efficiently manage and organize the biological information for easy retrieval.

The most notable achievement was the setting up of National Bioinformatics Network to efficiently provide the biological data resources nationwide (14). The Biotechnology Information System Network (BTIS), a division of DBT, has connection with 57 research centres nationwide. The research centres working on bioinformatics includes National Institute of Immunology, Centre for DNA fingerprinting and Diagnostics, National Centre for Cell Science and Institute of Microbial Technology (1). The research areas requiring bioinformatics application include gene and cell research, protein analysis, development of genetically modified products, drug development process, new pest resistant crops, drug toxicology, pharmacogenetics and livestock (22).

The responsibilities of DBT to promote the growth of biotechnology including bioinformatics are (11):

1. Encourage large scale application of biotechnology.
2. Setting up the infrastructure and facilities for research and development, and commercial production.
3. Promote the human resource development.
4. Promote International collaboration for knowledge and technology exchange.
5. Produce Bio-safety manual to ensure the occupational safety and health for research and commercial laboratory personnel.
6. Provide fund-in-aid supports for the governmental research institutes.
7. Serve as the collectors for national biotechnology information.
8. Introduce the latest technology from the world to the country.

In 2004, DBT has drafted the Bioinformatics Policy of India (BPI-2004) to monitor and manage overall bioinformatics activities (3). This policy has stated the importance of bioinformatics, the bioinformatics application as well as the current and future aspects, vision and strategies for the industry advancement.

Some of the current strategies DBT used are shown below:

1. Establish the international bioinformatics institute to allow international and entrepreneurial participation in the bioinformatics activities.
2. Promote training and education in bioinformatics as well as the human resource development through national institutes and universities.
3. Design and implement the system for computing, communication and infrastructure, bioinformatics utilities and others.
4. Coordinate the network through an Apex Secretariat.
5. Build the network with international resources in biotechnology information.
6. Broaden the application of bioinformatics.
7. Construct a program for collection of necessary information required for the economic development of India.

Future strategies had also been proposed in this policy to maintain a sustainable bioinformatics industry in India as shown below:

1. Promote research and development in bioinformatics.
2. Create a powerful bioinformatics resource nationwide.
3. Encourage the establishment of bioinformatics entrepreneurship.

In conclusion, the Government of India has successfully fulfilled the goals of developing, improving and eventually maintaining the bioinformatics industry in India. The government's strategies have benefited the bioinformatics activities carried out by the academic institutions as well as the private sectors. Thus, it is crucial to have collaboration between the government and private sectors to achieve the goals and objectives.

2.2 Government of Malaysia's Bioinformatics Policies

Bioinformatics was first introduced to Malaysia in early 1990s by offering computational biology courses and workshop (29). However, due to the emergence of modern biotechnology particularly fields of Genomics, Computational work is required to solve the biological problems such as the storage of biological data into database. Despite the failure of BioValley project, an initiative to set up biotechnology hub and recruit foreign research experts which was launched in May 2003, It has become one of the key fields for biotechnology development which was included in the Category of Biotechnology for Wealth Creation of Ninth Malaysia Plan 2006-2010 announced on 31 March 2006 (1,6). Together with other significant biotechnology fields such as Agriculture, Healthcare and Industrial Biotechnology, several strategies were outlined to strengthen the Bioinformatics industry:

1. **Development of skilled professionals**
   Bioinformatics education is offered at undergraduate and graduate level at public as well as private institution such as Universiti Malaya (UM), Universiti Teknologi Malaysia (UTM), and Multimedia University (MMU) (6,19,32,36). A career opportunity on bioinformatics is also created to attract talents to develop this field in Malaysia.
2. **Enhancement of Research and Development**
   Bioinformatics research is crucial and is generally conducted by academic institution and not-for-profit research organization. The government of Malaysia plays a key role in funding and enhancing the research and development.
3. **Setting up the infrastructure and facilities**
   Bioinformatics laboratories and facilities are to be set up to provide bioinformaticians the necessary resources, equipments and environment to conduct their relevant research. One of the most remarkable government-based research facilities in Malaysia is Malaysia Genome Institute (MGI) in affiliation with the Universiti Kebangsaan Malaysia (UKM). The research centre is governed by Ministry of Science, Technology and Innovation and has advanced facilities capable of doing wet lab and dry lab.
4. **Participation of Private sectors**
   Local private bioinformatics companies are encouraged to collaborate with the government to facilitate the growth of the field. BioNexus, part of the National Biotechnology policy was promoted to private sectors who emphasize on research and development whether they are in the stage of commercialization. The BioNexus status companies are provided with some benefits such as tax breaks and matching grants and thus attracting more private sectors to have a vision to become world class biotechnology companies and simultaneously the enhancement of bioinformatics industry in Malaysia.

Bioinformatics in Malaysia is currently governed by the Ministry of Science, Technology and Innovation (MOSTI) (17). In order to promote this exciting field to the public, MOSTI has reported The Malaysian Technology roadmap for Bioinformatics in 2007 to accelerate the development of bioinformatics in Malaysia. The technology roadmap was finalized after regular planning and meeting of the prominent Malaysian bioinformatics experts. MIMOS Berhad (Malaysian Institute of Microelectronic Systems Berhad, strategic agency under purview of the MOSTI) has conducted a series of workshops with workshop facilitators to formulate the strategies for finalizing the Roadmap project.

Much of work has been done to finalize the Technology Roadmap. Some of the prominent local bioinformatics experts from Universities and Private Sectors are invited to participate in the prioritization of the proposal. The milestones of the prioritization process are:

1. **Planning**
   Subsequent milestones were planned accordingly before constructing the roadmap.
2. **Pre-Workshop Meeting and Bioinformatics Workshop Attendance**
   Meeting was carried out regularly to draft the roadmap, discuss and prepare for the following bioinformatics workshop. Areas of Domains were determined during the final workshop.
3. **Group Facilitators Meeting**
   Research areas in the proposed roadmap were further discussed and expanded. Deadline of the milestones was also decided prior to release of the roadmap.
4. **Program Prioritization and Final Meeting**
   The project proposal was reviewed and prioritized before finalization.
5. **Submission**
   The roadmap was ready to be submitted for publication.

Six domains in bioinformatics were developed during the workshops which are to be focused:

1. Governance
2. Common Enabling Tools
3. Bioinformatics Applications
4. Systems Biology
5. Structural Bioinformatics
6. Molecular Bioinformatics

The Governance (Domain #1) plays an important role in monitoring the overall bioinformatics industry in the country. Their main task involves implementing various policies on bioinformatics such as intellectual property policy and accounting policy as well as providing education and training to researchers in the field. Biotechnology and commercialization database is set up for easy access by the investors to locate the biotechnology companies and identify the research and development projects for investment and collaboration. National Bioinformatics Resources Centre is also built up to store the country's resource data and the resources information can be shared by members who have the access right to the center. Besides, specialized biological grids and the Malaysian Integrated Bioinformation System (MyBIS) are established to store the particular biological data. These biological data can be easily retrieved by the researcher to conduct their research more effectively.

In conclusion, The Government of Malaysia has been putting in a lot of effort to vitalize the bioinformatics industry in the country. However, due to the lack of highly skilled experts and insufficient training of new bioinformaticians, the development of the industry is far behind the timeline to become well known to the globe and is unable to compete with other countries interested in growing the field as well. Thus, more work needs to be carried out to achieve the goal.

3.0 Bioinformatics Education

Education in bioinformatics undergoes a drastic change since peoples realize the importance of the multidisciplinary field that encompassing biology, mathematics and computer science. From casual self-enriching courses (workshop, training, certificate) to structured degree programs (undergraduate, master, doctorate) shows that the challenges in teaching bioinformatics is trying to fulfill the breadth of knowledge created by the fusion of multidisciplinary areas (24). The first Workshop on Education in Bioinformatics (WEB) was launched at the International Conference on Intelligent Systems for Molecular Biology (ISMB) meeting in Copenhagen in 2001. WEB meeting provides a forum for bioinformatics educators to discuss relevant issues. Early WEB meeting focused on bioinformatics degree and training programs. Later meetings addressed a wider range of issues including education in bioinformatics for biologists (24).
Advances in bioinformatics are possible only with the highly skilled manpower and active collaboration of specialists from diverse field such as biology, computer science, mathematics, statistics and related sciences. So, proper planned education for bioinformatics is important if we want to develop a successful bioinformatics industry.

3.1 Bioinformatics Education in India

The Department of Biotechnology (DBT) has played a key role in the advent of bioinformatics in India by establish a nationwide bioinformatics network. The DBT initiated a program on bioinformatics in 1986 called the Biotechnology Information System Network (BTISnet). BTISnet promoted the creation of a valuable database, software tools, and infrastructure facilities. BTisnet now comprises 155 Bioinformatics centers spread across the country. A North East Bioinformatics network (NEBInet) has been specially designed for North Eastern states of India to speed up growth in the region because more than 25 of these centers are located in that region. NEBInet is to promote communication among the scientific community, sharing of information and help in initiating collaborative R&D activities in various fields of life sciences. There are more than 80 institutions of the country have been included under the BTISnet by creating Bioinformatics Infrastructure Facilities (BIF) for Biology Teaching through Bioinformatics (BTBI).

The scheme is designed to expose teachers and students to the real-world of science and the use of bioinformatics for solving hard core biological problems and networked through high speed internet connectivity (12, 28). There are six Centres of Excellence (CoE) in Bioinformatics that established in six leading universities. These CoEs are located at Bose Institute, Kolkatta; IISc, Bangalore; JNU, New Delhi; MKU, Madurai; University of Pune, Pune; and IIT, Delhi. These CoEs undertake advanced research in bioinformatics, provide PhD and postdoctoral training, develop new solutions to support the Indian Bioinformatics industry and its academic institutions in India, help in solving complex biological problems, and retain required high-end manpower (12, 28). Several universities in India have established a network program on higher education and based on consortium basis. The objective of this network program is to share the expertise of teachers and the resources which are created by these universities, through video conferencing and virtual class room approaches. The CoEs are providing Master and PhD programs and the BTISnet centres have organized short-term training course for bioinformatics also (4, 28).

DBT was introduced a certification examination for professionals in the area of bioinformatics called Bioinformatics National Certification Examination (BINC). This exam is employs a three-tier system to evaluate the knowledge and skill of the candidates. All successful candidates are awarded certificates of proficiency in bioinformatics. DBT was launching the e-Library Consortium (DeLCON) in January 2009, which provided access to more than 900 journals for online access.

3.2 Bioinformatics Education in Malaysia

Bioinformatics initiatives in Malaysia began in the 1990s through individual initiatives within academia, offering introductory-level computational biology modules in seminars and workshops. Currently bioinformatics education in Malaysia encompasses undergraduate and postgraduate programs (23). Institutions of Higher Learning (IHLs) started offering bachelor degrees in Bioinformatics include public universities such as Universiti Malaya (UM), Universiti Kebangsaan Malaysia (UKM) and the Universiti Teknologi Malaysia (UTM), as well as private universities, including Management and Science University and Selangor Industrial University. On the postgraduate level, these universities offer only research degrees, with the exception of the UM, which in 2008 began offering a master's degree in bioinformatics through coursework (23).

At first, bioinformatics was integrated into existing subjects such as genetics, molecular biology, computater science as introductory-level course to create awareness and exposure within the domain of each field. Subsequently, it gradually spins off from the traditional subjects and develops its own foundation by offering specialized module (undergraduate and postgraduate). Besides, Malaysia has established different bioinformatics networks and centers of excellence such as APBioNet (Asia Pacific Bioinformatics Network), NBBNet (National Biotechnology and Bioinformatics Network, upgrade into Genome Computing Centre), CGAT (Centre for Gene Analysis and Technology) and Malaysian Synergy Centre for Biology and Information Technology (MSC-BIT) to support the activities of bioinformatics in Malaysia, enhance research and accelerate productivity (23).

APBioNet aims to encourage cross border information exchange and collaborations in the bioinformatics field between the countries of the network. NBBnet aims to give R&D support to the researchers for conducting Biotechnology and Bioinformatics researches allow sharing of resources to using dedicated bioinformatics architecture (23, 31). The aim of this network is to EMASGRID, an NBBNet Grid initiative for Bioinformatics & Computational Biology, was established between UKM, USM, and UM and to harness the power of a centralized compute grid system operated by Sun Microsystems's Sun Grid Engine (SGE) (31).

4.0 Bioinformatics Economy

Apart from education and government policies, economics also plays a key factor in the success of bioinformatics in the country. Economics and market share is considered as the 'measure-stick' on the performance of a certain field. If there is less or no market for the field, it will not be developed extensively and will be remained as an academic field. Although bioinformatics is been around for some time (as early as 1960s), it rapidly being developed in the 80s and 90s and soon become a key element in any '-omics' researches (16). With the extensive research and development (R&D) especially on new drug development (with a low success rate), the bioinformatics plays an important key in the drug discovery using in-silico measures.

Bioinformatics rises and falls together with the pharmaceutical and biotechnology (especially in '-omics' field) and each of the industry cannot sustain well alone. With more than $1billion income from the top 125 pharmaceutical drugs (34), there is no chance of this field slowing down (so do bioinformatics). Biotechnology encapsulates all the bio-related field which includes bio-pharmaceutical and bioinformatics. We need to look into the development of biotechnology industry in order to glimpse at our targeted industry, bioinformatics.

4.1 Bioinformatics Economy in India

Bioinformatics in India are mainly based on B2B structure where it provides services to other business. More than 200 bioinformatics companies have been established in India to cater to the growing need in biotechnology industry.

Biotechnology is always rising in India especially from outsourcing from other countries. Figure 1.1 shows us that bio-pharmaceutical generated the highest revenue compared to the other segments in biotechnology. Although bioinformatics has the lowest revenue, its growing importance cannot be ignored.

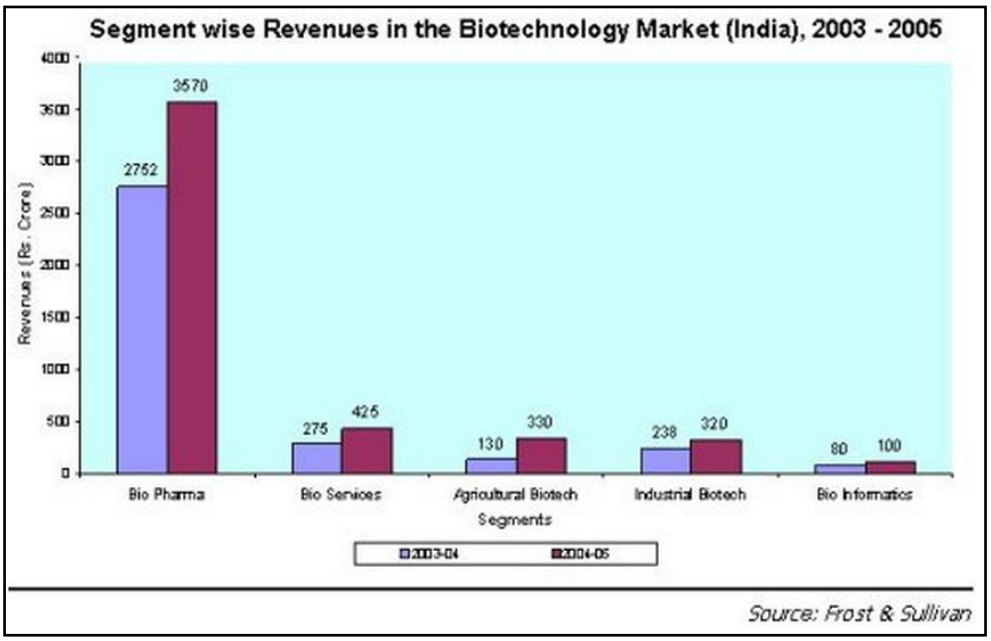

Figure 1.1: Revenues of Segments in Biotechnology in India (2003-2005)

With the aiding policies from government and increasing attention from outside India, investment on biotechnology in India grows from year to year (as shown in Figure 1.2). A steady investment allows biotechnology in India to flourish and prosper.

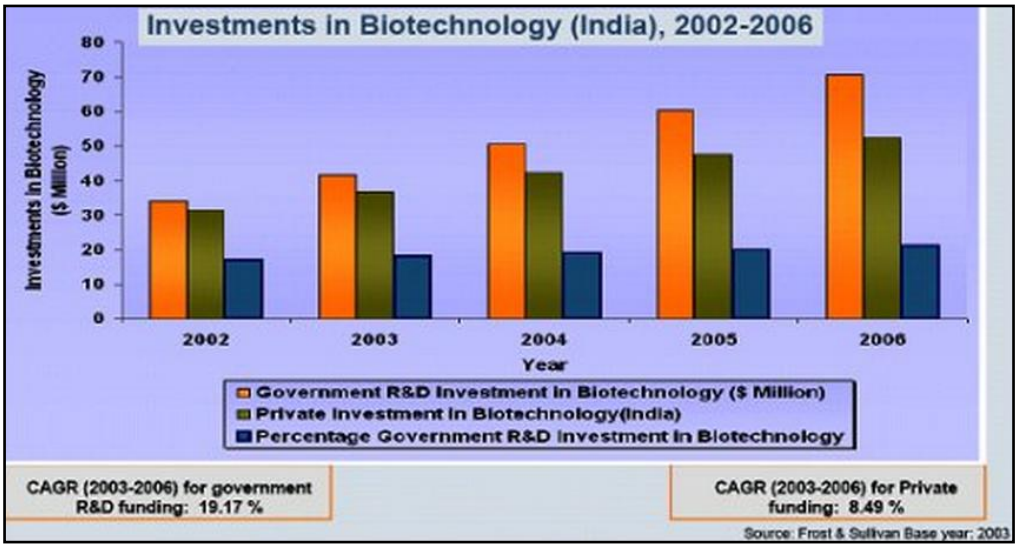

Figure 1.2: Investment in Biotechnology Industry in India (2002-2006)

Addition to that, there are a steady and increasing number of related graduate from the education sector to maintain the growing work force in biotechnology industry in India (as shown in Figure 1.3).

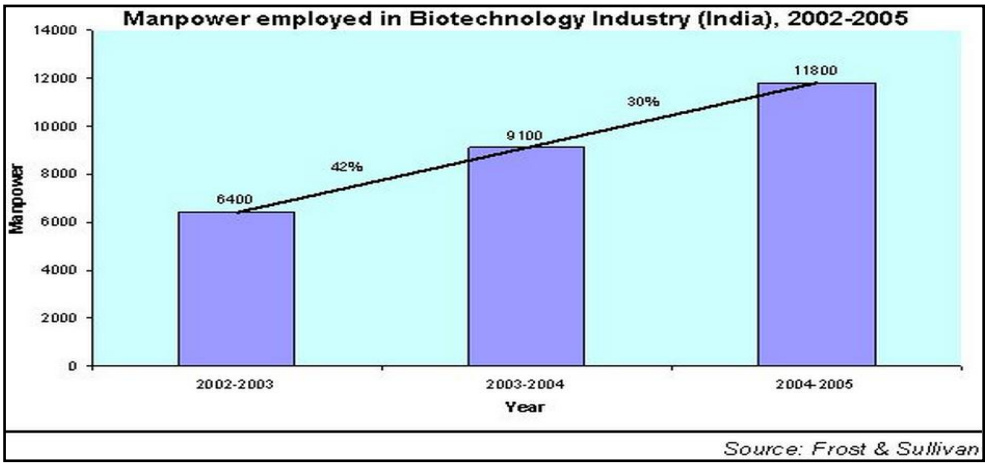

Figure 1.3: Manpower in Biotechnology Industry in India (2002-2005)

In 2009 to 2010, Indian BioPharma market contributed US$ 1.95 billion which accounted for 62% of the total revenue in biotechnology industry of India. This encourages the growth of bioinformatics in India.

BioInformatics is the smallest segment of the industry with about 2 percent segment share in the overall industry. It registered a 5 percent growth over 2008-09, clocking at Rs 2310 million in revenues last year as compared to US$ 48.62 million (Rs 2200 million) in FY 2008-09, when it recorded a growth of 16 percent. Domestic market contributes 68% of BioInformatics revenue (as shown in Figure 1.4).

The major BioInformatics companies in India include Strand Genomics, Ocimum Biosolutions, SysArris, CytoGenomics and Molecular Connections. These companies have come out with products that cater mainly to the needs of the pharmaceutical and biotechnology companies. Most of these companies are small and medium enterprises based at locations such as Bangalore, Hyderabad, Pune. The focus of the bioinformatics export is mainly on the services and tools.

Segment	2008-09		2009-10	
	Exports Rs Crore (US$ Million)	Percentage Share (%)	Exports Rs Crore (US$ Million)	Percentage Share (%)
BioPharma	7883 (1,740.78)	62	8829 (1,949.58)	54
BioServices	2062 (454.75)	95	2639 (582.88)	95
BioAgri	1413 (311.94)	4	1936 (427.61)	3
BioIndustrial	478 (105.56)	11	564 (124.56)	22
Bioinformatics	220 (48.58)	23	231 (51.02)	32
Total	12137 (2,680.63)	59	14199 (3,132.38)	53.04

Source: Association of Biotechnology led Enterprises (Able)

Figure 1.4: Biotech Industry Exports of different sectors in India during FY 2009-10

4.2 Bioinformatics Economy in Malaysia

Bioinformatics industry in Malaysia is not developing well as the perspective of Malaysia on bioinformatics is only as an analyzing tool to biotechnology. Malaysia encouraging biotechnology growth by allocation funds as shown in Figure 1.5

DEVELOPMENT EXPENDITURE AND ALLOCATION FOR BIOTECHNOLOGY, 2001-2010
(RM million)

Programme	*8MP Expenditure*	*9MP Allocation*
Research and Development (R & D)	**190.0**	**463.0**
Biotechnology R&D Initiatives	190.0	363.0
Biotechnology Commercialisation Fund	–	100.0
Biotechnology Acquisition Programme	**–**	**100.0**
Biotechnology Business Development	**216.8**	**529.8**
Technology & IP Management	69.9	100.0
Entrepreneurship Development	–	50.0
Agro-biotechnology Projects	46.9	79.8
Institutional Support and Equity	100.0	300.0
Biotechnology Infrastructure	**167.6**	**928.5**
Total	**574.4**	**2,021.3**

Source: Economic Planning Unit

Figure 1.5: Allocation for Biotechnology in Malaysia Plan 8th and 9th (15)

There are only one public listed bioinformatics company in Malaysia – Synamatix (and its subsidiary, Malaysian Genomics Resource Centre (MGRC)). In other companies, bioinformatics is just a division for R&D or the focus of the company is on mainly on IT (as show in Figure 1.6).

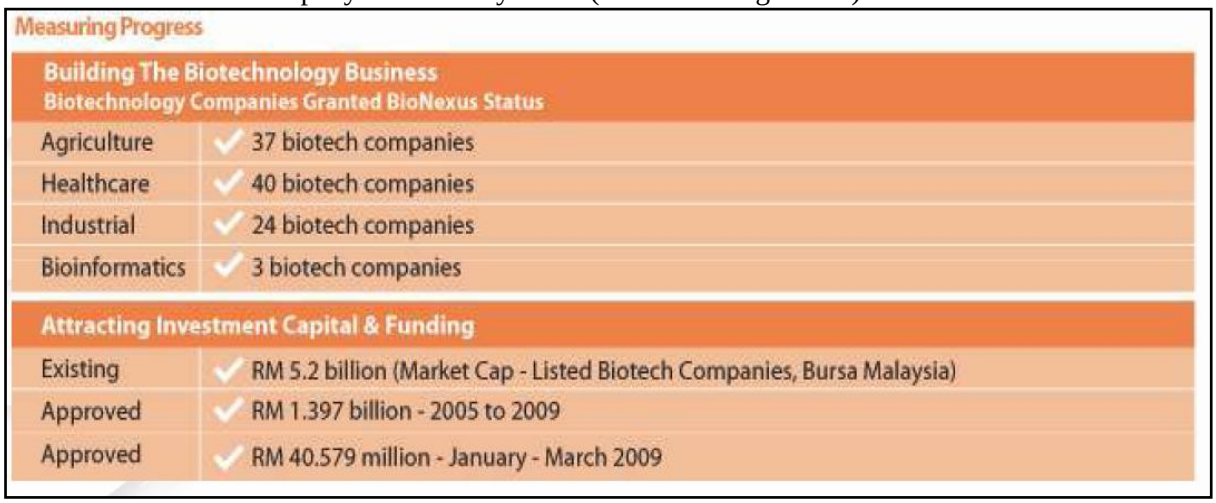

Figure 1.6 The Progress of Biotechnology in Malaysia in 2009 (17)

Figure 1.7 shows a low focus in bioinformatics field but it will surely grow.

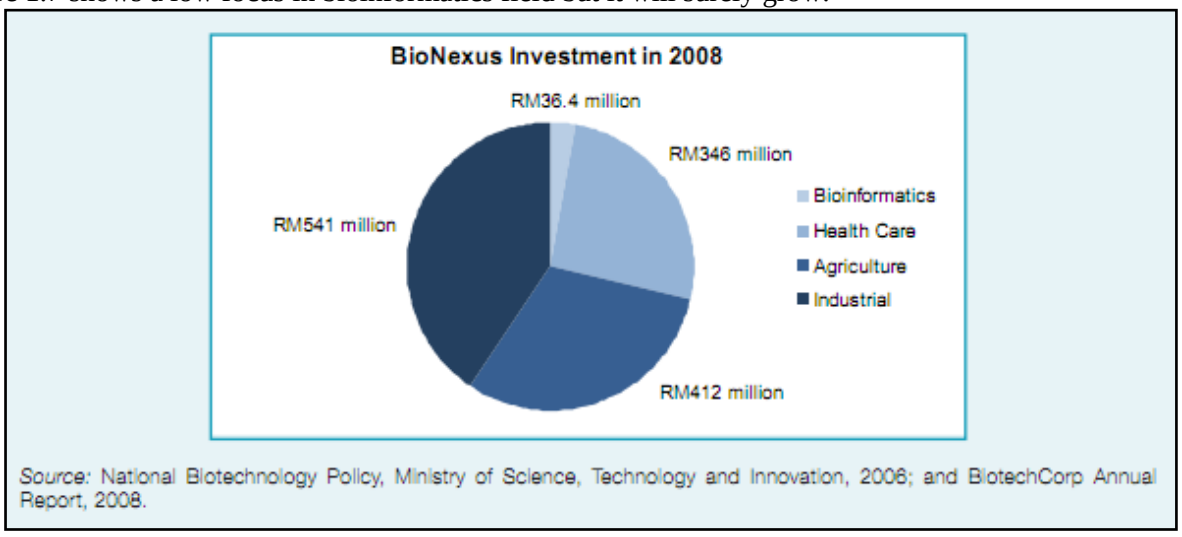

Figure 1.7 BioNexus Investment in 2008 in Malaysia (7)

Although it is changing with increasing employment of bioinformaticians, this industry is still very academic and job vacancy is very limited (despite the growing number of graduates in bioinformatics). Bioinformatics is still regarded as a background process which continues to reduce its awareness.

5.0 Discussion and Recommendation

In terms of the biotechnology industry, the Government of Malaysia and India have differences in areas to be focused as well as research strength (15). However, both governments are similarly concerned about how the bioinformatics industry in their countries would be. Unfortunately, due to the fact that the Information Technology industry in Malaysia is weak, the development of bioinformatics industry has not been going smoothly. Besides, the lack of skilled bioinformaticians is also the major barrier to the development of bioinformatics industry. In comparison to India, research centers in Malaysia tend to have higher preference on research other than bioinformatics. Thus, the goal to set up the bioinformatics-focused research centre is not as promising as planned by the Government of Malaysia. Furthermore, most of the private sectors are not interested to invest in this industry. The liaison between the government and private sectors as well as the research institutes is also insufficient. Besides, the bioinformatics resources are yet immature to be harvested for providing large scale support for the significant research of other areas. Thus, more work has to be done to create a sustainable bioinformatics industry. In India, DBT play a major role in producing and maintaining expert and skilled bioinformatics researchers and knowledge workers. Huge networks between institutions, university and centre of excellence have been established in order to support the education in bioinformatics. These networks are important because it allow information and technology able to share between different bodies so that researchers or bioinformaticians are keep track with the latest skills in this field.

For Malaysia to become a success latecomer in this field, similar structure and bioinformatics network have to be establish. An education roadmap and committee should be set up to identify the bioinformatics education framework at various levels (secondary schools, certificate, diploma, college (undergraduate) degree, and postgraduate degree) in line with the identified key thrust areas in research and development. The committee should comprise of key personnel from different areas such as academic, government and industry and they are responsible for review and quality assessment all the programs that offer by different institutions or university (23). Due to the nature of bioinformatics, teaching bioinformatics will require an educator with in-depth knowledge of different components in bioinformatics. Malaysia's local industry and academic research were in the past affected by the lack of available human capital in the field (23). Conducting bioinformatics courses without the necessary depth will produce bioinformatics technicians rather than bioinformatics scientists (21,28). So, persistent and continuing education for bioinformatics at all levels (formal, informal, face-to-face, distance learning, and short-term training and rigorous long-term academic programs) have to be establish in order to allow bioinformaticians always familiar with new bioinformatics' technology (27). Besides, invite trainers from well-known bioinformatics institutes or send researchers to international training centre will allow local bioinformaticians expose to different level of education.

Aside from formal education (degree level), short courses, workshop or seminar that provides the problem-solving method for a specific problem are important in order to let bioinformaticians to acquire the knowledge from different fields. Certification programs for bioinformatics skill just like certification programs in IT industry is recommended to allow bioinformatician to upgrade by themselves and become more competent without going through a formal degree programs. In order to develop bioinformatics education in Malaysia, policies and strategies have to be properly planning in order to produces qualified bioinformaticians. Currently, bioinformatics-related degree programs have been offered by many universities in Malaysia. Bioinformaticians is constantly increased from year to year so human capital for bioinformatics market in Malaysia will have enough of supply in the future. Both Malaysia and India started in the biotechnology rather late compared to other developed countries but India has the competitive edge compared to Malaysia. India has been one of the primary targets for outsourcing for IT for awhile which makes them excels in IT compared to Malaysia. Bioinformatics which part IT makes India faster and easier to develop.

The attention and awareness of India as an outsourced country encourage and ease other countries to invest on other industry such as the biotechnology and bio-pharmaceutical. Pharmaceutical is a very profitable industry but in order to discovery new drugs a costly and long process must be done. However with help of bioinformatics, in-silico methods such as simulation can be used to facilitate novel drug processing. In Malaysia, bioinformatics started slowly as biotechnology focus primarily in wet lab processes without regard to in-silico process. Bioinformatics is just regarded as an analysis tool and not a key element in a research. Although there are changes of perspective to bioinformatics, the delay cost it to be left out compared to other countries. From an economic perspective, Malaysia lacks the market share to support the growth of bioinformatics industry. One of the main reasons is the awareness of the bioinformatics industry. Many regard bioinformatics is just a tool and software to analyze the data. In major reports or policies, bioinformatics is often neglected and regard as subset of biotechnology which further lowers the awareness. Even though reports such as from Biotech Corp mentioned about bioinformatics, it is still just regarded as a support tool rather than a new source of income. Malaysia relies on available bioinformatics tools and do not take the initiative to develop or customize a bioinformatics tools. Through the availability of the new tools, Malaysia can be a contributor rather than a passive user.

Addition to that, through the experience and knowledge in development and utilizing bioinformatics tools Malaysia could be the service provider of bioinformatics service. Companies with bioinformatics as a sub-division of biotechnology should be expanded as a full division or a new company (or sub-company) and provide the services to other companies (as well as other countries) as done by India.

In summary, in order to vitalize the bioinformatics industry in Malaysia, bioinformatics advanced countries such as India shall be used as a study model to understand the key steps in developing a national as well as global-level bioinformatics industry in the ways of gaining essential knowledge, technology and skilled personnel for the development of bioinformatics-based economy and education. With the adequate technology, national collaboration and sufficient number of bioinformatics experts, it is believed that Malaysia is able to become one of the leaders in bioinformatics industry.

References

1. Christ College Rajkot. Working on Bioinformatics. [Online] available: http://www.christcollegerajkot.edu.in/Download/Indian%20research%20institutes%20working%20on%20Bioinformatics.pdf
2. Cyranoski D. (2005). Malaysian Biotechnology: The Valley of Ghosts. Nature, 436, 620–621.

3. Department of Biotechnology, Ministry of Science and Technology, Government of India (2004). Bioinformatics Policy of India (BPI – 2004). [Online] available: http://btisnet.gov.in/writereaddata/12173386811_draftpolicy.doc
4. Department of Biotechnology, Ministry of Science and Technology, Government of India. Annual report 2009-2010. [Online] available: http://www.dst.gov.in/about_us/ar09-10/annual_report_2009-10.pdf
5. Department of Industries and Commerce, Government of Andhra Pradesh (2001). Biotechnology Policy 2001. [Online] available: http://www.aponline.gov.in/quick%20links/industrial%20policy/biotechnologypolicy.pdf
6. Economic Planning Unit, Prime Minister's Department, Government of Malaysia (2006). Ninth Malaysia Plan 2006 – 2010. (Chapter 6). [Online] available: http://www.epu.gov.my/html/themes/epu/html/rm9/english/Chapter6.pdf
7. Economic Planning Unit, Prime Minister's Department, Government of Malaysia. (2009). Knowledge Content in Key Economic Sectors in Malaysia Phase II, Section 4 – Knowledge Content in Biotechnology- Related Firms. Kuala Lumpur: Percetakan Nasional Malaysia Berhad. [Online] available: http://epu.gov.my/web/guest/265
8. Eisenhaber F., Kwoh C-K, Ng S-K, Sung W-K & Wong L. (2009). Brief Overview of Bioinformatics Activities in Singapore. PLoS Computational Biology, 5(9)**,** e1000508
9. Ghandi, B. M. Biotechnology: The Indian Scenario for Research, Capacity Building and Regulatory Framework. [Online] available: http://swissbiotech.com/php5/aa2/UserFiles/File/31605_GHANDI-Zurich-BMG.pdf
10. Government of Karnataka. The Millennium Biotech Policy. [Online] available: http://www.bangaloreitbt.in/worddocument/pdf/Gos/biopolicy.pd
11. Khurana, G. India Biotechnology Sector. [Online] available: http://www.indialawoffices.com/pdf/biotechnology.pdf
12. Krishnan, R.T., Gupta, A. & Matta V. (2003). Biotechnology & Bioinformatics: Can India Emulate the Software Success Story? Paper presented at Workshop on the Indian Development Experience, Department of Management Studies, Indian Institute of Science, Bangalore, March 3-5.
13. Kulkarni, M. India, Biotechnology and Patents: Industry Perspective. [Online] available: http://bicpu.edu.in/ipr_ppt/15/kulkarni.pdf
14. Langer E. (2008). India's Bioinformatics Industry: An Engine for Global Growth. India Today, 20-24. [Online] available: http://www.bioplanassociates.com/publications/articles/Bioinformatics0708India.pdf
15. Mahmood I. M. (2009). Case Study: The National Biotech Policy, Workshop: Assessment of Industry Needs for a Sustainable & Productive Science & Technology Policy, 22 – 26 June 2009. [Online] available: http://istic-unesco.org/meetingdoc/Case%20Study%20-%20The%20National%20Biotech%20Policy.pdf
16. Mapari J., Industry Analyst, Healthcare Practice, Frost & Sullivan's Study on Bioinformatics (30th Nov 2006). [Online] available: http://www.frost.com/prod/servlet/market-insight-top.pag?Src=RSS&docid=88398731
17. Ministry of Science, Technology and Innovation, Government of Malaysia (2007). The Malaysian Technology Roadmap for Bioinformatics. [Online] available: http://www.mosti.gov.my/mosti/images/pdf/grid-computing.pdf
18. Moreno E., Lomonte B. & Gutie´rrez J.M. (2008). Computational Biology in Costa Rica: The Role of a Small Country in the Global Context of Bioinformatics. PLoS Computational Biology, 4, e1000040.
19. Multimedia University Bioinformatics Program. [Online] available: http://www.mmu.edu.my/index.php?req=5
20. Neshich G. (2007). Computational Biology in Brazil. PLoS Computational Biology, 3, e185.
21. Palacios R. & Collado-Vides J. (2007). Development of Genomic Sciences in Mexico: A Good Start and a Long Way to Go. PLoS Computational Biology, 3, e143.
22. Panacea Biotec (2006). Conference on Biotechnology in India: Ushering in a New Revolution. [Online] available: http://www.panacea- biotec.com/PanaceaBiotec%28OLD%29/conferences/Background_paper.pdf
23. Pearson W.R. (2001). Training for bioinformatics and computational biology. Bioinformatics 17, 761-762.
24. Pevzner, P.A. (2004). Educating biologists in the 21st century: bioinformatics scientists versus bioinformatics technicians. Bioinformatics, 20, 2159-2161.
25. Pons T., Montero L.A. & Febles J.P. (2007). Computational Biology in Cuba: An Opportunity to Promote Science in a Developing Country. PLoS Computational Biology, 3, e227.
26. Ranganathan S. (2005). Bioinformatics Education—Perspectives and Challenges. PLoS Computational Biology, 1(6), e52.
27. Sawant D. (2008). Life sciences education in India. In: Langer ES, editor. Advances in Biopharmaceutical Technology in India. Rockville, MD: BioPlan Associates.
28. Shamsir M.S. et al (2006). Educating the educators: Incorporating bioinformatics into biological science education in Malaysia. Presentation in National Biology Conference, UTM.
29. Takeuchi K., Nomura M. (2008). IT-Based Industrial Development in India and Trends in Human Resources Development with the Aim of Realizing a Knowledge-Based Society. Science and Technology Trends, 36-51
30. Thampi S.M., Dept of CSE, LBS College of Engineering, Bioinformatics notes. [Online] available: http://arxiv.org/ftp/arxiv/papers/0911/0911.4230.pdf
31. Tongsima W., Tongsima S. & Palittapongarnpim P. (2008). Outlook on Thailand's Genomics and Computational Biology Research and Development. PLoS Computational Biology, 4, e1000115.
32. Universiti Malaya Bioinformatics Program. [Online] available: http://www.um.edu.my/mainpage.php?um=bW9kdWxlPU1ha2x1bWF0JmthdGVnb3JpPTgyJmlkPTU1NSZwYXBhcj0x
33. Universiti Teknologi Malaysia Bioinformatics Program. [Online] available: http://webs.cs.utm.my/bioinformatics/#
34. URCH Publishing. Pharmaceutical Market Trends, 2010 -2014. [Online] available: http://www.urchpublishing.com/publications/market_trends/pharmaceutical_market_trends_2008_-_2012.html
35. Workshop on Education in Bioinformatics. International Society for Computational Biology. [Online] available: http://www.iscb.org/ismb-mm/media-ismb2009/materials-workshop09
36. Zeti A.M.H., Shamsir M.S., Tajul-Arifin K., Merican A.F., Mohamed R., Nathan S., Mahadi N.M., Napis S., Tan T.W. (2009). Bioinformatics in Malaysia: Hope, Initiative, Effort, Reality, and Challenges. PLoS Computational Biology, 5(8), e1000457.