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COMMERCIALIZATION OF BIOINFORMATICS AND BIOTECHNOLOGY PRODUCTS IN MALAYSIA: AN OVERVIEW

Cheong Leng SAN *Bioinformatics Division, Institute of Biological Science University of Malaya 50603 Kuala Lumpur, Malaysia lengsancheong@yahoo.com*

Priyah NARAYANASAMY *Bioinformatics Division, Institute of Biological Science University of Malaya 50603 Kuala Lumpur, Malaysia priyah0386@gmail.com*

Abdul Rahman Ahmad DAHLAN *Department of Information Systems Kulliyyah of Information and Communication Technology International Islamic University arad@iium.edu.my*

ABSTRACT

Commercialization of Research and Development (R&D) Products, particularly bioinformatics and biotechnology has always being overlooked by the industry and academic sectors. There are some misleading concepts that triggers both these sectors that commercialization of R&D products is not as part of their responsibilities. This is because the knowledge of R&D products emerges from academic world while commercialization involves business oriented field. This article is produced based on reference of various papers on commercialization of R&D products in Malaysia. Highlights of this article is to enlighten the current efforts and challenges faced by Malaysia in promoting R&D, specifically bioinformatics and biotechnology products, and produce thoughtful

discussion in improving the current effort.

KEY WORDS *Bioinformatics, Biotechnology, Research &Development, Commercialization, Collaboration, Innovation, Malaysia.*

JEL CODES *O13, O44, Q16.*

1. INTRODUCTION

Biotechnology can be best defined as a technology focus on biology usage in agriculture, food science, and medicine ("*The Convention on Biological Diversity*", 2006). Information technology carries the definition of an industry that uses computers, networking, software programming, and other tools and processes to store, process, retrieve, transmit, and protect information. As per illustrated by Figure 1, bioinformatics can be defined as an industry that uses information technology tools to study biotechnology data or findings. Therefore, biotechnology and bioinformatics field are dependent on each other. Malaysia has been working on this industry for more than two decades. There are rapid development observed in these two industries and it is a good prognosis for Malaysia to excel in Research and Development area (R&D). R&D is an on-going investment and there is no limitation for the achievement. Malaysia involvement and investment in R&D, particularly biotechnology, stated with agricultural and then developed until it merges with information technology to initiates bioinformatics which makes the R&D industry more realistic and reliable.

Innovating Malaysia (n.d.) states that even though open innovation has been a fifty years concept, only recently this concept was fully understood by government agencies and firms. This awareness on open innovation results on the registration of Malaysia as a member of National Biotechnology and Bioinformatics Network (NBBNet) in the year of 1999. Through this association, a Workbench named WebANGIS (MANGIS) was established to facilitate a nationwide network which supports bioinformatics and biotechnology researches (Zeti et al. 2009). Other than that, Malaysia also a participant of Asia-Pacific Advanced Network (APAN) which works on the National Research and Education Networks (NRENs) in Asia. This network connects Asia to the United States of America through Transpac Project and to Europe through Trans-Eurasia Information Network (TEIN) (Ranganathan, S., 2005). This network creates borderless worlds which create opportunities for developing nations such as Malaysia to exchange information and be more innovative in the R&D area.

The most recent APAN meeting, APAN-33rd meeting was held in Thailand from 13th February 2012 until 17th February 2012. Several workshops, paper presentation and exchange of knowledge was organised through this community network (http://www.apan.net/meetings/ChiangMai2012).

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Figure 1: Correlation between bioinformatics and biotechnology.

Commercialization process in a research field starts from the recognition of opportunities, then continue with basic and applied research with creativity which leads to innovation. Basically the final stage in commercialization is entrepreneurship and commercialization (Farsi, J.Y. & Talebi, K., 2009).

2. MALAYSIA'S CURRENT EFFORT IN BIOINFORMATICS AND BIOTECHNOLOGY

2.1 Government Policies

The progress of science and technology in Malaysia went through different phases. The First National Science and Technology Policy (NSTP1) were formulated in 1986 with the purpose of outlining a framework for science and technology development in Malaysia. NSTP1 aims to ensure the achievement of continuous scientific and technological development to accelerate economic growth, industrial development and creating high-tech (advanced) society (Chandran et al., 2005).

Malaysia Plan which is structured in a 5 years basis is designed to achieve the nation's vision which is on par with globalisation. As such the National Science and Technology Policy were incorporated into the Fifth Malaysia Plan (1986-1990). In 1991, The National Action Plan for Industrial Technology Development (TAP) was launched to specifically promote industrial technological development. However, STP1 and TAP was incapable of commercializing research outputs and lacked the techno-entrepreneurship (Chandran & Wong, 2011).

The Sixth Malaysia Plan (1991-1995) focuses on the market-orientated commercialization. Collaboration between government and private sectors are initialized to expand the R&D sector by providing basic infrastructure incentives and supporting services. The Seventh, Eighth and Ninth Malaysia Plan subsequently focus on economic growth and competitiveness by increasing productivity. One decade journey in R&D sector lead to the review of the science and technology policy in the year 2000 and subsequently the Second National Science and Technology Policy (STP II) was launched in the year 2003. The implementation of this plan is centralised by joint venture of government, industry, universities and public research institutions together in a synergistic partnership (Zain, 2010).

Based on The Ninth Malaysia Plan, the National Biotechnology Policy was launched in 2005 to increase creation and innovation in the agriculture industry through biotechnology. The National Biotechnology Division (BIOTEK) under the Ministry of Science, Technology and Innovation (MOSTI) is responsible in enforcing the National Biotechnology Policy. There are nine thrusts included the development in different biotechnology field, human capital, financial infrastructure, strategy positioning, and government commitment. Biotechnology creates a sustainable bio-based economy. The policy is implemented in academic research, transfer of technology and industrial adoption. It envisions that biotechnology will be a new economic engine for Malaysia, enhancing the nation's prosperity and well-being. Through the policy, the government has established BiotechCorp (Malaysian Biotechnology Corporation), a one-stop centre for biotechnology; and three national R&D institutes, namely the Malaysia Agro-Biotechnology Institute (ABI), Institute of Pharmaceutical and Nutraceutical Malaysia (IFNM) and Malaysia Genome Institute (GenoMalaysia). The policy also allows the government to

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provide various fiscal and tax incentives to biotechnology companies ("*Overview: Malaysian Agricultural Biotechnology*", 2009).

2.2 Government Schemes and Policy Mechanisms

Various initiatives and mechanisms have been introduced by the Government to promote the development of biotechnology and bioinformatics. One of such effort is providing grants and loans as well as incentives to promote and support research into the public sector, and encourage more private sector investment in new technologies. Ministry of Science, Technology and Innovation (MOSTI), Malaysian Technology Development Corporation (MTDC), and National Biotechnology Directorate (NBD) are some of the various governmental bodies which take lead in structuring the schemes for fund allocation. These agencies each have different objective, sector and activity focus (Krishna, 2006).

Under MOSTI, the Industrial Research and Development Grant Scheme (IGS) was established with an initial allocation of RM100 million to promote market-oriented R&D and technology development projects involving the collaboration of the private sector, universities and research institutions. Based on Seventh Malaysia Plan (1996), the Commercialization of Research and Development Fund (CRDF) and Technology Acquisition Funds (TAF) were launched in 1997 and managed by Malaysian Technology Development Corporation (MTDC) with allocations of RM63 million and RM 118 million respectively. The allocation increases in the Eighth and Ninth Malaysia Plan to RM110 million and RM 250 million respectively. The objective is to accelerate and upgrade the development of indigenous technological capabilities, especially CRDF focuses on the commercialization of R&D findings undertaken by local universities and research institutions as well as companies and individual researchers and inventors.

According to Malaysian Science & Technology Indicators 2008 Report (2008), several new schemes were introduced by the Malaysian Government in order to achieve the mission to harness Science, Technology and Innovation included the Malaysian Life Sciences Capital Fund (MLSCF), Biotechnology R&D Grant Scheme, ScienceFund, TechnoFund and Spectrum Research Collaboration Program (SRCP). In the Ninth Malaysia Plan, these funding are available and support the Research, Development and Commercialization (R&D&C) programs in different phases: creation, research, development, and commercialization (Fund Management Unit, MOSTI, n.d.). Table 1 showed the available grant schemes provided for Biotechnology field in Malaysia.

Agency	Type of Scheme	Priority Areas
Ministry of Science, Technology and Innovation (MOSTI)	Intensification of Research in Priority Areas Grant Scheme (IRPA)	R&D activities in line with national R&D priority areas
	Industry Research & Development Grant Scheme	R&D in priority technology areas including biotechnology with prospects of

	(IGS)	commercialization
	Human Resource Development Fund (HRDF)	Hands-on S&T training for researchers & officers at local research institutions & universities
	ScienceFund	Carry out R&D projects that can acquire and generate new knowledge in strategic basic and applied sciences
	TechnoFund • Pre-commercialization • IP Acquisition	Foster greater collaboration between Malaysian private entities and government research institutions of higher learning
Malaysian Technology Development Corporation (MTDC)	Technology Acquisition Fund (TAF)	Acquisition of technology & licensing procurement; Acquisition of patent rights, prototypes & design
	Commersialisation of Research & Development Fund (CRDF)	Market survey & research; product or process design & development; standards & regulatory compliance & IP protection; demonstration of technology
	Business Growth Fund (BGF)	Support and encourage entrepreneurship and creation of new strategic businesses that are important and potentially scalable, and the funding of supporting companies within a technology eco-system
	Malaysian Life Sciences Capital Fund (MLSCF)	Biotechnology, pharmaceuticals, diagnostics, devices, human healthcare and related medical technologies, nutraceuticals and wellness, agricultural biotechnology, and industrial biotechnology (biomaterials/bioprocesses)
Multimedia Development Corporation (MDC)	Multimedia Super Corridor Research & Development Grant Scheme (MGS)	R&D in products & services across multimedia value chain & the MSC application
Malaysian Institute Microelectronic	Demonstrator Application Grant	IT & multimedia technology proposals & local

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System (MIMOS)	Scheme (DAGS)	content with identified beneficiaries
National Biotechnology Directorate (NBD)	Biotechnology R&D Grant Scheme	Research completed but still requires developmental research of data prior to commercialization i.e. scale-up of research findings to commercial level
Bank Pertanian Malaysia	Bank Pertanian Malaysia Fund for Food (BPM)	Domestic projects where at least 50% of total production is sold in domestic market; projects involving primary food production (using animal husbandry, agriculture cultivation, fisheries & biotechnology), integrated agriculture & processing and/or distribution of food
Malaysian Communications & Multimedia Commission (MCMC)	Spectrum Research Collaboration Programme (SRCP)	Promoting research collaboration between institutions of higher learning (IHL) and various other public and private sectors.
Malaysian Biotechnology Corporation (MBC)	Seeds Fund	To finance start-up costs in setting up biotech companies and assist towards the development &commercialization of biotechnology projects in line with the objectives of the National Biotechnology Policy
	R&D Matching Fund	To provide matching fund for R&D projects to develop new or improved products and/or processes and/or technologies.
	International Business Development Matching Fund	To provide matching fund for R&D projects to develop new or improved products and/or processes and/or technologies.

Table 1: Biotechnology Grant Schemes in Malaysia. (Source from Malaysian Biotechnology Information Centre (MABiC), Malaysian Science & Technology Indicators 2008 Report)

In an effort to commercialize research outcomes, the techno-infrastructure was strengthened by providing facilities to the private sector. Techno-infrastructures such as technology incubator centres were collaboratively set-up by Malaysian Technology Development Corporation (MTDC) and Technology Park Malaysia (TPM). MTDC also collaborates with local institutions of higher learning (IHL) to set up

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incubation parks near the IHL to assist their start up ventures such as UPM-MTDC Technology Centre, UTM–MTDC Technology Centre and UKM-MTDC (Krishna, 2006). Establishment of TPM provides infrastructure services for technological innovation and R&D which enables knowledge based enterprises to grow and compete in the global marketplace. On top of that, it also facilitates government and private sectors smart partnerships in technology development.

In addition, Bio-XCell in Iskandar Johor is a biotechnology park is a dedicated, purpose-built space and facilities for biotechnology companies. Bio-XCell has attracted substantial Foreign Direct Investment (FDI) leading global players such as Biocon Ltd, Metabolic Explorer SA and Glycos Biotechnologies Inc. with a total approved investment of RM1.146 billion (approximately USD 370 million) (Italia, 2011).

BioNexus is a special status awarded to qualified international and Malaysian biotechnology companies. The status endows fiscal incentives, grants and other guarantees to assist growth. Since 2005, the BiotechCorp has facilitated the development of 207 BioNexus status companies in Malaysia with total approved investment of RM 2.118 billion. The BiotechCorp also provides a wide range of capacity building programs covering a variety of subjects to assist biotechnology entrepreneurs in managing their business locally and internationally (http://www.biotechcorp.com.my/).

The National Science and Research Council (NSRC) was proposed under Tenth Malaysia Plan to improve the governance of R&D, to have a move on S&T priorities through an effective network of all government research institutes and facilities and to monitor the impact of sectorial R&D productivity in the effective implementation of the government's plan for a high income economy (Pillai, 2011). This council which acts as an advisory body is comprised of high-level representatives from Ministries, Government Agencies, Universities, Industry and the Academy of Sciences and is supported by MOSTI.

2.3 Private Sectors

With the vast amounts of data and information being generated due to advance in myriad of technologies, Bioinformatics provides an important support function to manage, analysis, and distribute biological information derived from genome sequencing and functional analysis of research projects. In addition to become a new source of growth, bioinformatics is making significant contribution towards discoveries and biotechnology development. ICT platforms in research institutions including MIMOS, universities and the Multimedia Super Corridor (MSC) help in accelerating of the development of bioinformatics sector in Malaysia. In Ninth Malaysia Plan, the second phase of Malaysian Research and Education Network (MyREN) was initiated to enhance universities and research institutions, and industry with international linkages to increase collaboration efforts.

Although Malaysia has just started its journey in the field of bioinformatics (early 1990's), there are few bioinformatics companies which are doing well in this field. They are able to provide world class bioinformatics solutions ("*Bioinformatics for Malaysia*," 2008). Some of the companies are:

i. Synamatix

Founded in 2001- primary focus is on the research and development of customized bioinformatics and one of the first bioinformatics company to earn MSC status in Malaysia. Other than its focus on industry it also collaborates with educational institute to promote the growth of biotechnology and bioinformatics in Malaysia. One of such effort was done on January 2008 when Synamatix announced research collaboration on license of cutting- edge bioinformatics technology with University Malaysia Sabah's Biotechnology Research Institute (BRI).

ii. Malaysian Genomic Research Centre (MGRC)

Subsidiary of Synamatix- provides Contract Genomics Services, Sequencing Services, and Data and Access Services- one of the Bio Nexus Status Company. MGRC is a well based bioinformatics company which gain the trust of Malaysian Government to carry out research projects. One of such effort is involvement in MyGenome Project which was awarded by Ministry of Science, Technology and Innovation (MOSTI). MGRC has remained profitable and expected to produce revenue in the future. This can be clearly illustrated in the table below:

REVENUE COMPOSITION - 5 YEARS

	Genomics Data Access Services (RM'000)	Contract Genomics Services (RM'000)	Total Revenue (RM'000)
FY2011	4,800	7,346	12,146
FY2010	5,200	10,579	15,779
FY2009	4,800	12,256	17,056
FY2008	4,800	1,389	6,189
FY2007	2,000	13	2,013

Table 2: Revenue Composition- 5 years. (Source: Annual report of MGRC for year June 2011)

iii. Infovalley

Started in the year of 2000, with the aim of becoming the powerhouse of life sciences by providing rationale solutions and create socio-economy value in Malaysia. The main line of business for these companies relies on bioinformatics, biotechnology and medical informatics. One of its valuable inventions is digital autopsy services. Besides, Infovalley is one of the leaders in providing medical and forensic tools to customers around the world in addition to bioinformatics solutions. Association of this company with the nation's ICT lead Multimedia Development Corporation (MDeC) catalysts global marketing in high rate. Another wise move of Infovalley in the move of penetrate into global market is through association with world class companies such as Intel, Oracle, SGI, Illumina and GE Healthcare even from the beginning. Co-existence and co-branding had great a fundamental platform for the growth of infovalley (*Stories of Innovative Entrepreneurship*, 2009).

Development and achievement of these companies clearly indicates that Malaysia is moving the right way to commercialize bioinformatics and biotechnology products and services. Growth of bioinformatics industry will simultaneously trigger the growth of biotechnology industry as it works as a catalyst for the latter.

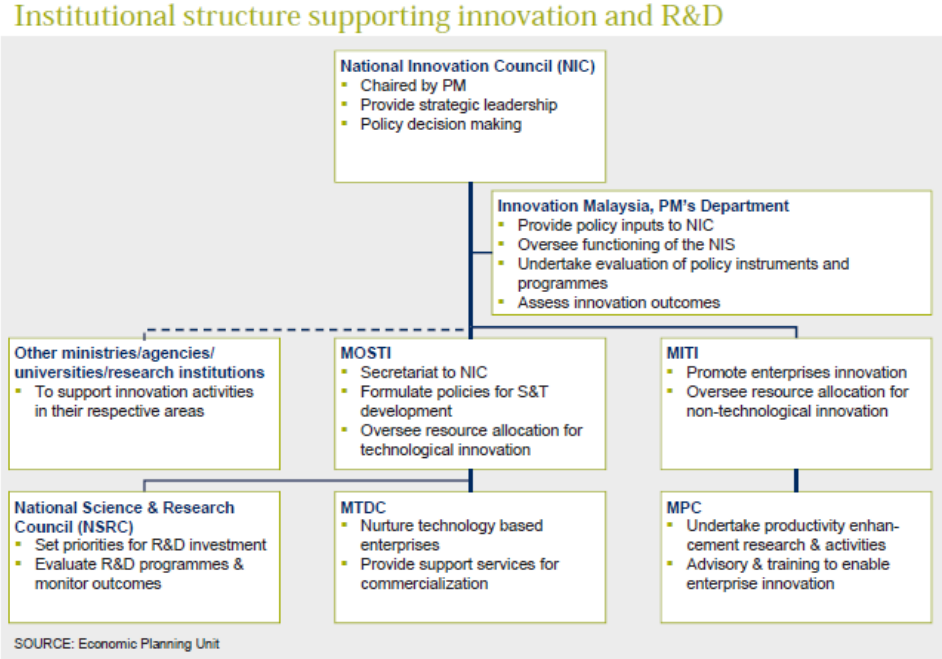

Figure 2: Institutional Structure Supporting Innovation and R&D (Source: Malaysia Tenth Plan)

2.4 Education

Education is the base for the establishment of any industry. It provides the knowledge and produces the expertise to commercialize an industry. Any new venture of an industry to a nation's market is technically based on the education frame of the nation. The same concept applies to bioinformatics and biotechnology industry. Currently, Malaysia's education system is leading towards research based knowledge to produce innovative products and services. As for bioinformatics, it serves as a bridge for connecting biology and information technology. Basically industries invest in a new area of business based on the educational growth as it is the source of expertise. In the year of 2006, four public universities are designated as research universities; namely University Sains Malaysia (USM), University Malaya (UM), University Putra Malaysia (UPM) and University Kebangsaan Malaysia (UKM). University Technology Malaysia (UTM) was designated as a research university in 2010. This certification was granted to the universities as a move to encourage and focus on research works. An additional of RM 100 million is allocated for each university for research, development and commercialization. There are twelve universities and colleges inclusive of UM, UPM and UKM offer Bioinformatics course at undergraduate and also higher level. Multidisciplinary criteria of this course attract various ranges of students who wish to apply their strength in a wide area. Crystal project was one of the efforts initiated

by UM in order to consolidate multidisciplinary research between life sciences and computational sciences. (http://educationmalaysia.blogspot.com)

2.5 Collaboration

The market-societal driven collaborative R&D commercialization model was introduced during the Third Islamic Economic Congress by University of Technology Malaysia in 2009. The relationship between universities, community and industry is vital for Malaysia's development. They need to learn from and collaborate with each other. Based on the model, universities play role in creating new knowledge and ideas in basic research. Applied research is being done collaboratively by academic institutions, such as universities, research agencies, and private sectors to do pilot study and simulation, and prototyping in development stage. Then it can be used to bring out new products in the market place in the collaboration with entrepreneurs and private sectors.

Besides, the openness to foreign technologies and to cross-border cooperation in R&D will increase the capacity of Malaysia to absorb and adapt technologies developed worldwide. International collaborations between Malaysia and foreign institutions help to build a foundation for a sustainable agricultural biotechnology industry. Some of Malaysia's local and foreign collaborative partners are shown in the Table 3 below.

Collaboration between	Field
SIRIM Berhad with Vinetech Sdn Bhd	The development of specialty vinegars such as pineapple vinegar, rambutan vinegar and Bario rice vinegar
J. Craig Venter Institute (JCVI) with Asiatic Centre for Genome Technology Sdn Bhd (ACGT)	The application of genome technology to improve oil palm and other crops
INTROP UPM with the Oak Ridge National Laboratory, the Woods Hole Ecosystems Centre and Rutgers University, USA	Assisting the Institute of Tropical Forestry and Forest Products (INTROP) Universiti Putra Malaysia (UPM) to provide adequate exposure towards the significance of trees and their function in preserving carbon facet of the forest.
Forest and Research Institute of Malaysia And Nimura Genetic Solution	To screen soil microbes for useful compound
Sarawak Biodiversity Center And Nimura Genetic Solution	Sign a research collaboration MOA on microbes
BioPerak (M) Sdn Bhd And Nimura Genetic Solution	Collaboration for research in bioresources of Belum Tropical Forest
SIRIM Berhad with Bio Essential Sdn Bhd	Product and process development for the extraction and preservation of natural produce and products using the Technology of Controlled Instantaneous Pressure-Drop vide DIC I and DIC III® patents. The DIC technology is a proprietary technology owned by ABCAR FRANCE, the parent company of Bio Essential Sdn Bhd.

Table 3: Local and International Collaboration, year 2009. (Source: Overview: Malaysian Agricultural Biotechnology)

3. CHALLENGES IN COMMERCIALIZATION OF BIOINFORMATICS AND BIOTECHNOLOGY PRODUCTS

3.1 Funding

The level of biotechnology accomplishments in Malaysia is low compared to global standards. The Government should identify the factors that affect the level of adoption and development in Malaysian biotechnology innovation system and to define the predictors of level of innovations as perceived by

academic researchers. Farid et al. (2011) commented that the level of knowledge, level of cooperation, level of acceptance and amount of fund are effective factors that encourage adoption of biotechnology innovations from the perspective of university researchers. However, the amount of fund allocated to adopting companies by the government is the most powerful predictor of the increase of the level of adoption for both biotechnology companies and academic researchers (Farid et al. 2012).

National surveys of innovation and R&D have been routinely carried out in Malaysia since mid-1990s. The surveys suggested that appropriate source of financing continues to be a serious problem for innovation firms (C., Lee & C-Ging, Lee, 2007). The government has responded to this problem by providing support in the form of direct financial grants and various tax incentives. Various studies show that the funds for these two industries basically come from government agencies (Chandran, 2010). Fund provided by government agencies only able to support a research project at a starter level and is not enough for commercialization. Other than that, there is lack of funding from banking institution. The available loans in banking sectors are not prone towards the starters in the field. Importance and trust is placed on the property owned by the researcher rather than the innovative ideas. According to Kassim (2009), Malaysia enjoys 52% of R&D funding from the private sector while 32% funding is still by the Government while compared to Japan and South Korea with almost 75% funding from the private sector.

3.2 Education

The number of graduates from public institutions from year 1994-2002 for first degree courses is shown in Figure 3. The chart clearly indicates that only small amount of students graduating from natural sciences and computer science field compared to social science and humanities field. Number of students in a field is an indicative of the available human resource in the respective field. This factor will indirectly cause the lack of expertise problem in the field of science generally and particularly in the field of biotechnology and bioinformatics. According to Dr Megawati Omar and Dr Abu Bakar, the number of Science stream students dropped by 29% since 2007 ("*Where are we heading in research?*", 2012). For instance, a research group which is working on a DNA sequencing project should have depth knowledge on both experimental and analytical part of the studies. Lack of knowledge to apply bioinformatics tools will cause extra cost for the R &D group as they send the sequences to an external source for analysis. Malaysia's stand in research field can well picture by considering number of citation per paper as it is the measurement of true quality research. For the past decade, Malaysia was able to produce 44000 research papers lagging behind Singapore which produced 85000 research papers while Thailand managed to produce 49000 research papers. (StarEducate, 2012).

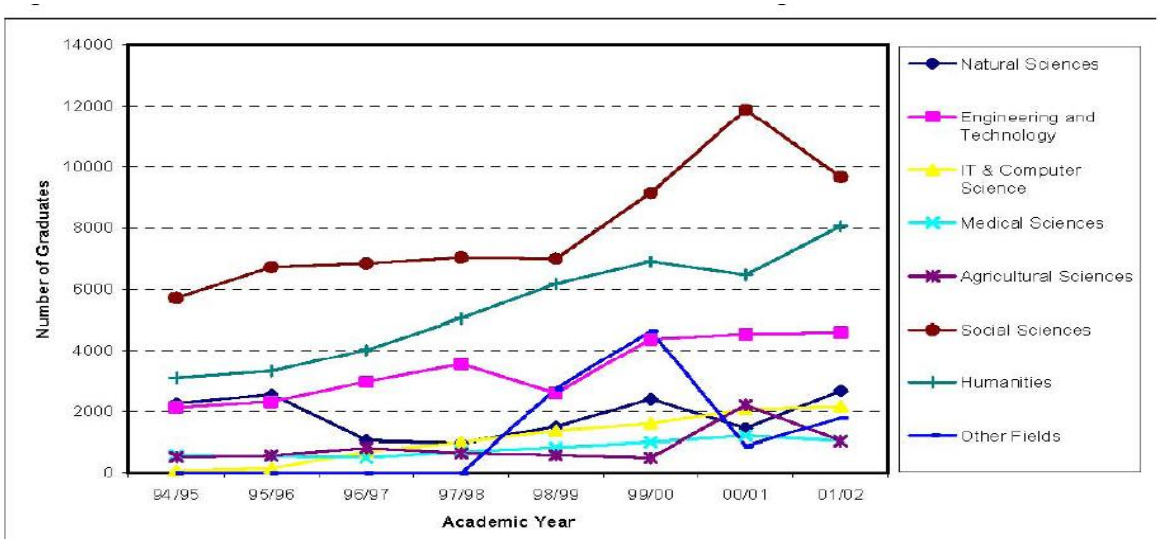

Figure 3: Graduation from Public Universities for First Degree Courses. (Source: This report has drawn from Ahmad, F. and Krishna, V.V. (2006); Malaysian websites on S&T and other sources. The draft is the outcome of collaboration with Dr Fadzilah Ahmad of MOSTI)

Tenth Malaysia Plan emphasises the development of human capital to meet industry's requirement to drive productivity improvements to move up the value chain. Public and private universities should work towards to achieve world class educational institution status. In order to produce a pool of talent and expertise in biotechnology and bioinformatics fields, various programmes should be implemented to increase the number of graduates in higher education. For example, National Science Fellowship programs provided scholarships to 156 Masters and PhD students in biotechnology-related fields (Ninth Malaysia Plan, 2006). Besides, MyMaster & MyPhD programmes were created under the 10th Malaysia Plan via MyBrain15 program for the sponsorship of postgraduate study at the Masters and PhD levels. Under this programme, the government aims to produce 60,000 PhD holders in Malaysia by the year 2023 (https://payloan.mohe.gov.my/MyBrain15/index2.php).

3.3 Lack of expertise

Commercialization of a product in scientific field requires understanding of the product from even the management structure. Deep and correct understanding of a new product in research and development sector is crucial in order for the product to hit the market at the right time. This also will be a factor in the determination of the target market. Identifying the right target market will gear up the commercialization activities. This can best be illustrated at Technology Transfer Office (TTO) in universities which are responsible in the release of a product. It enable better liaison with the private sector and to facilitate business arrangements between the researchers and the private sector. This section is usually managed by academics that are lack of the expertise needed to scientific creations of the researchers (Chandran Govindaraju, 2010; Innovating Malaysia, n.d.). Not able to understand the mechanism of the product affects time lines and outcome of commercialization activity. R&D sector in Malaysia is still focus at the first generation stage where performing the experiments at laboratory level is given the top priority (Chandran Govindaraju, 2010). At first generation stage in research, most of the

time, funding and knowledge are drifted into the laboratory methodologies. Priority is given to produce the best product which can perform well at laboratory level but not commercially. This scenario is inversely proportional with countries in the West with the priority in R&D is evolved at the fourth generation where the priority given at the market needs in a very early stage ("*The Convention on Biological Diversity*," 2006). There is always a gap exists between marketing and scientific field. This gap intrudes the commercialization activities of R&D products.

There are many mechanisms for the technology transfer of research and technologies developed by local universities and research institutions. For example, getting involved in an undergraduate research project or providing a placement for a student to get work experience. The mechanisms for the technology transfer of research are consultancy service, outright sale of technology, licensing of technology, joint-venture, and start-up ventures.

3.4 Lack of collaboration

Another aspect in hindering commercialization success of Bioinformatics and Biotechnology products is lack of university-industry linkage (Chandran, 2010) due to the unhealthy user-experience that the private sector encounters differs from what is term "best practices" to "worst practices" (Innovating Malaysia,2011). The University and private sector still cannot work well due to different point of view and policies. In Malaysia, normally the research is referred to as "blue sky" research. It aims to discoveries of new breakthroughs but have no links to commercial or societal benefits. Generally, researchers and inventors do not make business people (Innovating Malaysia, 2011). Innovating Malaysia states that commercialization success is more likely to come from the private sector, which understands the markets, distribution channels, sales and marketing strategies, along with efficient mass-production techniques and process. The Government plays a key role in forging linkages between the generators of knowledge and the users of knowledge. Innovating they should work hard in develop the linkage between academia and industry to achieve the higher success rate in Biotechnology and Bioinformatics products commercialization (Innovating Malaysia, n.d.).

The Prime Minister Datuk Seri Najib Tun Razak stated that Malaysia is the first country to introduce Quadruple Helix strategy in its innovation ecosystem. The Quadruple Helix Model is an improvement on the "Triple Helix Model", which popularised the interaction between industry, academia and government. Quadruple Helix Model adds another dimension that is equally important today as the other three – the Rakyat ("*Quadruple Helix' way to innovation*", 2012). The four segments of the helix work together in making Malaysia globally competitive.

3.5 Intellectual Property (IP)

Although the government undertakes various initiatives to accelerate the rate of commercialization by setting up institutions and programs, there still some challenges exist. The national progress in intellectual property (IP) and technology commercialization is low. Chandran & Wong (2011) indicates that the current local indigenous innovative capabilities are still weak and require better policy intervention to accelerate the inventive capabilities of Malaysia.

Patent data was obtained from the Malaysian Intellectual Property Association (MIPA) database. The real number of patent applications by foreign and local companies in Malaysia is showed in Figure 4. Overall, the patent applications over 1988-2012 is only 8.8% compared to the foreign companies' application of 91%. The main reason of limited number of patent fillings by local companies is lack of understanding on the contribution of patents to the company's performance and lack of knowledge on the importance of protecting intellectual property (IP).

This is also restricted to Malaysia's low investment in R&D and poor human capital development. Malaysia has to identify the R&D projects undertaken by universities and private research institutes that have commercial value, convert them to real wealth, through commercialization. These projects are typically embodied in commercially valuable Intellectual Property (IP). In addition, local companies were found to mainly engage in process technology and in product modification. In other words, they often engage in incremental innovation and not radical innovation. (Chandran & Wong, 2011).

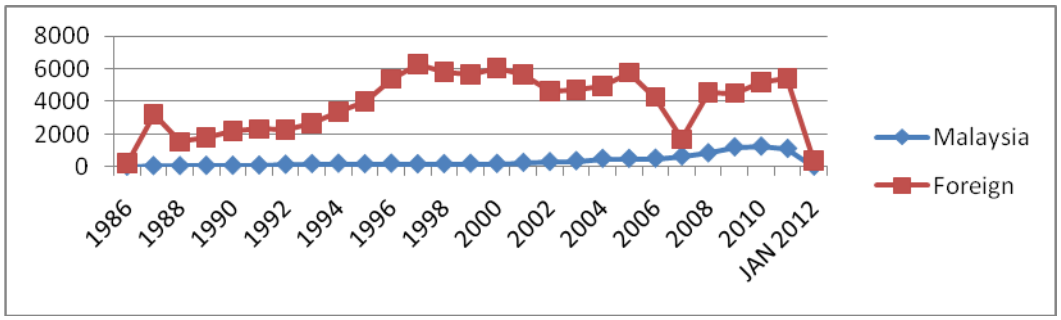

Figure 4: Patent applications by foreign and local companies in Malaysia (Source: Malaysian Intellectual Property Association (MIPA) database)

4. BENCHMARKING, DISCUSSION AND IMPLICATION

South Korea was once a poor nation. This is a good example of a country that was able to develop and become part of the world industry leaders. During the 1980s, South Korea rapidly expanded into information technology and in 1994, seven government ministries work on 'Biotech 2000' plan, to make South Korea as one of the world's top seven biotechnology producing countries by 2010 (Wong et al., 2004). South Korea increased its R&D intensity steadily and reached the level of an advanced country in 1990s. The growth rate of R&D intensity by South Korea surpasses that of Japan and Taiwan, with the growth rate being especially high in the 1980s and the 1990s. However, it is only in the 1990s when Korean R&D efforts finally became comparable to developed countries, including Germany and France (Bartzokas, 2008).

Funding and commercialization are two important dependant elements for South Korea. In a nutshell, it simply means that adequate funding will lead to successful commercialization. Malaysia Government has invested heavily in biotechnology and bioinformatics especially the Universities and public Research Institutes. Each 5-year Malaysia Plan has increased its R&D budget consecutively. Wong et al. (2004) revealed that the investment capital in South Korea is both abundant and smart. Due to the availability of capital resources, by year 2001, the private sector provided for nearly three-quarters of R&D

expenditures. On the other hand, Malaysia is still heavily relying on government funding. It is important for Malaysia to develop more funding organizations to ensure the government investment in innovation is efficiently and transparently allocated and also boost up the private sector's role in venture funding. At the same time, the government disbursement agencies have to transform themselves and behave like fund managers where grants are treated as government investment capital in innovation (Innovation Malaysia, 2011)

Besides as a growing nation, Malaysia's funding has always been a challenge because it is easily influenced by the economic crisis faced by the developed nations. The recent economic crisis leads the growth of biotechnology industry muted, while lower the growth rate in bioinformatics industry. Lack of risk taking attitude among the giants in private sector inhibits them from investing in researches based on bioinformatics and biotechnology. This is due to the uncertain outcomes from the field.

In order to train scientists of top quality, the transformation of current teaching-oriented universities into research-commercialized-oriented universities is critical. In Malaysia, exam oriented education system also become a barrier for the innovative ideas among the students. Students in Malaysia are more focused on the need of passing the exam and get an 'A' rather than understand principles in a theory. Malaysian education system should aim at producing groom thinkers and not facts memoriser. As the Innovation Malaysia states that our graduate must master higher order thinking skills, as the foundation of innovation lies in one's ability to think critically and analytically, constructively and analytically. In order to sustain in the field of research one need to invent and invention requires more thinking and not memorising (StarEducate, 2012). A student who was brought up in such situation is unable to produce innovative ideas as memorising facts as been a habit all the while. Malaysia should come out from the spoon-feed environment and trust the younger generation, can be a vital resource of this industry. There are high chances to produce world-class students if the educational institutions are based on world class status.

One of such efforts is to engage the final year projects and R&D works with the industries. Applied R&D projects in universities have to be driven by market needs identified by the practitioners in the sector, coupled with the foresight in science and technology (innovating Malaysia, n.d.) Therefore, higher education institutions should engage themselves with private sectors from the very beginning itself. After all, the purpose of an education is to produce human resource for the industries and government sectors. To stimulate such a transformation, the government is suggested to provide financial support to those universities with excellent research performance. Many of the major universities in Korea have responded to the government policy by preparing and launching various reform programs that are anticipated to bring about drastic changes in university education in Korea (Wong et al., 2004). In addition, entrepreneurial university which emphasises on university R&D commercialization and technology transfer is a good concept Malaysia should adopt in the process of enriching commercialization process. The commercialization process has three key aspects namely the opportunity, the exploitation process and the support community. An appropriate knowledge management (KM) which gives priority to creation, utilization and development of a tertiary institution's business intelligence should be implemented via higher education system *("Application of Knowledge Management for Research Commercialization",* 2009*).* Figure 5 illustrates an example of knowledge

management flow suggested by Jahangir Yadollahi Farsi and Kambeiz Talebi in the paper Application of Knowledge Management for Research Commercialization.

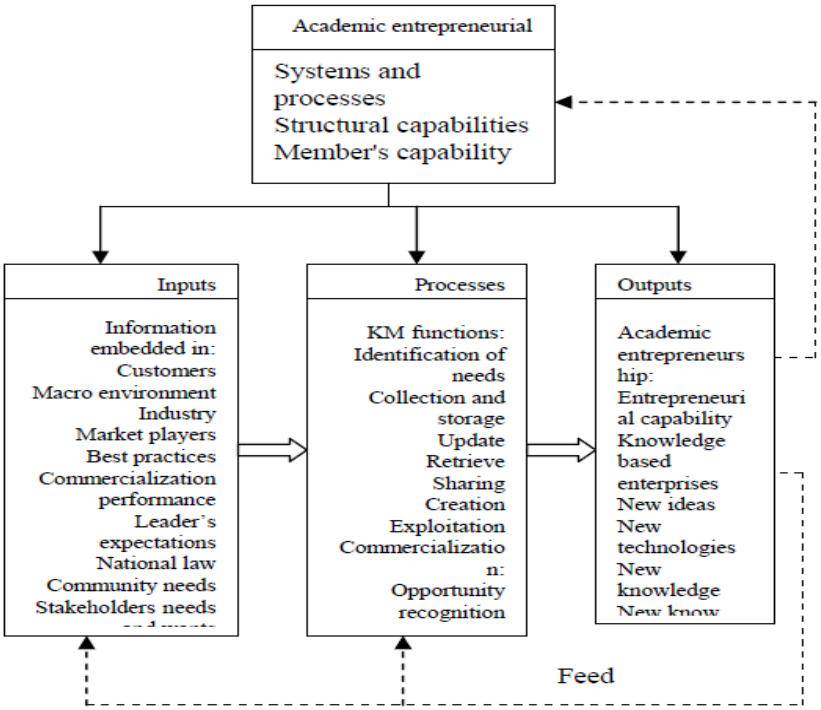

Figure 5: Knowledge Management Model for Research Commersialisation with 5 components: Academic entrepreneurial capability, inputs, processes, outputs and Feedback loop.

To reduce the inherent risks in the biotechnology field, the South Korean industrial policy makers and private sector investors are focusing on creating enterprises that leverage on the country's existing industrial competitive advantages in fields such as pharmaceuticals and information technology (Wong et al., 2004). Malaysia has a strong foundation agriculture base and leading the production of industrial crops, for example oil palm, rubber, cocoa, pepper and tropical timber. Malaysia has taken similar approach by focusing on agricultural biotechnology as one of the key to boost the level of commercialization of R&D products through the development of a public financed research system. This is an investment to enhance the innovative capacity of the national biotechnology research program, and creation of institutions and regulations.

On the other hand, South Korea-based scientists collaborate with researchers from other countries. Because of the policy swift in South Korea, the amount of foreign direct investment in Biotechnology field was tripled between year 1997 and 2001. According to Wong et al. (2004), South Korea biotechnology firms participate in transnational collaborative linkages in R&D, investment, licensing partnerships and arrangements with Asia, North America, Europe and the Middle East. Due to the lack of expertise in Malaysia, local research institutes and universities should take approaches in collaboration or partnership with foreign institutes in term of technology transfer and

commercialization. This effort helps to build a foundation for a sustainable Malaysian agricultural biotechnology industry.

In addition, the lack of well trained and experienced patent examiners in Malaysia Intellectual Property Corporation (MyIPO) determining the number of successful patents. It is suggested to setting up of an institute that can up-skill IP Agents in Malaysia (Innovating Malaysia, n.d.). The drafting of IP documents is a specialised skill that makes the critical difference between the successful granting of IP or its rejection.

To date, Malaysia still heavily relaying on public, foreign and large companies R&D activities. The continued reliance on foreign technologies and foreign direct investment may have negative effects on the economy in the future as foreign companies may be more attracted to new markets which offer better returns for their investment. It is important that governments in developing countries such as Malaysia to introduce some reforms to improve the Biotechnology products commercialization. The local companies have to emulate the methodologies, systems and processes of Multinational Corporations in order to shorten their learning curve. However, they should take into account for several factors, especially the need to attract and maintain foreign investments and at the same time the desire to encourage local domestic innovations. The government assist local innovators in all their efforts to file a patent. Nevertheless, this cannot ensure the successful commercialization of the patent and for that purpose; foreign companies may still be of some importance that has all the resources to commercialize it. By license out the technology to a foreign or local company, the local patent holder could get revenues from royalty fees and reinvest into local private R&D in order to eventually obtain new patents (Jusoh, 2006).

5. CONCLUSION

The Malaysian government plays direct role in promoting the commercialization of Biotechnology and Bioinformatics R&D products. Malaysia should improve its fundamental agendas in order to strive to be a knowledge and technology driven economy. A number of efforts have been taken to some extent supporting the shift of Malaysia to become a high-income economy based on Biotechnology and Bioinformatics. However, many challenges had been discovered such as the fund availability and support programmes that are spread over multiple agencies; industry and academia speaking “different languages”; national and international linkages; government agencies internal structure including transforming like fund managers and extracting more value from IP management. Further improvement is vital especially in our education system, research and development, and human capital to enhance the current R&D&C efforts. Moreover, Malaysia government should consolidate nation-wide policies with an integrated approach to support innovation and increase the success rate of Research, Development and Commercialization.

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