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BIOTECHNOLOGY INDUSTRY STRUCTURE, FIRM RESOURCES AND INNOVATIONS: IMPLICATIONS FOR FIRMS' STRATEGIES

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ABSTRACT

Literature that focus on firm strategy emphasizes the importance of innovations, firms' resources, and industry structure in determining profitability and venture growth of high-technology and high-growth sectors, which the biotechnology industry is one of them. Using the integrated strategy framework as our theoretical lenses, we examined the Malaysian biotechnology-based industry to understand the factors that influenced profitability and sustainability of the firms within this industry. We gathered data on 309 Malaysian companies that were considered as biotechnology-based businesses, and that were in operation in January 2009. The data collected was on their industry structure, firm resources, and innovations. We found that the biotechnology businesses concentrate mostly in agri-biotech and healthcare fields. The industry is dominated by large firms (64%) while the remaining 36% is being purely private operations. Close relationship exists between the biotechnology business field of a firm and the business of its parent company, with most parent companies are involved in the upstream core markets for retail, industrial and plantations businesses. These companies added their product depth and expanded their business width into the biotechnology value-chain over time. Their internationalization processes are also pursued incrementally through collaborative agreements, with the younger companies entering international markets at a higher rate. The Malaysian biotechnology companies are still local-centric, which makes the markets difficult for new entry. Employing a strategy that allows collaboration with others, focuses on international markets, and utilizes local capability and resources, is one way to achieve profitability and sustainability for Malaysian biotechnology companies. Moreover, for the newcomers, they should be focusing on research-based biotechnology business and bioinformatics as the two are considered as lucrative markets for new firms.

*Keywords***:** biotechnology; innovation; industry structure; strategies; industrial-organization.

1. Introduction

Biotechnology is defined in this study as the developmental and application technology utilized to transform living organisms from human beings, animals and plants into products/services of agriculture, healthcare and industrial biotechnology. It could also be referred to their related development processes and methods, such as bioinformatics. Biotechnology has been designated as a strategic industry in many world economies in both developed and undeveloped countries (Ernst & Young, 2006). Such a policy requires that the industry to be strategically developed and sustained. This, in turn, necessitates that firms operating within this industry strategize their efforts toward achieving high growth, while policy makers design a support structure that ensure the industry to continue to prosper and bring strategic advantages to the host country.

Many literatures on business strategy emphasize the importance of firms to have supportive industry structure, internal resources availability, and innovative products or business activities, in gaining marketplace advantage and long term business sustainability

(Barney, 1986; Jacobson, 1992; Porter, 2008; Grunert & Hildebrandt, 2004). The Industrial organization (I/O) perspective proposes the need to understand characteristics of industry structure. This would enable a firm to manipulate the structural elements of its industry to help it attain profitability and sustainability in business. The resource-based view (RBV) emphasizes the importance of a firm's unique and internally owned resources as the requirements to achieve a competitive advantage. The Schumpeterian-Strategy (SS) perspective on the other hand, emphasizes the significance of innovations not only in assisting the gaining of profitability for particular members within an industry, but also, in sustaining the whole industry survivability in the long-run (Jacobson, 1992). Barney (1986) argues that an integrated perspective of the three theoretical streams would provide a greater explanatory power in describing firms' survivability and sustainability.

Thus, the purpose of this study is to use this integrated conceptualization of firm strategies to identify variables that have an influence on firms' profitability and sustainability, especially on those that are involved in the biotechnology business. The ultimate aim is to discuss about the implications of utilizing these integrated strategies by these biotechnology firms. To achieve this, we examined the types of innovations created by the companies and the structure of biotechnology industries in Malaysia. We have chosen Malaysian companies as our research subjects mainly because Malaysia has a large natural biodiversity. This becomes the main source of raw materials for biotechnology.

Moreover, the country has a comprehensive government policy on biotechnology industry development, which is an advantage to those in the Malaysian biotechnology industry. This biotechnology policy has an International Advisory Panel, whom the members are comprised of world-renowned biotechnology players, and they serve as advisors to the biotechnology initiatives implementation. The government has also committed about RM2Billion (or USD500Million) with the goal of developing the biotechnology industry into an industry that would contribute 2.5% of the Malaysian GDP in the year 2010 (Biotech Corporation, 2007). However, the country has a weak innovation support system for technology-based companies (Khairul Akmaliah & Mohd Fuaad, 2007), which is a critical element in promoting the growth of firms and also the biotechnology industry (Hall & Bagchi-sen, 2007). Malaysia also has low number of R&D researchers, with only 3,400 people (compared to Singapore, for example, which has a talent pool of about 17,000 people) (Biotech Corporation, 2007). They could act as barriers to those in the industry from achieving high growth and performance.

2. Perspectives on Business Strategy

Strategy literature views business strategy in three perspectives: 1) Industrial Organization (I/O) perspective, 2) Resource-Based View (RBV), and 3) Austrian School of Strategy or Schumpeterian-Strategy (SS) perspective (Barney, 1986). I/O suggests that characteristics of a particular industry structure determine profitability of the firms that operates within the industry (Porter, 2008). RBV suggests that the resources that the firm has determine its capability to make profit and to sustain in the business, while the SS perspective highlights the importance of innovations in sustaining a firm's life-cycle and proposes that strategizing is in fact the action of innovating, as the outcome of such an action generates profitability at a premium for the innovator firm (Barney, 1986; Jacobson, 1992).

From the Industrial Organization (I/O) perspective, the level of competitiveness to be faced and the degree of profitability to be made by a firm are influenced by its industry structure. In this regard, Porter (2008) describes industry structure in term of the ease of entry into an industry, the degree of current rivalry within that industry, the bargaining power of the

industry's customers and suppliers, and the availability of the substitute products for those sold within the industry. An industry structure also includes active institutions that support the survivability of industry members i.e. research institutes and government agencies (Nelson, 1992). The relationship between an industry structure and a firm's performance is viewed as a *structure-conduct-performance* paradigm (Mason, 1939; Bain, 1956; 1968). In this notion, an existence of an industry structure (i.e. current rivalry, bargaining power of suppliers etc.) forces a firm within the industry to modify its own internal processes, structure and/or strategy to face the challenges of operating within an industry with such structure. This adaptation will help it increase its performance. To achieve the desired performance, a firm needs to modify/create the structural characteristics of its industry to tip the competitive scale toward its favor. In this sense, the internal processes/structure/strategy that are to be modified should, for example, attempt to create higher barriers toward its industry market entry, or offer a product that is significantly different from that of rivals. This would help the firm to increase its market share and profit (Porter, 2008). Thus, an important consideration for a firm in designing a strategy based on I/O perspective is to identify the idiosyncratic characteristics of its industry structure.

The RBV perspective, on the other hand, believes that what influence the attainment of higher profit and performance by a firm is the effective deployment of its own internal resources, unique skills and distinctive competencies. Here, the resources/skills/competencies could be listed as *technical know-how*, *patents*, *trademarks*, *firm's reputation*, *brand awareness*, and/or *cooperative ability of managers* (Chamberlin, 1933), which may vary across industries. The relation between firms' resources, skills and/or competencies and its performance could be described as *resource-conduct-performance* paradigm (Barney, 1986). In this relation, it is assumed that no two firms own a same set of resources/skills/competencies. Thus, to increase its performance (profits and market share), a firm must know what resources, skills and competencies that it has, that are different from those owned by its rivals. It then needs to design a strategy that exploits this 'positive' difference that it has over the rivals. For example, if a firm has the ability to operate at a lower cost compare to others, then it should adopt a strategy that focus on producing lower price product. Thus, based on the RBV perspective, a firm must design a strategy that allows it, once it is able to identify them, to exploit internal resources/skills/capabilities that would give it a better competitive edge.

The last perspective, the SS, suggests that industries are either revolutionized or incrementally affected by introduction of new technology or modifications to existing technologies and/or systems (Schumpeter, 1934; 1942). Thus, the SS perspective suggests that to be successful, a firm must have the ability to be entrepreneurial and innovative. SS perspective believes that a market is never stable in term of demand and supply, and business opportunities will always exist when there is a difference in the two. This gap causes unfulfilled needs among customers (Jacobson, 1992) which could be acted upon by an entrepreneur, by introducing to the customers, new product/service. However, although opportunities for business always exist, an entrepreneur must be able to see them and be able to gather information about them. Therefore, based on SS perspective, before a strategy is to be developed, a firm must be able to identify new opportunities that exist in the market. The strategy it planned to adopt, on the other hand, must help it to be able to fulfill this market gap through the offering of new product/service (innovation). Thus, under this perspective, firm performance could be described as *innovation (new product)-conduct-performance*.

While some authors emphasize the significance of each of these three perspectives, I/O perspective (e.g. Porter 2008); RBV perspective (Chambelin, 1933; Barney 1991; 2001), and

Schumpeterian (Barney, 1986; Jacobson, 1992), there have been some efforts in complementing these perspectives. For example, Leyland and Hitt (2002) augment the entrepreneurship theory, which originates from the Schumpeterian-strategy concept, through the use of resource-based perspective. Armstrong and Shimizu (2007), on the other hand, suggest incorporating industry elements when examining resources of firms, to further refine the conceptualization of firms' resources. Barney (1986) views the I/O perspective and RBV as complementary; the I/O look outside at the industry structure, while RBV emphasizes on looking inside the firm's resources in deciding what resources are to be exploited in the firm's strategy implementation. Barney (1986) further proposes an integrated view of the three perspectives, in which the perspectives complement each other. He particularly emphasizes the importance of complementing the three perspectives as firms need to consider the structural and the Schumpeterian elements against their internal characteristics, in formulating and implementing their strategies.

We utilized Barney (1986)'s integrated conceptualization of business strategy to help us understand the factors that influence profitability and sustainability of firms operating within the biotechnology industry. However, we extended it by adding firms' contextual elements, such as *supportive institutions* (Nelson, 1992), *proximity of firms to these supportive institutions, and firms' locations* (Porter, 1998). This contextual-based integrative strategy perspective serves as the conceptual framework for this study.

3. Strategy Conceptual Framework for Examining Industry Contexts, Firm Resources and Innovations

The study's conceptual framework contains constructs from the I/O, RBV and SS perspectives: *type of biotechnology product/service innovation*, *firm resources, customers, intra-industry rivalry, suppliers, substitutes, barriers to industry entry,* and *supportive related firms* (Barney, 1986; Jacobson, 1992; Nelson, 1992; Porter, 1998; 2008).

3.1 *Biotechnology Innovations/products/services and Innovation-process value-chain*

these are related to the output of a biotechnology firm that is offered to potential customers to fulfill their needs. The biotechnology innovations can be described as output from a value-chain process which could be classified as *research based, production based,* and *distribution-based* (Hall & Bagchi-Sen, 2007). Moreover, following the categorization of biotechnology businesses by Biotech Corporation (2007), the types of product/service of biotechnology companies can be distinguished into agriculture, healthcare, industrial, and bioinformatics products. *Agriculture-biotechnology* involves the use of biotechnology to turn agricultural produces into foods and agricultural-based products; an example is a genetically modified plant. *Healthcare-biotechnology* refers to the applications of biotechnology to produce medicine and health-care products. This includes new diagnosis and diagnostic tools, therapies, and medicine. While *Industrial-biotechnology* involves the utilization of biotechnology in managing the natural environment, including the development of new energy sources and other new products that could help protect the environment from rapid degradation. As the name suggest, *bioinformatics* involves the application of knowledge in biological sciences, information systems, and statistical methods that address problems in biotechnology and/or its related products/services development and/or processes.

3.2 *Intra-industry Rivalry*

This indicates the level of competitiveness that a firm faces from others within its own

industry. One important factor that influence the intra-industry rivalry is the number of firms that sell the same type of products, or offer the same kind of services to a similar group of customers.

3.3 *Customers*

Customers are those who buy products or pay for services offered by a firm. Customers of biotechnology firms include both individuals and businesses. The survivability and sustainability of a firm within an industry is influenced by the customers' ability to control down the price of a firm's product/service, demand higher quality or more services from the firm, and play it off against its competitors (Porter, 2008).

3.4 *Suppliers*

This group of businesses provides supports to a firm to allow it to run its operations, which can be in the forms of raw materials, human resource, monies, technology, and information. Suppliers within the biotechnology business environment also include the research institutes and independent firms supplying research services and technologies. Because of the high capital nature of the business, biotechnology firms are also dependent on the public and private capital markets (Hall and Bagchi-Sen, 2007). Supportive government, which provides funding during certain stages of the firms' product development life-cycle, could help mediate the effects of high cost of product development within the industry (Hine & Millen, 2006).

3.5 *Substitutes*

Substitutes are alternatives to a firm's products and services in satisfying the need of customers. They can be in the form of another product, services, process or technologies that could replace the existing biotechnology products/services. Certain types of biotechnology products could be protected by patents; however, patent application is time consuming and, once earned, does not guarantee that the firm's right would not be infringed by others. There is also a possibility that a firm launching a new product is not aware that it is infringing the right of others. There is also a threat of substitute product that utilize a different technology and process (Hine & Millen, 2006).

3.6 *Market Entry Barrier*

This describes the level of difficulty for other firms to enter and set up business within an industry. The level is affected by barriers such a1s the need to have required financial capacities, expertise, technology and equipment to start the business. It is also influenced by the existing industry members' abilities to retaliate toward and fight off the 'intruders'. These abilities would also make market entry difficult for the newcomers as they need extra financial strength to counter the attacks. Because of the nature of the biotechnology products, which require long developmental time for commercialization, high capital intensive, and patent protection (in certain products), the barriers into the industry can be very high (Hine & Millen, 2006; Hine & Griffiths, 2004).

3.7 *Related Institutions*

They are entities that are usually not considered parts of an industry, but provide support in terms of financial, technical and regulatory assistances. These organizations can include research institutions and universities that are involved in the biotechnology research, and also related government agencies that provide grants and legal helps (Nelson, 1992). And such

institutions can be more beneficial if they are located in close proximity to the biotechnology firms (Porter, 1998).

3.8 *Agglomeration/clustering of firms*:

These can be in the form of supplying and relevant companies/agencies that exist in close proximity to the biotechnology firms (Hall & Bagchi-Sen, 2002; Porter, 1998)

3.9 Firms' Unique Resources

Resources are anything that a firm possesses that can be utilized toward achieving a higher profit than its competitors. This can be accomplished by operating at a lower cost and/or by providing greater values to its customers in relation to its competitors. If the resources have high levels of unimitability, there is high possibility that a firm's competitive position could be sustained (Barney, 1991; 2001; See also Armstrong & Shimizu, 2007).

4. Research Methodology

This study employed three stages of data gathering method. The process was conducted from November 2008 to January 2009, with the final collecting date was on 31st January, 2009.

Step 1: Gathering the list of Malaysian biotechnology companies using:

a) Bursa Malaysia website (http://www.klse.com.my). This website provided information on companies listed in its three boards: Main Board, Second Board and the Malaysian Exchange of Securities Dealing & Automated Quotation (MESDAQ). The third board is an exchange platform specifically designed for technology-based companies. The keywords used when searching for biotechnology companies listed in these three boards were *biotech* and *biotechnology*.

b) Biotech Corporation website. It provided listing and profile of BioNexus companies (http://www.biotechcorp.com.my/bionexusnetwork/bionexuscompanies. htm). Biotech Corporation is a government-based agency that was chosen to manage the granting of BioNexus to selected biotechnology firms and the dispensing of government incentives including financial incentives to them. The agency was formed in 2005 as a part of the Malaysian Biotech Policy initiative to support the government's biotechnology industry development policy. The government incentives and the operations of Biotech Corporation are managed under the Ministry of Science, Technology and Innovation (MOSTI). Bionexus is a status given to biotechnology firms that applied for the ranking and managed to fulfill the various criteria specified by the Biotech Corporation to obtain it. Among others, the agency stipulates that they are to be involved in exploiting leading-edge biotechnologies. The status, which was introduced in 2006, enabled a biotechnology firm to gain tax-deferred advantage, receive priority in getting government funding and gaining access to the expertise and networks of the Biotech Corporation (Biotech Corporation, 2007).
c) Biotec Malaysia website. This website provided listing and profile of exhibitors in BIOMalaysia 2008 (http://www.biotechcorp.com.my/usefullinks/MBC0065-Company%20Listing.pdf).

d) Suruhanjaya Syarikat Malaysia website. This website provided information on companies that are registered in Malaysia. In the search function, we used the keyword *biotech*. This

search procedure generated a total of 105 private limited companies involved in biotechnology. However, except for getting this list, no further information were available in the public domain about these companies. Therefore, the list of these companies are taken out from our profiling.

Step 2: Analyzing the companies using the predetermined constructs of: *type of biotechnology product/service innovation, firm resources, customers, and supportive related firms*
For listed companies, in the KLSE website, we a) checked the KLSE website for company profiling information provided by Bursa Malaysia, or b) clicked on the link to company's website, or if these are not available, c) searched listed company information/profile from Google finance website. d) researched the companies' annual reports (checked their company profile and analyzed their biotechnology businesses and activities). The procedures for non-listed companies include checking a) the companies' websites; b) their profiles in the Biotech Corp website and c) their profiles in BioMalaysia 2008 exhibitor booklet.

Step 3: Information from published sources as well as other sources in the public domain.
Any relevant data that could not be found in Step 2 were supplemented by information available in the public domain. Data on the types of markets (local vs. foreign) that the biotechnology firms were involved in were mainly collected from their own websites. This was supplemented by those gathered from MATRADE's website, which provided a listing of all firms that export their products to overseas' markets. Information from the public domain was also used to construct details about *substitutes*, *suppliers* and *market entry barriers* that these firms had to deal with.

5. Findings

There were 309 companies that were involved in the biotechnology business, as of end of January 2009. Table 1 shows the classifications of these companies, according to the types of company and business that they were involved in. As shown in Table 1, private companies dominated the biotechnology market. Their number constitutes more than 75% of the analyzed firms. The second largest group type was the private firms with Bionexus Status, and they comprised about 15% of the 309 companies.

Information in Table 1 and Figure 1 show that there was a pattern of domination by the agriculture and healthcare-based businesses within the biotechnology industry. Both groups made up of half and 39% of the total number of biotechnology firms analyzed. Among those that were involved in the agriculture and healthcare-based businesses, they only concentrated on either one of these. Only a very few took up the challenge of operating in both.

Of the 309 companies analyzed, only four were listed on MESDAQ—which is the dedicated exchange platform for high-tech, high-growth businesses. Moreover, 48 firms or 15% of the total number of analyzed companies had BioNexus status. This status is only bestowed to a company that is involved in state-of-the-art exploitation of biotechnology activities. Thus, the low percentage indirectly implied that most of the 309 firms were operating "low-tech" biotechnology activities. Among the 48 firms with BioNexus status, the majority were in the healthcare and agriculture areas, which reflected the high representation of these two sectors in the overall biotechnology industry. However, of these BioNexus status firms, there were a higher percentage of them operating in healthcare (27%), in comparison to agricultural activities (23%). Moreover, none of them were involved in the industrial sector.

Table 1: Types of Biotechnology Businesses and Companies

Types of biotechnology business	Main Board	Second Board	MESDAQ	MSC	Private Companies	BioNexus	Total
Healthcare	2	1	2	-	81	14	100 (32%)
Agriculture	9	3	1	-	90	14	117 (38%)
Bioinformatics	-	-	-	2	3	2	7 (2%)
Industrial	1	-	-	-	39	-	40 (13%)
Healthcare +Agriculture	-	-	-	-	2	9	11 (3.5%)
Healthcare +Bioinformatics	-	-	-	2	1	5	8 (2.5%)
Healthcare +Industrial	-	-	-	-	2	-	2 (1%)
Agriculture +Bioinformatics	-	-	-	2	-	3	5 (2%)
Agriculture +Industrial	2	-	1	-	15	1	19 (6%)
Total	14 (4.5%)	4 (1.3%)	4 (1.3%)	6 (2%)	233 (75.4%)	48 (15.5%)	309 (100%)

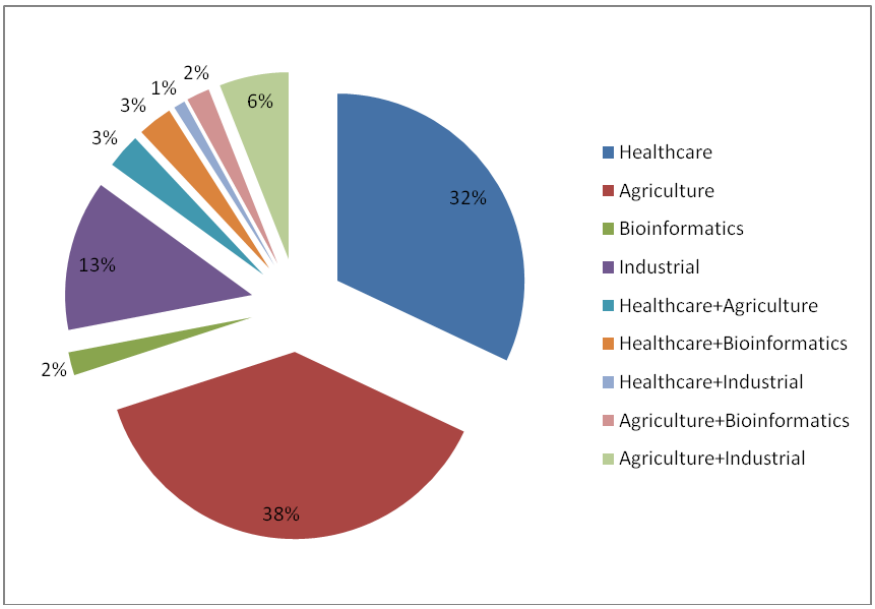


Figure 1: Types of Biotechnology Businesses

When innovations in value-chain were examined against the types of business (in Table 2), the distribution of combined innovations, of *research* and *production* (A+B) and of *production* and *distribution* (B+C), was the most common one in the healthcare business. Within the agriculture-biotechnology business, on the other hand, the combination of production and distribution was more prevalent, and for the industrial business, the production-type innovation was most widespread.

Table 2: Innovation Process Value Chain and Types of Business

Type of Business	**Value Chain**							**Total**
	A	**B**	**C**	**A+B**	**B+C**	**A+B+C**	**A+C**	
Healthcare	10	14	33	21	13	9	-	**100 (32%)**
Agriculture	17	21	6	23	31	18	1	**117 (38%)**
Bioinformatics	2	-	-	5	-	-	-	**7 (2%)**
Industrial	3	29	-	2	4	2	-	**40 (13%)**
Healthcare+Agriculture	1	1	-	5	-	4	-	**11 (4%)**
Healthcare+Bioinformatics	1	1	-	5	-	1	-	**8 (3%)**
Healthcare+Industrial	1	-	1	-	-	-	-	**2 (1%)**
Agriculture+Bioinformatics	-	-	-	1	1	2	1	**5 (1%)**
Agriculture+Industrial	1	5	3	2	6	2	-	**19 (6%)**
Total	**36 (11%)**	**71 (23%)**	**43 (14%)**	**64 (21%)**	**55 (18%)**	**38 (12%)**	**2 (1%)**	**309 (100%)**

Notes:A=Research; B=Production; C=Distribution; A+B=Research & Production; B+C=Production+Distribution; A+B+C=Research,Production & Distribution; A+C=Research & Distribution

When the value chain innovation process of the biotechnology businesses were examined against the company types, findings show that *production-based* (23%) and *research and production-based* combined activities (21%), conducted by private companies dominated the biotechnology market. However, on the whole, a mix of *research and distribution* is the least likely innovation type to be adopted by them (1%) (See Table 3). In addition, *research and production*-based innovations were widely adopted by the BioNexus companies, while among the public listed companies, *production-based* one was the main innovative activity.

Moreover, results also show that the majority of the firms were located within the Klang Valley region (60%), as shown in Table 4. This region is an area of 30 by 50 square kilometers with its center is the Malaysia's capital of Kuala Lumpur. The second most popular location for Malaysian biotechnology firms was the Southern region, which is an area that borders Singapore. This was followed by the Northern region, and by the Eastern region, which had the lowest number of firms. When the these regional locations was analyzed against the firms' businesses (in Table 5), it was found that about 80% of the bioinformatics, and at least 50% of the healthcare business, and 35% of agriculture business, were located in Klang Valley (in Table 5). Among the different types of business, agriculture business is the most geographically distributed, with the Northern region having 37% of these firms, the Southern region with 74% , and the whole Sabah region, being located only by the agriculture firms.

Table 3: Innovation Process Value Chain and Types of Companies

Type of Companies	Value Chain							Total
	A	B	C	A+B	B+C	A+B+C	A+C	
Main Board	-	4	1	5	1	3	-	14 (4.5%)
Second Board	-	-	-	-	4	-	-	4(1.5%)
MESDAQ	1	-	-	2	-	1	-	4(1.5%)
Private Companies	25	65	41	37	48	16	1	233 (75.0%)
MSC-status	-	-	-	4	1	1	-	6(2%)
Bio-Nexus	9	2	1	15	1	17	-	45 (14.5%)
Bio-Nexus+ MSC	1	-	-	-	-	-	-	1(0.3%)
Bio-Nexus+ MESDAQ	-	-	-	1	-	-	1	2(0.7%)
Total	36 (11%)	71 (23%)	43 (14%)	64 (21%)	55 (18%)	38 (12%)	2 (1%)	309 (100%)

Notes: For description of A, B, and C in the table, see notes below Table 3.

Table 4: Location and Value Chain

Location	Value Chain							Total
	A	B	C	A+B	B+C	A+B+C	A+C	
Klang Valley	19	40	36	40	29	21	1	186 (60%)
Northern Region	4	11	4	6	6	4	0	35 (11%)
Southern Region	8	8	2	9	7	12	0	46 (15%)
Eastern Region	0	2	0	0	0	0	0	2 (1%)
Sabah	1	6	1	4	8	0	0	20 (7%)
Sarawak	3	1	0	4	3	1	1	13 (4%)
Western Region	1	3	0	1	2	0	0	7 (2%)
Total	36	71	43	64	55	38	2	309 (100%)

Notes: For description of A, B, and C in the table, see notes below Table 3.

Table 5: Location and Type of Business

Type of Business	Region							Total
	Klang Valley	North	South	East	Sabah	S'wak	West	
Healthcare	77	15	8	0	0	0	0	100 (32%)
Agriculture	44	11	31	2	16	9	4	117 (38%)
Bioinformatics	6	1	0	0	0	0	0	7 (2%)
Industrial	30	5	3	0	0	1	1	40 (13%)
Healthcare +Agriculture	8	0	2	0	0	1	0	11 (4%)
Healthcare +Bioinformatics	7	0	1	0	0	0	0	8 (2%)
Healthcare +Industrial	1	1	0	0	0	0	0	2 (1%)
Agriculture +Bioinformatics	4	0	0	0	0	1	0	5 (2%)
Agriculture +Industrial	9	2	1	0	4	1	2	19 (6%)
Total	186 (60%)	35 (11%)	46 (15%)	2 (1%)	20 (7%)	13 (4%)	7 (2%)	309 (100%)

Of the 309 firms, 87% of them operated in the local markets, with only 13% had foreign market presence (See Table 6). These 13% were mainly made up of Bionexus companies (15 companies). This indicated the aggressive marketing efforts of these firms to enter foreign markets. In fact, some of these companies were originally *born-global* firms or *rapid globa*l firms. For example, one BioNexus company, InfoValley started its operations in Malaysia in 2002, but quickly set up a subsidiary in India in 2004. The establishment of this Indian subsidiary was to serve dual purposes, to access to Indian expertise and to serve as the access point for the firm to enter the Western bioinformatics markets.

Out of 309 companies that were involved in biotechnology businesses, 197 were either listed companies themselves or were an affiliation of a listed company (64%). The remaining 112 companies, on the other hand, were privately-owned operations (36%), as shown in Figure 2. One important characteristic of these firms is that they were younger, smaller, and had a higher percentage of BioNexus status, in comparison to those that were listed company affiliations.

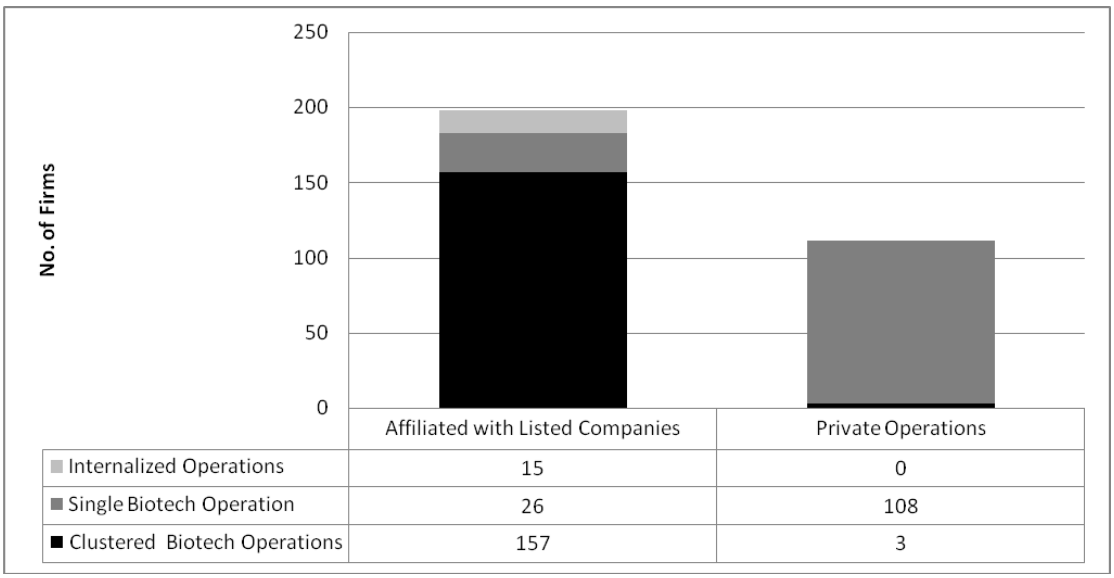
Table 6: Types of Companies, Business and Markets

Status of Companies	Type of Business	Types of market		Total	Total/ Status of Companies
		Local	Foreign/Export		
Main Board	Healthcare	2	-	2	
	Agriculture	7	2	9	
	Industrial	1	-	1	
	Agriculture+Industrial	2	-	2	14(4.5%)
Second Board	Healthcare	1	-	1	
	Agriculture	3	-	3	4(1.3%)
Mesdaq	Healthcare	2	-	2	
	Agriculture	2	-	2	
	Agriculture+Industrial	1	-	1	4((1.3%)
Private Companies	Healthcare	81	-	81	
	Agriculture	75	15	90	
	Bioinformatics	1	2	3	
	Industrial	36	3	39	
	Healthcare+Agriculture	2	-	2	
	Healthcare+Bioinformatics	1	-	1	
	Healthcare+Industrial	2	-	2	
	Agriculture+Industrial	14	1	15	233(75.4%)
MSC	Bioinformatics	2	-	2	
	Healthcare+Bioinformatics	2	-	2	
	Agriculture+Bioinformatics	2	-	2	6(2%)
Bionexus	Healthcare	10	3	13	
	Agriculture	11	2	13	
	Bioinformatics	2	0	2	
	Healthcare+Agriculture	5	4	9	
	Healthcare+Bioinformatics	3	2	5	
	Agriculture+Bioinformatics	1	1	2	
	Agriculture+Industrial	-	1	1	45(14.5%)
Bionexus+MSC	Healthcare	-	1	1	1(0.3%)
Bionexus +Mesdaq	Agriculture	-	1	1	
	Agriculture+Bioinformatics	-	1	1	2(0.6%)
Overall total		270 (87%)	39 (13%)	309 (100%)	309 (100%)

Table 7: Time of Company Establishment and Value Chain

Year of Incorporation	Value Chain							Total
	A	B	C	A+B	B+C	A+B+C	A+C	
Under 2 years	6	1	2	5	3	3	0	20 (7%)
2-4 years	4	15	7	11	5	8	0	50 (16%)
4-6 years	9	7	4	13	6	4	0	43 (14%)
6-8 years	2	11	1	6	0	8	1	29 (9%)
8-10 years	1	4	3	1	3	1	0	13 (4%)
More than 10 years	14	33	26	28	38	14	1	154 (50%)
Total	36 (11%)	71 (23%)	43 (14%)	64 (21%)	55 (18%)	38 (12%)	2 (1%)	309 (100%)

Notes: For description of A, B, and C in the table, see notes below Table 3.



	Affiliated with Listed Companies	Private Operations
Internalized Operations	15	0
Single Biotech Operation	26	108
Clustered Biotech Operations	157	3

Figure 2: Affiliated with Listed Company vs. Private Operations

From the 198 firms that were affiliated with public-listed companies, 22 were involved in biotechnology business themselves (11%), while 175 had a listed company as their parents (89%). From the group of 198 firms, 157 firms belonged to a group of 46 families of companies (i.e., firms that are sister companies to each other and are strategically managed as a group). The remaining 26 were single-operation biotechnology subsidiaries, while 15 companies conducted the biotechnology activities all by themselves. Thus, the total number of public-listed companies that were either themselves involved in biotechnology businesses without any subsidiaries (15 companies) or that have a single subsidiary that managed the biotechnology activities (26 companies) or that were parents to more than one biotechnology subsidiaries (46 companies) was 87 firms. See Table 8.

Of the 85 analyzed public listed companies, results show that the biotechnology industries were dominated by companies that were listed within the sectors of *Trading/Services*. This was followed by sectors of *Consumer Goods*, *Industrial Goods*, and *Plantations*, as shown in Table 8. However, when the *Trading/Services* firms were further evaluated, it was found that they were mainly diversified conglomerates, with their core businesses were in *Consumer Goods*, *Industrial Goods*, and *Plantations*. Therefore, it could be concluded that these three sectors were the three largest players in Malaysian biotechnology businesses.

Of the 46 families of companies that were identified in this study, their mean number of "children" (subsidiaries) is 157/46 or 3.48. Moreover, 17 companies (43%) from these families were fully-integrated biotechnology firms, and they owned subsidiaries that had operations covering all aspects of the biotechnology value-chain (See Table 9). When evaluated, it is found that all 40 families' subsidiaries had activities that were related. Each of the subsidiaries served as a part of the biotechnology value chain, and/or supported 1) the firm's expansion into a particular value-chain, 2) the company's acquisition of needed technology, 3) the firm's expansion into new markets locally, and/or 4) the firm's market development strategy into new geographical areas. For example, Hai-O Enterprise Bhd. had five related subsidiaries in biotechnology businesses. This included Hai-O Marketing that was

responsible for marketing activities of the group, QIS Research Lab, the company's research arm, Sanjiu Hai-O TCM, the development and production unit, while SG Global Biotech is its manufacturing house. Its Peking Tongrentang subsidiary, which is a Chinese medicinal clinic was formed to support the firm's strategy in penetrating further into that market in Malaysia. The Peking and Sanjiu subsidiaries involved collaborative joint-venture with mainland Chinese firms, which allowed the acquisition of know-how and the necessary expertise to operate its Chinese clinic and to develop and produce new medicines, respectively.

Table 8: Listed Companies, By Sector and Types of Operations

Companies' Status	Sectors	Companies' Operations			Total
		Internalized Operation*	Single Subsidiary Operation**	Family of Companies Operation***	
Main Board	Construction	-	-	2	2(2.3%)
	Consumer Product	1	5	11	17(19.5%)
	Industrial Product	4	4	9	17(19.5%)
	Plantation	4	2	8	14(16%)
	Trading/ Service	-	12	11	23(26.5%)
	IPC	-	-	2	2(2.3%)
Second Board	Consumer Products	2	-	-	2(2.3%)
	Industrial Products	-	2	-	2(2.3%)
	Trading/Services	1	-	-	1(1.2%)
Mesdaq	Industrial Products	2	-	1	3(3.5%)
	Trading/Services	1	1	-	2(2.3%)
	Technology	-	-	2	2(2.3%)
		15 (17%)	26 (30%)	46(53%)	87(100%)

Notes: *=The listed company conducts the biotechnology business themselves, and does not operate any subsidiary dedicated for biotechnology activities; **=The listed company operates a single subsidiary that manages the biotechnology activities; ***=The listed company operates more than one subsidiary that are involved in biotechnology activities.

The biggest family size is of Chemical Company of Malaysia Bhd, which has nine biotechnology children under its corporate umbrella. These subsidiaries either reflect expanded value-chain, and/or the company's acquisition of needed technology or know-how. In the case of Hovid Bhd, it has three subsidiaries, two are serving different markets, while one is its marketing arm. Table 9 provides the list of all 40 families of firms, and the value chain that each is having subsidiaries in. For companies that have penetrated overseas' markets, their operations were mostly managed by their subsidiaries, which were incorporated in the foreign countries.

Moreover, 26 of these 46 families (57%) had their own research arm. This indicated a lack of reliance amongst these companies on the research conducted by the universities and research institutes. By the end of January 2009, there were 12 public universities that conducted biotechnology research that spanned from agriculture-biotechnology to DNA recombinant exploitation. Of these 12, five had a department or institute dedicated to biotechnology research, which were Universiti Kebangsaan Malaysia (UKM), Universiti Putra Malaysia (UPM), Universiti Malaya (UM), Universiti Sains Malaysia (USM), and Universiti Malaysia Sabah (UMS). By the end of January 2009, the amount of grants given by the Malaysian government to these universities for biotechnology research was amounted to more than USD50 million. Additionally, there were 14 research institutes that conducted biotechnology research, with 13 were government-owned institutes and one was a privately operated entity. These research institutes carried out researches that were more of applied

types in comparison to the university-based researches, which were more of science-based ones. However, for these research institutes, most if not all are conducting R&D for their own consumption. The Malaysian government also provided several grant schemes for biotechnology product commercialization. However, on the whole, the universities' reports show that very few of universities' biotechnology research outputs were either patented, or successfully commercialized.

Table 9: Value-Chain Analysis for Families of Firms

No.	Family	Value Chain		
		Research	Production	Distribution
LISTED COMPANIES				
1.	Aliran Ihsan Resources Bhd.		■	
2.	Analabs Resources Bhd.		■	
3.	Ancom Bhd.		■	■
4.	Apex Healthcare Bhd		■	■
5.	Boustead Holdings Bhd	■	■	
6.	Chemical Company Of Malaysia Bhd	■	■	■
7.	CNI Holding Berhad		■	■
8.	DXN Holding Bhd	■	■	■
9.	Ecofirst Consolidated Bhd	■	■	■
10.	Ecofuture Bhd.	■	■	■
11.	Esthetics International Group Bhd.	■	■	■
12.	Goldis Bhd.	■	■	■
13.	Hai-O Enterprise Bhd	■	■	■
14.	Harrisons Holdings(M) Bhd.			■
15.	Hexza Corporation Bhd.		■	■
16.	Hovid Bhd.			■
17.	IOI Corporation Bhd.	■	■	■
18.	Jaya Tiasa Holdings Bhd.	■		
29.	Kim Loong Resources Bhd.		■	■
20.	Kulim (M) Bhd.	■	■	■
21.	Leong Hup Holdings Bhd.			■
22.	Lion Corporation Bhd.	■	■	■
23.	Loh & Loh Corporation Bhd.	■	■	■
24.	Malayan Flour Mills Bhd.	■	■	■
25.	Malaysia Steel Work (KL) Bhd.	■	■	
26.	Octagon Consolidated Bhd.		■	
27.	Pharmaniaga Bhd.	■	■	■
28.	PPB Group Bhd.		■	■
39.	Puncak Niaga Holdings Bhd.	■	■	
30.	QL Resources Bhd.			■
31.	Ranhill Bhd		■	
32.	Salcon Bhd		■	■
33.	Sime Darby Bhd.	■	■	■
34.	Sin Heng Chan (Malaysia) Bhd.		■	■
35.	Taliworks Corporation Bhd	■	■	
36.	TH Group Bhd.	■	■	■
37.	TSH Resources Bhd.	■	■	
38.	Weida (M) Bhd.		■	■
49.	Y.S.P Southeast Asia Holding Bhd		■	■
40.	Zhulian Corporation Bhd.	■	■	■
41.	INS Bioscience Bhd	■	■	■
42.	Equator Life Science Bhd	■	■	■
43.	Eksons Corporation Bhd.		■	
44.	Sarawak Plantation Bhd.	■	■	
45.	IJM Plantation Bhd.	■	■	■
46.	PBA Holding Bhd		■	
UNLISTED COMPANY				
1.	Infovalley Holding Sdn. Bhd.	■	■	

Even though a high number of university-industry relations had been promoted through the Biotech Corporation program, the number of new ventures that were established under this agency's support was still very low. While some efforts had been taken by the Biotech Corporation, the Malaysian-government agency, to provide the necessary supports in developing new biotechnology ventures, the agency's main focus was on promoting "high-end" technology. All the firms that achieved the Biotech Corporation BioNexus status were companies involved in leading-edge biotechnology. By January 2009, only 48 companies were registered under its programs. As the incentives allocated under the Biotech Corporation are provided only to these BioNexus companies, the program's benefits were not available to many other biotechnology companies. A biotechnology platform license purchased by Biotech Corporation, which costs a substantial amount of money, is likely to benefit only these few leading biotechnology firms under its umbrella (Biotech Corporation, 2007). The Malaysian government had also invested another USD 30 million in setting up a biotechnology manufacturing facility, called InnoBio, in Nilai, which serves as the platform for biotechnology businesses to outsource their manufacturing. InnoBio is also currently involved in constructing the new Inno Bio Innovation Center, an incubation facility that costs about USD40 million (The EdgeDaily, March 30, 3008).

When the establishment date of the listed companies' subsidiaries was examined, the results show that the subsidiaries were added to each families of company incrementally. Therefore, among the privately-owned operations, given their "younger" age, only one company, InfoValley has a family of companies, and similar to those listed companies, an addition of new family members was done over time. Moreover, consistent with the incremental expansion of the biotechnology value-chains, there was also a trend of incremental evolution toward internationalization among these 46 listed companies. For those listed companies without subsidiaries, they usually focused on specific value-chain processes. For example, Amway concentrated its effort on its distributorship business.

6. Discussion

Our finding of healthcare and agri-bio businesses dominating the Malaysian biotechnology industry is similar to that of Hall and Bagchi-Sen (2002) in their research on the Canadian biotechnology industry. On the other hand, ours do not concur with those findings on the biotechnology industry in the US. These findings indicate that the healthcare sector was the one that dominated the US industry (Hall & Bagchi-Sen, 2002). A higher percentage in agriculture-biotechnology is perhaps expected for a country such as Malaysia because it has rich agriculture diversity. Many Malaysian large firms are involved in agricultural businesses. Perhaps, this was one of the reasons that made Malaysia's core economic activity as agricultural prior to industrialization policy that was introduced in mid-1970s.

The Malaysian main board and second board do not have a specific sector called biotechnology. It was found that diversified public-listed conglomerates, which initial core businesses are in consumer goods, industrial goods and also plantation, are the most likely ones to move into biotechnology businesses. Others that also most likely to do the same are companies listed within the sectors of *Consumer Goods*, *Industrial Goods*, and *Plantations*. Thus, close relationship exist between the parent companies' agriculture consumers, industrial goods, and plantations and the establishment of related-biotechnology subsidiary or a portfolio of subsidiaries that is involved in either on research, production, or distribution businesses of biotechnology products. The fact that agriculture, consumer, and industrial biotechnologies are dominated by large companies indicates heavy reliance on resources of parent companies as a part of biotechnology value-chain. Therefore, starting up a

biotechnology business for a Malaysian firm requires the existing capabilities or operation experiences in one or more of the three sectors.

The biotechnology companies that are listed in MESDAQ are part of a sector category called Technology (2 companies); while the remaining two companies are under the category of Consumer Products. The low number of biotechnology companies listed in MESDAQ is indicative of the embryonic state of the pure biotechnology companies. It also shows perhaps the still inefficient state of MESDAQ as an exchange platform.

Moreover, the evolution of the firms in the biotechnology value-chain and the process of their internationalization happen over time. This shows that their business developments occur incrementally, in terms of extending the depths of their biotechnology operations and also expanding the width of their geographical markets. These firms' most aggressive expansion seemed to happen in the mid-2000s. The setting up of the biotechnology subsidiaries were more aggressive in the recent years, and pursued by firms in "unrelated" areas, such as construction and Infrastructure Project firms. This perhaps indicates that they are following the worldwide trends of diversifying into the biotechnology businesses.

On the other hand, small new biotechnology firms may be involved in a very specialized biotechnology value chain. However, over time, these firms would establish subsidiaries that serve multiple value chains. While these small companies can be born global—they are either local companies that serve overseas markets right from their inception, or global companies, set up in Malaysia, and serve foreign markets. Most of these firms follow a gradual pattern for internationalization, although theirs is more rapid compared to the bigger, older and firms. Going into the overseas markets, is perhaps a more viable strategy for the newcomer biotechnology firms. This is to avoid head-to-head encounter with the larger local firms.

Close relationship also exists between the size of company, age and involvement in the upstream market with the setting up two or more related subsidiaries in the biotechnology business. Only those that are more than five years old and/or listed companies operate family of subsidiaries. These related subsidiaries may include a company or companies that support their holding companies' value-chain extension, technology transfer and/or biotechnology internationalization efforts. Establishing subsidiaries, rather than internalizing these functions as divisions, was performed mainly through joint-ventures with others who have the necessary capabilities. This implies that collaborating with others is critical strategies for these companies in expanding further into the biotechnology markets. Moreover, joint-venturing with the locals is an important strategy pursued by these holding companies when venturing into overseas markets. This is performed to enable them to obtain the necessary capabilities, which are currently non-existent in the companies.

Furthermore, our finding shows that production-based and, research plus production-based activities dominated the biotechnology market (44%). However, this is not similar to the Canadian finding, in which 62% of their companies were involved in research and product development, 22%, were involved in the manufacturing, and the remaining 16% were active in marketing (Hall & Bachi-Sen, 2002). A biotechnology business may specialized in certain value chain of the innovation process (research, production or distribution) or at the other extreme may be involved in all of the activities. Having all of the necessary *functional capability*, *research-based*, *production-based*, and *distribution-based*, under one roof for many large companies indicates a lack of research-based output from research institutions, or the lack of collaboration with them. This forces the companies to develop their own capabilities in-house. With most of these functions performed by their subsidiaries, rather than by their own in-house divisions, indicates the need for the companies to collaborate with outside parties to gain the necessary capability in the specific value-chain. While all the

research-based public universities are involved in biotechnology research, most of their research were fundamental in nature. This and perhaps because of the lack of efficient university-industry linkages, forces the biotechnology firms to rely on their own R&D team in supporting their needs. The companies that fully internalized their R&D operations may indicate the availability of needed resources internally or they are involved in less-R&D intensive activities (Hall and Bagchi-Sen, 2007), for example, in distribution-based value chain exclusively, or perhaps the companies are involved in "low-end" biotechnology which does not require collaboration with outsiders to gain R&D capabilities.

The majority of the healthcare and bioinformatics firms are agglomerated within the Klang Valley region and this shows that the location still have a lot to offer to these firms. This is particularly true in terms of proximity to the high skilled workers, the healthcare companies, and their own customers. For agricultural-based biotechnology companies, most of the productions were still conducted at or near the locations of the plantations. This implies the need for the firms to operate near their plantation sites.

The industry receives extensive Malaysian government support and involvement in its development. However, some form of this 'luxurious' support might encourage the agencies to spend "unnecessary" amount of money, just because the government had allocated the money. For example, in its attempt to help the industry develop the latest biotechnologies, the government resorted to 'helping' the industry members buying a new technology platform. This platform not only would benefit a few companies, but also, the technologies that are transferred also required operational capabilities in the part of the recipients. In some cases, these firms may not possess the necessary capabilities to ensure that the technologies would be further developed and commercialized.

7. Conclusions

The Malaysian biotechnology industry is, not only, fragmented with many "traditional" biotechnology sectors, but also, overcrowded. These characteristics indicate the need for industry members to focus on innovations, as a way to distinguish them from the competitors, and also to ensure the viability of the industry as a whole in the long-run. The emphasizing on a firm's innovation to differentiate it from others supports the Schumpeterian-strategy perspective. This is important as otherwise the competition would concentrate on price, which is to be avoided by every industry members, as it will put the whole industry in a losing position.

The industry receives extensive Malaysian government support and involvement in its development to enable biotechnology firms to be on the leading-edge of technology; The government support includes acquiring a license for a technology platform, providing financial incentives, creating incubation facilities, and operating manufacturing facilities. However, the Malaysian biotechnology businesses still must develop the necessary capabilities to ensure that the technology platform and the supportive commercialization structure is fully utilized.

Therefore, the Schumpeterian's view of strategy, which suggests the need to introduce innovations as a way to sustain both the business and industry, must be modified to suit the business situation of the firm. It is recommended that the biotechnologies platforms are to be either developed by the Malaysians themselves or Malaysians to be heavily involved in the development, to ensure that the technologies could be fully commercialized by them. Industry development through technology acquisition must be made in accordance with the level of knowledge possessed by local firms.

Moreover, in Malaysian biotechnology industry, there are huge business opportunities within the fields of *bioinformatics* with only 20 companies being involved in such businesses, and also in the combined areas of *healthcare and agriculture*, and *bioinformatics, industrial and agriculture*, as well as *bioinformatics and industrial*.

The fact that 87% of the companies are selling to the local markets indicates the markets are currently very crowded. Thus, given that their country is a small one with a population of about 27 million people, to sustain their existing businesses, Malaysian biotechnology companies should look abroad for customers. Moreover, new firms that plan to enter the industry should not compete in the markets for agricultural and healthcare products. This is because these markets are dominated by large companies. With their larger resources, they could make it difficult for the small companies to operate in these particular markets. Therefore, new companies are better off if they operate in bioinformatics fields, in which the major distinguishing factor would be the skills and knowledge of employees, rather than having assets like plantation (which may take high capital and longer time periods to be developed).

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