

Sustainable Development Impacts of Investment Incentives

A Case Study of the Pharmaceutical Industry in Singapore

Hank Lim and Lim Tai Wei
Singapore Institute of International Affairs

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Acronyms and Abbreviations

A*STAR	Agency for Science, Technology and Research
AIA	ASEAN Investment Area
ASEAN	Association of Southeast Asian Nations
BMRC	Biomedical Research Council
BMS	biomedical sciences
EDB	Economic Development Board
FDI	foreign direct investment
GDP	gross domestic product
MNC	multinational company
R&D	research and development
SGD	Singapore dollar
USD	U.S. dollar

Executive Summary

The Singapore government has embarked on an integrated strategy to develop a globally competitive pharmaceutical and biomedical industry in Singapore, with a focus on human healthcare applications as its niche. The biomedical sector is to make up for the relative decline of the manufacturing sector in Singapore, caused by the gradual erosion of the electronics industry, which used to contribute nearly half of Singapore's manufacturing output. The government's strategy has been multifaceted and has included initiatives both to attract foreign investment and nurture a domestic industry. It has also involved boosting investment across the various supporting services to ensure the industry's long-term growth in the face of competitive pressures.

Singapore has invested over SGD 3 billion (USD 2.1 billion) in the biomedical sciences (BMS) initiative that was launched in 2000, including a second tranche of SGD 1.5 billion (USD 1 billion) in 2006 to build up translational and clinical sciences capabilities. The continuing expansion of the sector will depend on whether investment poured into the industry can be translated into commercial success. Much of the government's efforts to bolster research and development (R&D) is centred on the multimillion dollar Biopolis hub. Biopolis, which opened in late 2003, consists of a cluster of seven purpose built buildings to house 2,000 researchers working in privately and publicly funded R&D activities. Already close to its current capacity, Biopolis will ultimately serve as the hub of a 200 hectare BMS cluster. Biopolis today hosts international centres such as the Swiss House, the UK's Science and Technology Office and the Regional Emerging Disease Intervention Centre, as well as international scientific conferences and symposiums.

In terms of funding, Singapore's Economic Development Board (EDB) has led the government's efforts to develop a BMS and pharmaceutical cluster. The EDB has established three principal implementing agencies to focus on developing areas regarded as key to the sector's continued growth: the BMS Group, established in 2000 within the EDB; the Agency for Science Technology and Research (A*Star), which seeks to provide high quality human capital for the biomedical industry, primarily through the management of five research institutes and the provision of research funding for university and hospital researchers; and Bio*One Capital, a fund management company with assets of USD 700 million, which makes strategic investments in biotechnology companies and start-up ventures, with the goal of creating highly skilled jobs and transferring technology and expertise to Singapore.

Have Singapore's biomedical policies worked?

Life sciences and biomedical industries are a business with a long gestation period and it would therefore be unrealistic to expect a windfall or the discovery of a blockbuster drug or therapy within a few years of launching. The Singapore government has committed to providing long-term investments to grow the biomedical industry. Initially, the focus is on foundational work by putting in place core expertise in biomedical research and building a global reputation as a long-term player in this industry.

Singapore's biomedical policies are aimed at luring foreign investors to set up operations in the city state. Investment incentives—including generous tax benefits, infrastructure provision and the training of personnel—are a central part of this strategy. Core research capabilities developed in Singapore's public research institutes have resulted in collaboration with multinationals such as GlaxoSmithKline and Novartis, which have set up R&D facilities in Biopolis, often paving the way for value added activities. By 2007, the pharmaceutical and biomedical sector had drawn in the largest share of foreign direct investment (FDI) and pharmaceutical products had generated one of the highest returns within the

manufacturing sector. This is a promising development, although it remains unclear whether these investment trends will be sustainable.

Between 2000 and 2007, employment in the biomedical sector almost doubled from 5,880 to 11,500 people. Investment in 2007 alone contributed more than 1,700 jobs. Over the next few years, the expansion of the BMS sector is predicted to contribute more than 5,000 jobs for engineers, scientists, technicians and corporate executives across manufacturing and R&D. The type of employment created by the BMS sector could bring additional spillovers, including the goods and services consumed by foreign skilled workers with higher disposable incomes and the brainpower they bring to the city state that could spur further entrepreneurial efforts in Singapore. However, although high in value added, the BMS sector has limited employment prospects for the workforce compared to other manufacturing subsectors, especially electronics, whose decline the BMS sector is meant to mitigate.

The government's efforts to strengthen the BMS sector are part of a larger strategy to diversify the economy since the 1997–98 financial crisis. The aim is to reduce the country's susceptibility to external volatility and bolster its competitiveness in the face of increasing regional competition. The government's success in attracting the leading multinational pharmaceutical firms to the city state has been the main engine of growth in this diversification strategy by introducing alternatives to electronics and chemical manufacturing. In addition to GlaxoSmithKline and Novartis, foreign firms that have recently established operations include Pfizer, Merck, Aventis, Eli Lilly, Wyeth, Roche and Schering-Plough.

There may also be a danger that governments may pay too many incentives and actually reduce national welfare, a situation that is more likely when there is a multitude of governments bidding for FDI. Thus, incentives should be part of a comprehensive industrial policy that may include incentives to domestic companies to make them better able to absorb spillovers. Singapore is one of the freest economies in the world. It cannot institute economic policies that discriminate against local companies, even in a sunrise sector like the biomedical industry. In practice, however, the beneficiaries are overwhelmingly foreign companies. There is a perception that the domestic sector is therefore less equipped to extract benefits from the incentives and that the government is less attentive to small and medium-sized domestic firms in its overall economic strategy. Thus, additional policies may be needed to help local firms build up their capabilities to similarly benefit from the biomedical sector's incentives.

The stimuli to nudge Singapore in the BMS direction are also present in the advanced developing country members of the Association of Southeast Asian Nations (ASEAN) such as Malaysia and Thailand. These countries may find Singapore to be an interesting case study that they could learn from. Singapore's experience shows that success in the competitive arena of life sciences, and in particular biotechnology, can benefit from at least four factors: strong public administration and governance, effective institutions, infrastructure development, and clustering.

Looking ahead

To continue to invest and build on the basic biomedical science research capabilities in A*STAR and Singapore's universities, Singapore should focus on developing highly competitive programs in selected disease areas where Singapore has comparative advantages, given the presence in its population of three Asian ethnic groups and the higher prevalence of specific types of medical disorders. This effort should be funded through the Singapore government's commitment of allocating SGD1.55 billion to support translational and clinical research, with a performance review every five years. By investing in niche

ethnic-related, disease-specific research, the government would have taken up the burden of doing the basic foundation groundwork for the private sector by laying out specific diseases that affects the major ethnic groups in Asia, all present in multi-racial Singapore. This can then draw private sector companies, both foreign and local to continue and expand on such research to develop new drugs or nutritional products.

Progressive regional integration through ASEAN can also provide opportunities for Singapore to strengthen the biomedical sector. The ASEAN Investment Area was created to ensure that investments flow freely within the region and allow investors to harness the various complementary advantages of ASEAN member countries in order to maximize business and production efficiency at lower costs. In addition, Singapore can tap into the ASEAN market, one of the fastest growing in the world with an expanding middle class of demanding consumers who are well connected to the rest of the world.

1. Introduction

In the mid-1960s, Singapore began to seriously turn its attention towards export oriented industrialization. As part of this strategy, the city state threw its doors open to foreign investors, luring them with generous tax benefits and other investment incentives. More recently, the government has turned its attention to knowledge intensive industries in an effort to create employment, remain competitive in the face of rising wages and enable its own companies to move up the value chain. Investment incentives continue to play an important role in Singapore's strategy; by 2007 Singapore had clinched the global top spot for attractive investment incentives in the *World Competitiveness Yearbook*.

The life sciences and biomedical industry (hereafter referred to as the biomedical industry) is one such knowledge intensive sector that has seen significant government investments to create an attractive business environment for foreign investors. The Singapore government has committed itself to long-term investments to grow this sector, with an initial focus on foundational work. The emphasis has been on developing local expertise in biomedical research and building a reputation as a key player in this industry, with a view to attracting global talents and large multinationals.

In discussing this sector, it is important to note that the industry is inherently difficult to evaluate, given that it usually takes about 10 years before biotechnology research can be translated into commercial profits. The biomedical industry is a business with a long gestation period and therefore it would be unrealistic to expect a windfall or the discovery of a blockbuster drug or therapy within a few years of launching. This is therefore a comparatively new industry in the global context, and especially recent in Southeast Asia, particularly on the higher value-added components of biomedical research. Thus, large data sets are not available and there are challenges in accessing the public and private sectors. This report was produced within this constraint.

Nevertheless, although the sector's development is still at an early stage, a number of preliminary conclusions can be drawn on whether the government's strategy to provide generous incentives to foreign investors—and in particular financial incentives—has indeed helped to attract foreign investments and how these investments in turn have impacted employment creation, brought about economic diversification and generated spillover effects for the wider economy. The paper will also assess to what extent Singapore's experience might be transferable to other Southeast Asian economies.

2. The role of Foreign Direct Investment

Governments compete for investment using location subsidies for two reasons: their need for investment and the fact that capital is mobile. The first element requires governments to negotiate with owners of capital over the conditions of investment. The second element, in turn, creates the competitive aspect of this relationship insofar as a given investment potentially could be located in more than one jurisdiction. At the same time, governments also face political pressure to “win” investment and thereby gain employment and tax revenue, further driven by substantial press coverage emphasizing the importance of providing incentives to attract investment (Thomas, 2007).

A number of policy objectives motivate the use of investment incentives. Firstly, incentives affect investment location, given that a site location decision maker will, in the final stages of the decision-making process, only be talking to locations that are inherently profitable. Even if all the other finalists are inherently profitable locations as well, something needs to differentiate them (Thomas, 2007). Investment capital, being mobile and market driven, gravitates towards countries or economies that

provide investors with higher and secured net returns. Secondly, investment incentives may promote efficiency if they increase activities with positive externalities, such as research and development (R&D) or training, beyond what the recipients would have done in the absence of the subsidy.

Foreign direct investment (FDI) is a composite bundle of capital, know-how and technology. Its main contribution to growth is through the transfer and diffusion of technology, knowledge and skills in the countries attracting the FDI (Jensen, 2006). It is important to note that globalization also leads to an increasing number of locations that are inherently profitable for any given investment. Singapore has to cope with the trend of increasing competition among developing and industrialized countries for particular investments, particularly in the manufacturing sector. Through its incentives policy, Singapore is trying to differentiate itself in particular from other new emerging economies in the East/South Asian regional biomedical industry.

FDI has played an important role in many of the economies of the region as a vital source of capital and a key factor driving export led growth in Southeast Asia. FDI also provides a mechanism for technology transfer and access to established external markets. Foreign firms have by no means been the only actors, but they have played a leading role in those sectors with the fastest export growth. Through such investments, host economies have rapidly been transformed from agricultural producers and suppliers of raw materials into major producers and exporters of manufactured goods (Thomsen, 1999).

2.1 The role of FDI in Singapore

The Singapore government's objective of attracting multinational companies (MNCs) to establish manufacturing facilities in Singapore is not only to provide employment, but is also undertaken with the hope that sophisticated foreign technology would "trickle down" to local companies. Being at the forefront of innovation, their presence can provide a way of keeping up with technological progress. In addition to these advantages, MNCs also possess internationally established brand names, a global marketing presence and superior knowledge of marketing channels, as well as access to international flows of information (Dean, 2000).

In the early years of industrialization, Singapore depended on labour intensive industries to create much needed jobs for the population and attracted FDI to build up its economy (Lim, 2005). As part of this strategy, the Singapore Economic Development Board (EDB) was set up in 1961 with a budget of SGD 100 million (USD 71 million) to convince foreign investors that Singapore was a good place for business (Than, 1999). In the 1960s foreign companies started coming to the city state, with cumulative investment in manufacturing rising from SGD 157 million (USD 112 million) in 1963 to SGD 995 million (USD 708 million) in 1970 and SGD 3 billion (USD 2.1 billion) in 1974 (Rodan, 1997).

At the same time, employment opportunities grew significantly. Unemployment rates fell from nine per cent in 1965 to less than four per cent in 1974 (Rodan, 1997). By the 1970s, unemployment was no longer a problem and industrial development was surging ahead. EDB marketed Singapore as a quick operations startup location where factories were built in advance of demand and a highly skilled workforce was readily available. FDI promotion had become an important economic development strategy and the enthusiasm to attract investment became evident in the rise of government sponsored marketing campaigns to attract MNCs.

The industries that Singapore had managed to attract through its foreign investment policies until the beginning of the 1980s were labour intensive, of a low technological standard and required relatively low

skill levels. It was at this point that Singapore's "Second Industrial Revolution" was devised, which comprised a strategy to increase the technological sophistication of the island's manufacturing base with a shift to knowledge intensive activities such as R&D, engineering design and computer software services. The vision was for Singapore to become 'a total business centre' and a major regional business hub where MNCs would base their entire operations for East Asia and the western Pacific (Rodan, 1997). The government was also seeking to encourage wage increases, in contrast to its earlier policies of suppressing labour costs.

Overall, Singapore has made remarkable progress since the early 1960s. Some 7,000 MNCs now operate in the country, with about half having regional operations (EDB, n.d.). Singapore is now Southeast Asia's fourth largest economy (Adam, 2008).

2.2 Towards a knowledge-based economy

In a knowledge-based economy, the basis for competitiveness will be the ability to absorb, process and apply knowledge. Traditional factors of production such as land, raw materials and muscle power will therefore no longer be the primary sources for the creation of wealth; instead, the key success factor will be the knowledge residing in individuals and systems. Science and technology in particular, which has led to quantum leaps in productivity and competitiveness even in existing industries, will be the key driving force (Teo, 1999).

Singapore's focus on the knowledge-based economy is motivated by the reality that the city state cannot compete on labour or capital; rather, it must now compete on skills. Singapore has to continually upgrade into high value added manufacturing and services to move up the value chain. At the same time, globalization is triggering the restructuring of companies, industries and national economies, causing corporations to downsize, relocate and re-engineer production processes (Chia, 2001).

Therefore, the knowledge-based economy has become a crucial avenue for creating wealth and sustaining the economy. As Singapore moves out of the low wage, low cost league of economies, it has to compete with advanced industrialized countries and their knowledge-based enterprises. In these enterprises people and their ideas and capabilities should be the key source of wealth and opportunities (Chia, 2001).

2.3 How is Singapore going about setting up a knowledge-based economy?

Singapore is now in a transition between the investment driven and innovation driven phases of development. However, moving on to the next phase of development will not happen automatically (Lim, 2002a). Instead of resources driving growth, total factor productivity, particularly innovation, becomes more important. Instead of focusing only on managing labour and capital, Singapore now also needs to understand how to manage knowledge and intellectual capital.

To move Singapore towards a knowledge-based economy, the government is developing two key ingredients: a knowledge infrastructure, and human and intellectual capital (Teo, 1999). Building a knowledge infrastructure allows knowledge to be transmitted, shared and built upon among the masses, among individuals in a company or organization, across companies in the same or different sector, and among countries. It consists of the physical networks and their interconnections with knowledge or "thought" centres such as universities, research institutes and business centres around the world.

Singapore has rolled out various initiatives to build a comprehensive knowledge infrastructure that will support this sharing and exchange of information and knowledge, including the nationwide broadband network Singapore ONE. In addition, its network of educational and research institutes are linked to the major knowledge and business centres of the world.

In the early 1990s, Singapore's spending on research lagged behind that of other newly industrialized Asian economies such as Taiwan and South Korea. By 2002, the city state's R&D expenditure had surged to SGD 3.2 billion (USD 2.3 billion), accounting for 2.1 per cent of its total goods and services produced. This performance is on a par with the U.S. and Japan, which typically spend between two and three per cent of their gross domestic product (GDP) in this area. Also, similar to the U.S. and Japan, the bulk of R&D funds—62.3 percent—comes from the private sector, through companies such as Hewlett Packard and Agilent Technologies, which invest heavily in fine tuning old and developing new products (Lim, 2002b).

The 2004 National R&D Survey reveals that Singapore has 765 companies reporting R&D operations (as compared to 260 companies in 1990), with more than SGD 15 billion (USD 10.7 billion) in revenue reported from sales of their products or licensing of new technologies (Lim, 2005). The private sector now employs some 11,600 research scientists and engineers, or 61 per cent of a total of 19,000 scientists and engineers. National expenditure on R&D increased sevenfold from SGD 570 million (USD 405 million) to more than SGD 4 billion (USD 2.8 billion) over the past 15 years. In 1992, Singapore held only 20 patents awarded; by 2004 more than 1,250 patents had been filed and almost 600 awarded.

2.4 Importance of the biomedical industry

The Singapore government's policy decision to enter biomedical sciences (BMS) rapidly when it detected a slowing electronics sector allowed it to specialize early in the learning curve of the biomedical industry. The government has now embarked on an integrated strategy to develop BMS in Singapore, with a focus on the application of BMS in human healthcare as its niche.

Since the government began to develop the BMS sector in 2000, output grew steadily until 2007, when it reached SGD 24 billion (USD 17 billion), before dropping to SGD 19 billion (USD 13.5 billion) in 2008 (Table 1). This marked a significant increase from SGD 6.3 billion (USD 4.5 billion) in 2000, when the government began to develop the sector in a bid at economic diversification. The value added increased from SGD 3.8 billion (USD 2.7 billion) in 2000 to SGD 13 billion (USD 9.2 billion) in 2007, dropping to SGD 10.6 billion (USD 7.5 billion) in 2008 (EDB, 2008). More details on this will be discussed in section 4.

Table 1: Performance of the BMS industry, 2000–08

	2000	2005	2006	2007	2008
Manufacturing output (SGD billion)	6.3	17.7	23	24	19
Value added (SGD billion)	3.8	9.2	13.6	13	10.6
No. of employment opportunities	5,880	10,171	10,571	11,500	12,450

Source: EDB Singapore website

3. Investment Incentives for the Biomedical Industry

3.1 Incentives available to foreign and domestic investors

In Singapore, across the entire economy and range of industries, there are no laws or policies stating performance, local content or technology transfer requirements. Singapore's investment environment is among the freest in the world and the government welcomes foreign investments and participation.

The EDB provides a number of tax and grant incentive schemes for foreign and domestic investors to attract investments, including in the biomedical sector. These include the following (taken from Respondek, 2002):

- **Pioneer status:** this is allocated to new manufacturing and service investments introducing high tech skills, which qualify for complete exemption from the 25.5 per cent corporate tax on profits for 5–10 years.
- **Development and expansion incentive:** firms that engage in new projects or expand or upgrade operations in Singapore that result in significant economic spinoffs are eligible for a concessionary tax rate of 13 per cent for up to 10 years with the possibility of extension.
- **Investment allowance incentive:** companies engaged in industries like manufacturing, engineering services, R&D activities, construction or projects to reduce the consumption of water are eligible for exemption of taxable income equal to a specified proportion of new fixed investment.
- **Approved Foreign Loan Scheme:** a company that receives a minimum loan of SGD 200,000 (USD 142,000) from a foreign lender to purchase production equipment will be wholly or partially exempt from withholding tax on the interest payable to the lender.
- **Approved royalties:** full or partial exemption of withholding tax on royalties is given to eligible companies, usually subject to the condition that the tax relief does not result in an increase in tax liability in the foreign country.
- **Overseas investment incentive:** companies must be involved in overseas projects and must be 50 per cent owned by Singapore citizens or permanent residents and must be incorporated and resident in Singapore for tax purposes. Such companies can offset losses incurred from the sale of shares or liquidation of up to 100 per cent of equity invested overseas against their other taxable income.
- **Overseas enterprise incentive:** exemption of corporate tax on qualifying income earned from approved overseas investments and projects is granted for up to 10 years. Companies must be at least 50 per cent Singapore owned by Singapore citizens or permanent residents and incorporated and resident in Singapore for tax purposes.
- **Operational headquarters incentive:** entities providing management and other approved headquarters-related services to subsidiary, associated or related companies in other countries are taxed at the concessionary corporate rate of 10 percent, while global headquarters are eligible for full tax exemption.

- **Business headquarters status:** this is for companies in manufacturing and service activities that qualify for an incentive under the Economic Expansion Incentives Act and provide business and professional expertise, business and management direction and key support services to companies in the region.
- **Accelerated depreciation allowances:** instead of the normal 20 percent, companies can claim 33.3 per cent over three years for all plants and machinery; they may also claim 100 per cent in one year for prescribed automation equipment and robots, and certain environmental-related equipment.
- **Research and Development Assistance Scheme:** grants are offered to support specific projects on product or process R&D that lead to the enhancement of the company's competitiveness and inhouse capability development.
- **Initiatives in New Technology Program:** the object of this program is to establish new capabilities within companies or industries. It is designed to encourage personnel development in the application of new technologies; industrial R&D; professional know-how; and the design and development of new products, processes and services.
- **Research Incentive Scheme for Companies:** this scheme aims to encourage and assist Singapore registered companies and organizations to set up R&D centres in Singapore and to develop inhouse R&D capabilities in strategic areas of technology, with the longer term objective of strengthening the company's industrial competitiveness.
- **Innovation Development Scheme:** this aims to encourage and assist Singapore registered companies to engage in the innovation of products, processes and applications and develop depth in innovation capabilities.

3.2 Financial incentives for the biomedical industry

The Singapore government's strategy to establish a globally competitive pharmaceutical and biomedical industry has been multifaceted and has included initiatives both to attract foreign investment and nurture a domestic industry. It has also involved boosting investment across the various supporting services to ensure the industry's growth in the long term and in the face of competitive pressures. The continuing expansion of the sector will depend on whether investment poured into the sector can be translated into commercial success (Oxford Analytica, 2004). Singapore has invested over SGD 3 billion (USD 2.1 billion) in the BMS initiative that was launched in 2000, including a second tranche of SGD 1.5 billion (USD 1 billion) in 2006 to build up translational and clinical sciences capabilities (Lim, 2008).

3.2.1 Expenditure on infrastructure

Much of the government's efforts to bolster R&D activity are centred on the SGD 295 million (USD 210 million) Biopolis hub. Biopolis is an area dedicated to BMS that brings together various research and medical communities from the research institutes of molecular biology, genomics, bioinformatics, bioengineering, bioprocessing technology and chemistry. Biopolis opened in late 2003 with a cluster of seven purpose built buildings to house 2,000 researchers working in private and publicly funded R&D. The development hosts international centres such as the Swiss House, the UK's Science and Technology

Office and the Regional Emerging Disease Intervention Centre, as well as international scientific conferences and symposiums. Biopolis is set to expand to ultimately serve as the centre of a 200 hectare BMS cluster.¹

3.2.2 Subsidies for R&D

Prime Minister Lee Hsien Loong is leading the effort to bolster R&D capacities by chairing the new high level Research, Innovation and Enterprise Council. Between 2005 and 2010 the Singapore government will commit some SGD 12 billion (USD 8.5 billion) to R&D, which includes the expanded budgets of the Agency for Science Technology and Research (A*STAR) and the Ministry of Education. Another SGD 5 billion (USD 3.6 billion) for the new National Research Foundation aims to help gain a competitive advantage for Singapore for the next 15–20 years and create jobs and prosperity for Singaporeans (Lim, 2005).

The EDB has established three principal implementing agencies that have focused on developing areas regarded as key to the sector's continuing growth:

- the BMS Group, established in 2000 within the EDB;
- A*STAR, which seeks to provide high quality human capital for the biomedical industry, primarily through the management of five research institutes, and the provision of research funding for university and hospital researchers; and
- Bio*One Capital, which makes strategic investments in biotechnology companies and startup ventures, with the goal of creating highly skilled jobs and transferring technology and expertise to Singapore.

3.2.3 Support for training

To implement its biomedical plan, the government will need to attract, retain, develop and grow a pool of BMS employees to meet the demands of the rapidly expanding pharmaceutical projects. To this end, the government has expanded the local pool of production operators through the EDB's Company Training Scheme and urged the Ministry of Manpower to allow for flexibility on the foreign worker cap at both the industry and company level as a short-term measure to relieve personnel shortages (ERC, 2002).

R&D human capital development was given priority through a pro-local and pro-foreign talent policy (Lim, 2005). The first batch of A*STAR scholars was sent out in 2001 to pursue undergraduate and postgraduate studies in BMS, physical sciences and engineering disciplines. A*STAR has also started a new scholarship program for foreigners, bringing in 100–200 students a year by targeting non-traditional areas for recruitment, including Eastern Europe, Iran and Russia. In 2001, the government linked Genome Institute of Singapore was set up with funding from A*STAR. Located in Biopolis, the institute focuses on modern genome technology through research and the training of a new generation of Singaporean scientists.

1 For further information, see the Biopolis website, <http://www.one-north.sg/hubs_biopolis.aspx>.

In 2008, the Singapore government (through the EDB, Workforce Development Agency of Singapore and Health Sciences Authority of Singapore) also joined forces with multinational pharmaceutical companies such as Johnson & Johnson, GlaxoSmithKline and Novartis, among others, to establish the Singapore Academy for Good Industry Practices Excellence within the National University of Singapore. Under this framework, faculty members will be drawn from academia, health authorities and major industry players from across the region and the world. This comprehensive partnership ensures alignment with both international standards and local practices, and will train 500 professionals each year in various good industry practices to address the growing demand for talent in Asia.

4. Making up for the Electronics Sector: Have Singapore's Biomedical Policies Worked?

The biomedical sector was to help make up for the relative decline of the manufacturing sector in Singapore caused by the gradual erosion of the electronics sector, which used to contribute nearly half of Singapore's manufacturing output (Sitathan, 2002). This section attempts to assess how successful the government's policies have been to support a transition from hi tech electronics to knowledge-based biomedical industries, including in terms of attracting FDI, generating employment, supporting economic diversification and creating spillover effects for the wider economy.

4.1 Attracting foreign investment to Singapore

Using infrastructure provision, R&D support and the training of BMS personnel as investment incentives, Singapore's biomedical policies are calibrated to lure foreign biomedical investors to come to Singapore and set up their operations here. How successful has this strategy been?

By 2007, the pharmaceutical and biomedical sector had drawn in significant amounts of FDI (Table 2). The sector's share of total manufacturing investments increased steadily to 41 per cent in 2007, mirrored by a decline in the share of FDI in the electronics sector, which fell from 44 per cent in 2001 to 24 per cent in 2007. The statistics for returns on investments² also show that the pharmaceutical industry was profitable for investors compared to most other manufacturing sectors, in particular in 2007, when returns jumped to 43 percent, compared to an average of around 21 per cent for the previous four years (Table 3).

² The return on investment is a measure of the profitability of the investment and is calculated as the ratio of the current year's earnings to the average of the stock of capital invested in the current year and the preceding year. The returns are computed using after tax profits, as this is a better measure of the returns realized by investors.

Table 2: FDI by manufacturing industry, 2001–07 (stock as at year end, USD million)

	2001	2002	2003	2004	2005	2006	2007
Total FDI	222,319	235,105	251,652	285,877	311,084	370,471	457,024
Manufacturing	81,870	85,949	91,717	96,924	103,601	107,754	115,686
Food, beverages and tobacco	479	470	466	499	602	1,335	1,498
Textiles, clothing and leather	93	86	83	79	84	102	53
Wood and wood products	1	1	4	4	2	2	3
Paper and paper products, printing and publishing	723	766	634	666	796	649	669
Petroleum and petroleum products	12,281	12,623	13,640.4	13,668	13,953.9	14,336	14,148
Chemicals and chemical products	3,893	5,512	5,806	7,072	8,038	6,707	6,837
Pharmaceutical and biological products	18,115	23,447	29,322	31,874	38,682	38,340	47,435
Rubber and plastic products	924	908	967	1,033	881	1,154	985
Basic metals	35	29	35	40	22	335	625
Fabricated metal products	1,218	1,411	1,250	1,338	1,391	1,469	1,613
Machinery and equipment	2,506	2,667	2,783	2,693	3,480	4,295	5,180
Electrical machinery and equipment	1,563	1,331	1,600	1,652	1,524	1,276	1,336
Electronic products and components	35,996	31,801	29,657	29,908	29,153	32,267	28,241
Transport equipment	1,358	1,638	1,913	2,390	1,553	3,153	3,564
Instrumentation, photographic and optical goods	1,977	2,484	2,821	3,206	2,630	1,618	2,765
Others	709	777	737	800	809	718	734

Source: Singapore Statistics website, <<http://www.singstat.gov.sg>>

Table 3: Return on FDI by the manufacturing industry, 2003–07 (stock as at year end, percent)

	2003	2004	2005	2006	2007
Total return on FDI	12.7	16.8	17.9	17.5	19.7
Manufacturing	19.0	21.9	22.7	20.4	30.5
Food, beverages and tobacco	11.6	22.7	26.1	19.9	9.5
Textiles, clothing and leather	-13.2	-25.9	-7.2	-2.3	-0.4
Wood and wood products	-4.9	-2.9	-2.8	-2.6	-3.6
Paper and paper products, printing and publishing	4.0	4.2	6.3	15.5	4.0
Refined petroleum products	15.1	20.1	27.4	29.3	41.7
Chemicals and chemical products	13.6	36.5	21.8	20.5	17.1
Pharmaceutical and biological products	22.5	18.2	29.6	12.6	43.0
Rubber and plastic products	12.1	8.9	12.1	11.7	9.5
Basic metals	36.8	33.2	16.4	5.1	3.5
Fabricated metal products	3.9	10.6	5.7	-11.0	5.2
Machinery and equipment	12.1	4.8	27.6	20.5	18.2
Electrical machinery and equipment	12.8	2.5	2.8	7.4	19.6
Electronic products and components	21.0	27.1	15.3	26.6	16.4
Transport equipment	10.4	17.1	5.0	19.8	26.6
Instrumentation, photographic and optical goods	38.5	41.6	38.1	66.7	51.6
Others	5.2	16.2	17.5	5.0	6.8

Singapore Department of Statistics (2009)

As an early starter, Singapore was able to attract big players in niche biomedical areas such as GlaxoSmithKline, Pfizer, Merck, Aventis, Eli Lilly, Wyeth, Roche, Schering-Plough and Novartis, which were drawn by Singapore's biomedical research environment to set up R&D facilities in Biopolis (Box 1) (Lim, 2005). Core research capabilities developed in Singapore's public research institutes have

resulted in extensive collaboration with these companies, often paving the way for greater high value added activities.

Box 1: Novartis case study

The Swiss pharmaceutical giant Novartis is one of the largest companies in Singapore. The government has approved Novartis's biggest ever investment, involving a cell culture production facility in Singapore to support its growing pipeline of biopharmaceuticals, which is due for completion by 2012. The plant, to be located near Novartis's existing operation producing drugs from chemically synthesised substances, will support both clinical and commercial production of potential new products, including monoclonal antibodies to treat, for instance, rheumatoid arthritis, tumours, asthma and spinal cord injuries. It is also collaborating with the Genome Institute for dengue fever research.

At full capacity, the plant will employ 300 workers and produce drugs using mammalian cell culture technology. It is part of the Novartis Biologics unit, which brings together key elements for fast, high quality R&D activities in biological medicines manufactured via laboratory created processes involving living cells. Biologics now accounts for 25 per cent of the group's clinical research pipeline, says Thibaud Stoll, head of Global Biopharmaceutical Operations at Novartis: 'We have six facilities at the moment in biopharmaceutical operations—five in Europe and one in California. This new one will expand our operations in Asia and also in biopharmaceuticals.'

The investment follows Novartis's new tablet-manufacturing facility in Tuas, Singapore (USD 180 million), which will manufacture existing Novartis pharmaceutical brands, such as Diovan®—the world's most prescribed high blood pressure medicine—and new products like Tekturna®/Rasilez®, the first of a new type of high blood pressure medicine. By 2011 the 28,500 square metre plant will be manufacturing around 3.3 billion tablets and will employ 160 staff and use lean manufacturing practices.

Novartis's presence in Singapore began in 1971, with the opening of Ciba-Geigy. Following the 1996 merger between Ciba-Geigy and Sandoz, Novartis was created, with the company establishing its Asia-Pacific head office in Singapore. Its other local operations include the Novartis Institute for Tropical Diseases, which holds the mandate for discovering and developing therapies for neglected diseases, including dengue and tuberculosis, and a production facility for the CIBA Vision Business unit, part of Novartis's consumer health business platform that also includes over-the-counter medicines and animal health products. In Singapore, Novartis employs over 800 people, across pharmaceuticals, consumer health, and vaccines and diagnostics, and activities include marketing, R&D, manufacturing and regional management.

The Singapore government views these latest investments as a clear signal of the tremendous growth potential for Singapore's biologics and pharmaceutical manufacturing industry and claims that the industry has a reputation as the most competitive and trusted site for pharmaceutical bulk activities and secondary manufacturing, and is now aggressively pursuing investments in biologics.

According to Novartis, Singapore was picked as the ideal location for its new facilities after a thorough selection process. According to Tom van Laar, head of Global Operations at Novartis Pharma AG, "Singapore is attractive because of its increasingly strong biomedical cluster and proximity to growth markets in Asia. In addition, a solid educational system and favourable socioeconomic conditions assure access to local and international talent."

Sources: IIF (2007); Ali (2006)

4.2 Contribution to employment

Singapore's biomedical sector employed around 12,450 people in 2008; more than double the number employed in 2000 (see Table 1). Just over 4,000 of the employees worked in the pharmaceutical industry, while the rest were involved in the manufacture of medical technologies. Over the next few years, the expansion of the BMS sector is expected to contribute more than 5,000 positions for engineers, scientists, technicians and corporate executives across manufacturing and R&D facilities (EDB, 2008). The government has been working closely with MNCs to further augment its pool of skilled personnel to support this industry, aided by a program to develop skilled pharmaceutical workers without prior experience in the industry (IIF, 2007).

In terms of total employment, the biomedical sector has limited prospects compared to other manufacturing subsectors, especially electronics, whose decline it is meant to mitigate. Rather, the focus is on quality personnel, which is why training and foreign talent are so important. The value added per biomedical worker is one of the highest at SGD 900,000 (USD 641,000), compared to the manufacturing sector average of SGD 174,000 (USD 124,000) per worker (Tan, 2004).

Also, not all positions generated by the sector are filled by Singaporeans, as expertise is needed from all over the world to feed the intellectual content of biomedical research. It is difficult to quantify the kinds of spill-over effects that such employment will bring in terms of the services and goods consumed by foreign skilled personnel with higher disposable income or the brainpower they bring to the island that could spur further entrepreneurial efforts in Singapore.

4.3 Has diversification been successful?

One of the goals of Singapore's policies for the biomedical sector is economic diversification. Since the 1997–98 financial crisis the government has launched a series of policies aimed at diversifying the economy in order to reduce its susceptibility to external volatility and bolster its competitiveness in the face of increasing regional competition. The goal is to increase the breadth and depth of manufacturing. For pharmaceuticals and biotechnology, this includes new activities such as biologics manufacturing.

The government's success in attracting the leading multinational pharmaceutical firms to the city state has been the main driver of rapid progress in the diversification strategy. The government was able to introduce alternatives to electronics and chemical manufacturing while at the same time attracting a diversity of biomedical firms. The MNCs have been drawn to the city state by its:

- good physical infrastructure, which is able to support advanced technology, manufacturing and R&D activities;
- pool of well educated and skilled human capital;
- strong, coherent and well enforced intellectual property rights and patent laws;
- liberal legislation governing human stem cell research activity and therapeutic cloning as set out in the Human Cloning and Other Prohibitive Practices Act passed by parliament in September 2009;
- single regulatory agency in the form of the Health Sciences Authority;

- substantial venture capital and financing sector, including investment funds solely focused on the biomedical sector; and
- attractive fiscal and other investment incentives, including zero corporate income tax for 10–15 years (Oxford Analytica, 2004).

The electronics industry will remain the lynchpin of Singapore's manufacturing industry, despite declines in some of its subsectors. The biomedical industry, which is less labour intensive than other manufacturing industries, cannot fully hope to replace the electronics industry. Many of the kinds of biomedical investments that Singapore wants to attract are high tech, high value added and research based. Due to the nature of these investments, operations tend to be small, focused, nimble, highly specialized and in clusters.

4.4 Spillover effects

Spillovers of technology and knowledge through FDI are not automatic, but require a minimum level of technological and workforce sophistication among domestic firms for such spillovers to occur. Singapore is a case study of intense state investments in R&D, infrastructure and training to build up the biomedical industry. Have these policies been effective?

A U.S. Embassy survey undertaken in 2003 concluded that the spillover effects of the biomedical industry in Singapore have been limited: 'Manufacturing output in recent months has been bolstered by hefty jumps in output in the biomedical sector (mainly pharmaceuticals), overshadowing the near-stagnant electronics sector. Unlike electronics, the pharmaceutical sector has few linkages to the local economy, so that increased exports have little spillover to the rest of the economy' (U.S. Embassy, Singapore, 2003). But other economists commenting on the same issue in 2005 disagreed. In fact, Manu Bhaskaran, adjunct fellow at the Institute of Policy Studies, argued that Singapore has succeeded in diversifying its manufacturing sector with new engines of growth like the biomedical industry, whose spillover effects have effectively shielded the country from the adverse effects of slowdowns in other sectors (Tay, 2005).

There is also a danger that governments may pay too many incentives and actually reduce national welfare, a situation that is more likely when there is a multitude of governments bidding for FDI. Thus, incentives should be part of a comprehensive industrial policy that may include support for domestic companies to enable them to take full advantage of technology spillovers. While Singapore's investment incentives are in principle available to all companies, in practice the beneficiaries are overwhelmingly foreign companies. Therefore, the domestic sector is perceived to be less well equipped to extract benefits from the incentives and the government's overall economic strategy is thought to be less attentive to small and medium sized domestic firms. Additional policies may be needed to help local firms build up their capabilities to benefit equally from incentives granted to the biomedical sector.

Some progress has already been made to nurture the growth of domestic companies in the sector to avoid and protect against overdependence on foreign investments. While Singapore lacks the critical number of homegrown companies in relative terms compared to competitors like India, China, South Korea or Japan, a few domestic companies have emerged as important players in the sector. For instance, MerLion Pharmaceuticals, established in 2002, was previously a state owned centre for natural product research, but now focuses on R&D for pharmaceutical products derived from natural products (Oxford Analytica, 2004). In 2001 it set up a new scheme called Innovate 'N Create to promote further and

commercialise local technologies in the BMS, and companies that qualify will receive up to SGD 2 million (USD 1.4 million) as seed capital (Lim, 2002b). Another example is the Singaporean biotech company Nextwave Biomedical, a privately held company that has built a prototype to analyze DNA in the field to speed up detection of diseases such as dengue and bird flu. Biosensors International Group, listed on the Singapore Stock Exchange's main board, is positioned to become a leader in drug-eluting stents, which can be used instead of traditional options such as metal stents and open heart surgery. The company now manufactures in Singapore, the Netherlands and China (Delfeld, 2005).

5. Lessons for Other Southeast Asian Economies

The stimuli to nudge Singapore in the biomedical direction are also present in the advanced Association of Southeast Asian Nations (ASEAN) developing economies such as Malaysia and Thailand, for whom Singapore may serve as a valuable case study. To succeed in the competitive arena of life sciences and, in particular, biotechnology, a country needs five ingredients: talented scientists, strong corporate partnerships, resources to back R&D, protection of intellectual property and top-notch facilities (Delfeld, 2005).

How transferable is Singapore's experience in the biomedical sector to other Southeast Asian economies? What are the general or country-specific factors that account for the progress that has been made? This section will look at four prerequisites for success: public administration and governance, institutions, infrastructure development, and clustering.

5.1 Public administration and governance

When seeking to attract investments, governments must use their policy tools to cater to MNCs, which tend to be relatively fickle before committing to an investment location. Once made, multinational investments are relatively immobile, at which point the balance of power and leverage shifts to the side of the state. However, while politicians will try their best to attract investments into the country, whether they can keep their promise after the MNCs have committed themselves is another issue. Broken promises can discourage companies from expanding their existing operations and deter other potential investors. Policy stability is therefore crucial.

In this regard, consistency is one of the most important of Singapore's attributes. Science and technology played a significant role in Singapore's development and in shaping its economy. The National Science and Technology Board was set up in 1991, along with the launch of Singapore's first National Technology Plan. Since 1991, the government has committed over SGD 20 billion (USD 14 billion) to science and technology under four five-year plans (Png, 2006). The government's aim is to increase national spending on R&D to three per cent of GDP by 2010. The current Science & Technology 2010 Plan has committed SGD 5 billion (USD 3.6 billion) towards economically driven R&D in fields such as BMS (Delfeld, 2005).

In other words, Singapore's commitment to science and technology has never stopped. According to Singapore's minister for trade and industry, Lim Hng Kiang, the government will be putting increasing resources and attention to R&D to transform its economy into one that can compete on knowledge, innovation and talent, in addition to efficiency and cost-effectiveness, as a national priority (Lim, 2005). The government understands that foreign investors are there for the long term, to serve domestic markets or use the platform to export to world markets, rather than for speculative purposes (Jensen, 2006).

In addition, by remaining consistent Singapore can use its track record of MNCs already based in Singapore to draw more investors into the country. Singapore's Investment Promotion Agency can assure prospective investors about the low level of problems and political risk in Singapore by citing the number of other MNCs that already have a presence in the country.

5.2 Institutions

One possible institution that neighbouring ASEAN countries can learn from is the steering committee for Singapore's Biopolis project, otherwise known as the Biomedical Research Council (BMRC). The advantage of having this council is that Singapore can draw on experts to navigate the development of a biomedical sector much better than it would have if it had relied on an organic, learning-by-trial-and-error methodology. Established in October 2000, the BMRC has the following functions of overseeing the development of core scientific capabilities within A*STAR research units:

- overseeing bioprocessing, chemical synthesis, genomics and proteomics, molecular and cell biology, bioengineering and nanotechnology, and computational biology units;
- promoting translational and cross-disciplinary research as part of the effort to advance human health;
- supporting biomedical research in the wider scientific community, including at universities and hospitals;
- supporting the development of R&D human capital for the BMS; and
- promoting societal awareness of biomedical research through outreach programs (BRC, 2006).

To ensure that expert advice is implemented, the BMRC works in close partnership with the EDB BMS Group and Bio*One Capital to develop Singapore into the "Biopolis of Asia."

In addition to the steering mechanism, other factors have worked for Singapore's biomedical industry. They include:

- good physical infrastructure able to support advanced technology, manufacturing and R&D activities;
- a pool of well educated and skilled human capital;
- strong, coherent and well enforced intellectual property rights and patent laws;
- liberal legislation governing human stem cell research activity and therapeutic cloning as set out in the Human Cloning and Other Prohibitive Practices Act passed by parliament in September 2009;
- a single regulatory agency in the form of the Health Sciences Authority;
- a substantial venture capital and financing sector, including investment funds solely focused on the biomedical sector; and

- attractive fiscal and other investment incentives, which have included zero corporate income tax for 10–15 years (Oxford Analytica, 2004).

The protection of intellectual property is a high priority for companies conducting biotechnology research, and this plays into another of Singapore's strengths. Singapore has been ranked by the Political & Economic Risk Consultancy as having the best intellectual property rights protection in Asia since 1997 (Delfeld, 2005). Legal institutions, Singapore's traditional rule of law, its Anglo-Saxon legal heritage, and its reputation for legal proficiency and efficiency are just as important as any other factors in attracting biomedical investments.

5.3 Infrastructure

Given that the biomedical sector in Singapore is so new, the city state has mainly attracted "greenfield" investments, where MNCs construct new subsidiaries in foreign markets (as opposed to "brownfield" investments, where MNCs gain access to foreign markets by purchasing existing companies). The government, instead of waiting for the private sector to set up the needed infrastructure, has gone ahead with building facilities to attract more greenfield investments, such as the Biopolis facility.

5.4 Clustering

Initially, Singapore had focused on growing three major manufacturing clusters: electronics, chemicals and transport engineering. The critical mass of capabilities and key companies in these existing clusters form a strong bedrock for the future growth of the manufacturing sector. To engage in the knowledge-based economy, Singapore has added the BMS cluster comprising four industries: pharmaceuticals, medical technology, biotechnology and healthcare services. The vision is to develop Singapore as the global hub for the BMS in Asia (ERC, 2002).

The hub vision encapsulates two key elements. The first is to be globally competitive and attain global leadership in selected areas. The second is to become the preferred location in Asia among leading industry players. The overall aim is to develop world class capabilities across the entire value chain, from the discovery and development of new drugs and products, clinical trials management, and the manufacture of drugs and medical products to regional headquarter activities and healthcare delivery.

Another goal is to increase the breadth and depth of manufacturing. For pharmaceuticals and biotechnology, this includes new activities such as biologics manufacturing, and growing the base of formulation and finishing, pilot scale manufacturing, and process R&D activities. For medical technology, this will involve expanding the range of products developed and manufactured, as well as establishing Singapore as the supply chain management hub for regional distribution and global procurement.

In June 2000, the Singapore government embarked on an integrated strategy to develop the human, intellectual and industrial capital to support the growth of the BMS cluster in Singapore. Consequently, many important programs have been undertaken by A*STAR's BMRC and EDB's BMS cluster (ERC, 2002). Human capital development is key, as the BMS cluster is one of the most knowledge intensive relative to other industries.

New products and technology are the lifeblood of the BMS cluster. To facilitate successful innovation in Singapore at least in the short to medium term, large BMS MNCs with their development expertise and

marketing skills were encouraged to work with local startups and public sector research institutes, universities and hospitals. These institutions, in turn, attract and generate the critical mass of talent that the industry can tap into.

To promote competitive clustering, Singapore has adopted a specialized environment for both manufacturing and R&D. The Tuas Biomedical Park, for instance, is instrumental in attracting pharmaceutical manufacturers. For R&D, the co-location of academic and industry laboratories at the Biopolis facility promotes interaction and the exchange of people and ideas to catalyze innovation and breakthrough discoveries.

Singapore has also built strong supporting industries for the BMS cluster, such as BMS-specific engineering, construction and validation service providers. In addition to attracting new foreign and local players, the effort could include encouraging and training existing Singapore-based suppliers, vendors and contract manufacturers with relevant capabilities to diversify into supporting BMS companies (ERC, 2002).

6. Conclusions and Recommendations

From the perspective of long-term benefits, the main purpose of developing the biomedical sector in Singapore is not to manufacture products in Singapore, but to create knowledge and intellectual property. Singapore's attraction is not in market size, but an aggregation of many significant parts: infrastructure, intellectual property rights protection, government support, a diverse talent pool, and the environment and lifestyle it offers. By banking on the BMS, Singapore hopes to develop applications and tap into the knowledge-based economy. Thus, the objective of using investment incentives to lure the biomedical industry is not to create manufacturing jobs, but rather scientific research and innovative solutions to deal with future medical needs.

Nowhere is the term “long-term commitment” more ingrained than in the tiny city state of Singapore, where industries such as chemicals, electronics and engineering have been masterminded from the ground up and remain firmly planted as the country's key economic engines. To encourage the formation of new ventures and attract scientific talent to expand the biotechnology industry, Singapore has gone beyond simply building its robust base of MNCs (Tang *et al.*, 2003). Partnerships between industry and local research institutes, hospitals and universities are encouraged to spur innovation among local researchers and to help foreign companies secure a foothold in Asia using Singapore as a gateway (Tang *et al.*, 2003).

6.1 Finding niche areas

To continue to invest and build on the basic biomedical science research capabilities in A*STAR and Singapore's universities, Singapore should focus on developing highly competitive programs in selected disease areas where the country has comparative advantages based on the presence in its population of three Asian ethnic groups and the higher prevalence of specific types of medical disorders. This effort should be funded through the Singapore government's commitment to allocate SGD 1.5 billion (USD 1 billion) to support translational and clinical research, subject to a performance review every five years. Government supported basic research can then draw private sector companies, both foreign and local, to continue and expand this research to develop new drugs or nutritional products.

6.2 Capitalizing on future trends of regionalism

Within the next decade, Asia will emerge as a global powerhouse in the BMS industry—the size of its market, talent and resource base cannot be ignored. What distinguishes Asia from other regions is its sheer diversity—of political systems, culture and economic development—which presents monumental challenges, as well as tremendous opportunity (Lim, 2008).

Regionalism enables Singapore to expand market access through improving the regulatory environment and collaborating with foreign regulatory authorities. For this purpose, Singapore's Health Sciences Authority can work with key countries on mutual recognition agreements for manufacturing approvals, similar to that signed with Australia. The government can also explore the possibility of attracting foreign regulatory authorities to use Singapore as a base for their activities in the region (ERC, 2002). One way to increase awareness of this potential is to enhance marketing and communications strategies to profile BMS manufacturing and showcase Singapore's advantages as a manufacturing location (ERC, 2002).

As Singapore's biomedical sector matures in the future, it is likely to become a model for the region. Opportunities exist to integrate this sector with regional counterparts, taking advantage of the ASEAN integration process. The ASEAN Investment Area (AIA) was created to ensure that investments flow freely within the region and that the principle of non-discrimination is applied. The AIA allows investors to harness the various complementary advantages of ASEAN member countries in order to maximize business and production efficiency at lower costs.

Singapore can also tap into the rapidly growing ASEAN market—10 countries with a combined GDP of over USD 1.5 billion, one of the fastest growing markets in the world and a population of almost 600 million, including an expanding educated middle class of demanding consumers who are well connected to the rest of the world.

Moreover, the ASEAN region is rich in biodiversity in its rainforests and subtropical forests, with a huge and diverse range of ecosystems, constituting a tremendous potential for the development of biotechnology. Promising areas of collaboration with other ASEAN countries on biotechnology R&D include vaccines, diagnostics and pharmaceuticals (especially for tropical diseases); emerging diseases centres for diagnostics development in combating communicable diseases like avian flu and SARS; the development of functional foods; and systems biology and bioinformatics (Ong, 2004).

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