GERMAN DEVELOPMENT INSTITUTE

(GDI)

Frameworks for the Development of Innovative Industries
Biotechnology in Taiwan, South Korea and Thailand

Daniel Hobohm

Bonn, October 2004

The present study has been prepared during a short-term stay of Daniel Hobohm at GDI. Hobohm is a graduate student at Johns Hopkins University. The study has not been subject to the review procedure at GDI. All views presented are those of the author and do not necessarily reflect those of the GDI.

Tulpenfeld 4 · D-53113 Bonn
Telefon +49 -228 94927-0 · Telefax +49 -228 94927-130
die@die-gdi.de
www.die-gdi.de

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Abbreviations

DFG	Deutsche Forschungsgemeinschaft
FDA	Food and Drug Administration
GM	Genetically modified
IZB	Innovations – und Gründerzentrum
NIS	National Innovation System
PTJ	Projektträger Jülich
RTP	Research Triangle Park
TCM	Traditional Chinese Medicine
TNC	Transnational company
WIPO	World Intellectual Property Organisation
WTO	World Trade Organisation

Taiwan:

BPIPO	Biotechnology & Pharmaceutical Industries Program
DCB	Development Center for Biotechnology
HSIP	Hsinchu Science-based Industrial Park
ITRI	Industrial Research Institute
NHRI	National Health Research Institutes
SIPA	Science Park Administration
TSIP	Tainan Science-based Industrial Park

Korea:

ETRI	Electronics and Telecommunications Research Institute
KAIHMT	Korea Advanced Institute of Health and Medical Technology
KAIST	Korea Advanced Institute of Science and Technology

KBSI	Korea Basic Science Institute
KFDA	Korea Food and Drug Administration
KHDI	Korea Health Industry Development Institute
KOSEF	Korea Science and Engineering Foundation
MOST	Ministry of Science and Technology
NIH	National Institute of Health
NITR	National Institute for Toxicological Research
OBST	Osing BioHealth Science Technopolis
TAO	Taedok Science Town Office
TST	Taedok Science Town

Thailand:

AIT	Asian Institute of Technology
BIOTEC	National Center for Genetic Engineering and Biotechnology
MTEC	National Metal and Materials Technology Centre
NECTEC	National Electronics and Computer Technology Centre
NSTDA	National Science and Technology Development Agency
TIAC	Technology Information Access Centre
TSP	Thailand Science Park
TU	Thammasat University
WSS	White-spot Disease
YHD	Yellow Head Disease

Abstract

A number of theoretical frameworks describe the development of high-technology industries. These frameworks usually proscribe a minimum of government intervention and often emphasise a regional agglomeration of industries. The frameworks described here are the National Innovation System (NIS) and prevalent cluster-theories to explain why firms are often found in regional proximity.

The concept of the NIS describes the interaction of actors in an economy (or region) that, among them, create innovation. The NIS stresses knowledge flows and interactions and therefore provides a qualitative tool for policy guidance.

Cluster-theories aim to further explain why some industries are often found in proximity. Horizontal clustering occurs with competing firms occupying the same step of a value chain, the predominant driving factor of this type of clustering is the ability to imitate and improve the competitor's product.

Vertical clustering, in contrast, occurs with firms that maintain supplier and buyer relationships. The advantage is then due mainly to specialisation effects and economies of scale.

The development of industrial agglomerations can be further mapped in an evolutionary framework, according to which the characteristics of a concentration of firms changes with increasing research linkages with accompanying institutes and universities.

To investigate the applicability of these frameworks to map the development of high-technology industry clusters in Asian developing countries, in particular with view to the role of the government, the development of the biotechnology industry in Taiwan, South Korea and Thailand are reviewed. The biotechnology industry is becoming more and more important and aspiring economies in Asia seek to participate in this global trend. The rise of the biotechnology industry, in particular in biotechnology industry-clusters in these countries, therefore represent natural experiments to test the frameworks; special emphasis is therefore put on the Hsinchu Science-based Industry Park (HSIP) in Taiwan, the Taedok Science Town (TST) in South Korea and the Thailand Science Park (TSP).

The development of the biotechnology industry in all three examined countries shows that government intervention was indeed important and large. At the same time, the evolutionary development was different in all cases.

In Taiwan, the government had devised the HSIP as a multi-industry park to develop innovative small enterprises. At the HSIP the biotechnology industry found environments very conducive for its development and the industry quickly expanded into other sites.

The TST, in contrast, had been devised as a research park with little entrepreneurial activity. Only late came the development of spin-off promotion strategies, with a surprisingly fast founding of new firms. The biotechnology industry, however, did not participate to the same

degree and the Korean government devised, for that reason, the new Osong BioHealth Science Technopolis.

In Thailand the government aims to use biotechnology to aid its large agricultural industry, in particular the shrimp industry. Thailand therefore follows a demand-driven approach by adopting and using biotechnology for a specific industry.

The role of the government in boosting the biotechnology industry therefore appears instrumental in these Asian countries. The study also discusses the German BioRegio contest, where the government was equally important, but acted in a less interventionist manner. The contest aimed at selecting regions that presented the best conditions for developing a healthy biotechnology industry and therefore justified further funding by the government. The nature of the contest was such that even though only three out of applicants were selected as winners, all participants subsequently developed strong biotechnology clusters. The reason is that the effort to participate led to a conceptualisation of successful development strategies. Due to differing economic conditions, however, it is doubtful that such a contest could have been used as a strategy in Taiwan, South Korea or Thailand.

1 Introduction

Many theoretical frameworks describe the development of high-technology innovation and industries in an economy. Often, these theories proscribe a minimum of governmental intervention to aid this process. Emphasis is further put on explaining regional agglomeration of industries, a field often described by cluster-theories.

Aim of the study is to review some of the frameworks for explaining innovation processes, while special attention is paid to prevalent cluster-theories. In particular, the degree of governmental intervention and the evolutionary development of clustering is of interest. Key question is whether these frameworks, often developed after analysing industries in developed countries such as the USA, provide a meaningful reference for analysing a specific industry development in developing countries.

The frameworks are analysed using web-based information on the biotechnology cluster development in Taiwan, South Korea and Thailand. The biotechnology industry is a young and dynamic industry with enormous growth potential. Furthermore, the industry experienced an important push in these three countries and case-studies of the development of the biotechnology industry therefore serve as natural experiments for the described theories.

For this reason, the study first gives in chapter 2 an overview of the global biotechnology industry. In chapter 3, the concepts of the National Innovation System, industry-clusters and the evolution of science parks are presented. The study then proceeds in chapter 4 by presenting the development of the biotechnology industry in the three countries. Chapter 5 reviews the findings from chapter 4 in the light of the concepts of chapter 3, while special attention is being paid to the role of the government. As will be apparent, governmental intervention was quite instrumental. In light of this, chapter 6 presents the experience with the German BioRegio contest, a contest-led promotion of biotechnology in Germany, where governmental guidance was still important, but much less so than in the three Asia countries.

2 The Biotechnology Industry

2.1 An introduction to biotechnology

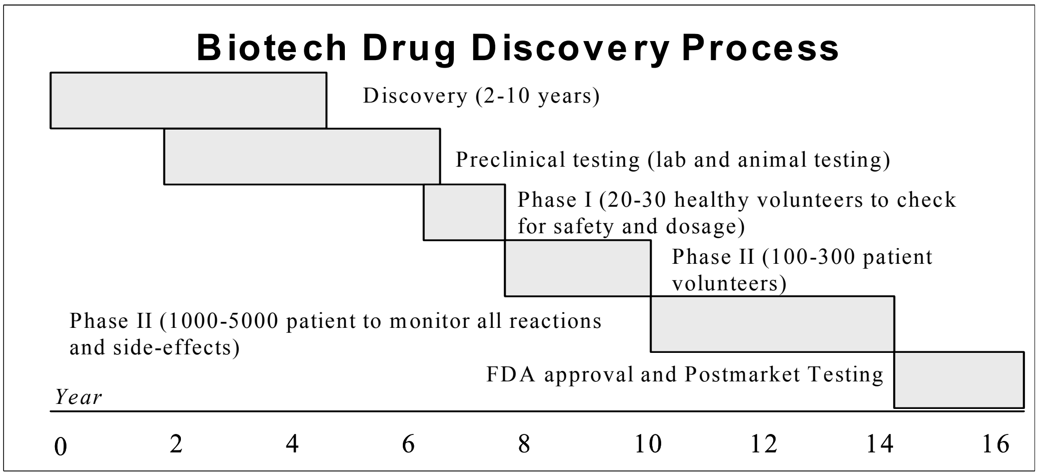
Biotechnology uses living organisms or products derived from organisms to make or modify a product. The product can be an inanimate object or substance, a plant, an animal or humans.

Arguably the most important use of biotechnology lies in the creation of pharmaceuticals (see also box 1). It is estimated that 80 % of all medical drugs in current clinical phase testing are derived by biotechnological means.

Box 1: **The biotechnology colour-code**
In some countries, the differing biotechnology industries are given a colour-code.
Red biotechnology: Pharmaceutical and diagnostic biotechnology
Green biotechnology: Biotechnology used to genetically altering plants
White biotechnology: Industrially used biotechnology, for example enzymes as additives in washing powder, solvents, dyes.

The biotechnology industry in the developed world concentrates on developing new drugs, a costly and time-consuming process: It is estimated that the development of a new drug, including clinical testing and marketing, costs on average US $ 800 million and takes at times more than ten years (see figure 2). For the developing world, this process is prohibitively expensive, even though many vaccines against HIV/AIDS, Malaria, Dengue Fever or Hepatitis B and C would serve in particular these countries. Unfortunately, the financial problems also affect companies in developed countries. The California-based firm Maxygen, for example, developed a candidate-vaccine[1] against four forms of the dengue-fever virus. Given a world-wide market of only US $ 200 million, however, the development and marketing was stopped. For that reason, the full integration of biotech companies, that is from R&D to the marketing of medical products, remains an option in only very few cases in developing countries.

Figure 1: The Biotech Drug Discovery Process



Source: www.bio.org

1 A vaccine that has been developed but which has not been tested in clinical trials.

The second large field of biotechnology is the agriculture business. Biotechnology can be used to genetically modify plants and therefore produce new traits. For many countries, in particular the developing world, but also the USA, boosting agricultural output is paramount. The political dilemma between the EU, which opposes genetically modified food, and the rest of the world often evokes serious problems. Nevertheless, genetically-modified (GM) food production is growing. However, GM plants are not only used for nutritional purposes. For example, GM tapioca is grown for biodegradable wrapping and GM cotton improves the quality and lowers the price of shirts.

The industrial use of biotechnology is also considerable and is sometimes described as the "third wave" of the biotechnology industry. The growth potential of this industry remains enormous: For example, enzymes can be used for chemical processes, biomolecules are used as solvents and bacteria can grow and eliminate toxic waste material.

2.2 An introduction to the global biotechnology industry

Mankind has benefited from the evolution of key technological drivers. Be it the use of steam power, the railway, electricity or synthetic materials, there have been waves of technological breakthrough, often described as Kondratieff-cycles.[2] They have, empirically, a "length" of about 50 to 60 years and world leaders in these technologies are also world economic leaders. It is not certain that biotechnology represents the next cycle. According to some, however, biotechnology is indeed the next key economic world driver.

The rise of the biotechnology industry started in the 1970s in the USA, Europe slowly followed later. Accordingly, the USA is the world leader, with the UK and Germany now in second and third place. Despite economic worldwide recession, biotechnology continued growing. In 2001, global biotechnology revenues totalled US $ 35.9 billion,[3] in 2002 they were up 15 % to US $ 41.3 billion. This development is driven by the general rise of the pharmaceutical market, which doubled since 1991.

Over the last twenty-five years, the global biotechnology market has grown strongly and is not to be compared with a virtual dot.com industry. Despite the economic slowdown, the biotech industry has not suffered from the same dramatic decline in venture capital funding as other industries; the long-term growth potential of the industry is still considered enormous. However, in particular in Europe, the conditions for an exit strategy, in particular through an initial public offering have dwindled. For that reason, venture capitalists retain their money in reserve to bridge the financing gap for existing firms until stock markets recover, rather than funding new ones. Globally, there are more than 600 publicly traded companies with a 2002

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2 Nikolai Kondratieff was the first to describe the long economic cycles (Kondratieff, N.D. (1926)), the term Kondratieff-cycle, however, was coined by Joseph Schumpeter (1961).

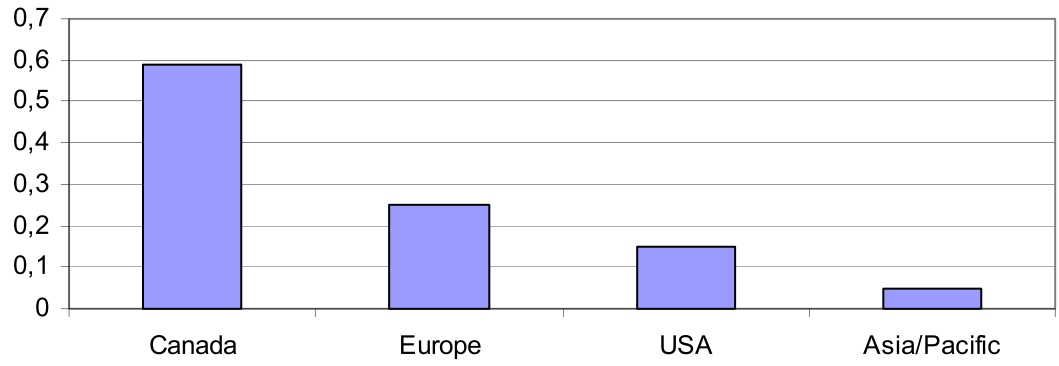
3 Ernst &Young (2003, A).

net loss of more than US $ 12 billion. This large number is indicative of the high up-front research costs, a factor more prevalent than in most industries, and which constitute a significant financing burden for young firms.

2.3 The biotechnology industry in Asia

In global comparison, biotech industries are mostly found in North America. The industry in the USA alone is about three times larger than the rest of the world combined. Interestingly, however, compared to the size of the regional economy, Canada and Europe show a larger concentration of biotech firms; only the concentration in Asia/Pacific is smaller (see also figure 2).

Figure 2: Number of companies based on size of regional economy (per $ billion in GDP)



Source: Ernst and Young LLP, Biotechnology Industry Report: Convergence, 2000

In Asia/Pacific (table 1), Australia has the most advanced biotech sector, with 38 of the 108 publicly traded companies. Except for Australia, which comes sixth, no other Asian country is ranked among the top twelve biotechnology countries. Given that the market for many of potential biotechnology products lies in fact in the most populated and climatically challenged

Table 1: Asia/Pacific biotechnology at a glance

	2002	2001	% change
Public Company (US $)			
Revenues ($m)	1.375	1.076	28 %
R&D expense ($m)	196.6	177.1	11 %
Net Loss ($m)	79.0	23	240 %
Number of employees	9.764	7.879	24 %
Number of companies			
Public companies	108	100	8 %
Private companies	493	415	19 %
Public and private companies	601	515	17 %

Source: Ernst and Young LLP, Beyond Borders – *Global Biotechnology Report 2003* areas, Asia, it is not surprising that these countries aggressively attempt to participate in the reckoning of this young industry. Several opportunities and risks, however, lie ahead. One is certainly differing intellectual property rights. In parts, these led to country-specific industry developments.

In India, for example, IP rights are at times weaker than in developed countries. This opened up the Biogenerics industry, a new business opportunity. Instead of developing new drugs, India takes already developed drugs and innovates on the production side of the drug. Consequently, India has found revolutionary new ways to produce recombinant human insulin; the same drug is produced less efficiently in Europe or the USA.

Not unlike India, China is also expanding its capabilities to copy and produce already marketed drugs at lower costs. The labour costs, even in this relatively high-tech sector, are only about 10 % of labour costs in the developed world. The workers are often employed not for product R&D, but for elaborative process R&D, making the production of drugs and vaccines cheaper. China's strengths lie in agriculture, production and sales of imported vaccines and Traditional Chinese Medicine (TCM). Apparently, Chinese companies are now able to produce eight of the ten best-selling drugs. In accordance with WTO regulations, these are only sold in the Chinese market.

The pharmaceutical use of biotechnology in Asian countries, however, comes only second to the agricultural use.[4] Even though a heated academic debate still revolves around the opportunities and pitfalls of using biotechnology to increase agricultural output, many Asian countries have started to use biotechnology to increase productivity and output to adequately feed its population. For this reason, China for example has approved about 50 genetically altered organisms; 103 genes have been evaluated for improving traits in 47 plant species. These include the staple crops rice, wheat, corn, cotton, tomato, pepper, potato and tobacco. Similarly, India has developed GM rice (with a high level of vitamin A), citrus, coffee, mangrove and cardamom.

The recent economic recession has in parts benefited the biotech industry in Asia. Young talents, educated at universities in the West, are now reversing the brain drain and set up companies in their home countries or conduct research in special areas, for example stem cell research. In this sector, China and Singapore offer much freer regulations than the West. These bilingual, bicontinental talents also engage in a number of cross-border alliances.

Another advantage for new entrants is the increased maturity of the market. In the early days, a biotech company that aspired to actually sell its products had to do everything itself, from R&D to marketing. Today, one can buy all those services. It is possible to run a "virtual biotech company"[5] and sell off services to companies that specialise in one specific technology.

4 Pearsley, G.J. (---.).

5 In the words of Edward E. Penhoet, Science Director Gordon and Betty Moore Foundation.

For that reason, countries in Asia may find it easier today than twenty years ago to enter the worldwide biotech market. However, framework conditions must be met, including adequate intellectual property protection, sufficient venture capital to finance early-stage companies and a flexible regulatory system. Human capital must be trained and be given incentives to work at home, infrastructure must be offered and markets be sufficiently open for technology transfer to occur. Developing countries therefore have to focus on this endeavour with a national plan, otherwise the chance of market failure, given by the high risks in development and the high costs in marketing, will be too great to permit endogenous development of a biotech industry. For this reason, the biotechnology industry, like any new-technology industry, faces the possible risk of market failure.[6] The market failure argument is particularly salient for technology-industries in developing countries.[7]

Equally, however, a large amount of governmental intervention can lead to inefficient and at times detrimental market distortions. Intervention requires strong government capabilities and many governments do not have these capabilities. The policy problem is not, however, a gigantic optimisation problem to establish quasi-perfect market conditions, but to foster winners under the given circumstances and choosing the conditions for them to succeed. It is much more feasible to create winners in imperfect market conditions than creating perfect market conditions.[8]

For this reason, the focus in the next section is about theories for innovation creation. It will first discuss the concept of National Innovation Systems and its levels of innovation creation, before continuing with cluster-development theories. Special attention is paid to the degree of governmental intervention.

3 Models for the Creation of Innovation

3.1 National Innovation Systems

For the purpose of understanding the evolution of high-technology industries within economies, the framework if National Innovation Systems (NIS) appears useful. The NIS-approach[9] is based on the macroeconomic classification of actors within a nation (or region) that, among them, create innovation. Unlike neoclassical and endogenous growth theories, the NIS puts particular emphasis on the interaction of these actors, knowledge diffusion is seen as important as knowledge creation. All instruments, institutions and markets that support the creation

6 Arrow, K. (1962).

7 Lall, S. & Teubal, M. (1998).

8 Stiglitz, J.E. (1996).

9 Follows Blum (2002).

and diffusion within a system are considered. Knowledge can be created by searching and learning, but also by interaction between actors (institutions, but also interactions between customer and providers or competitors). The NIS therefore also considers tacit knowledge which is hard to codify. The concept is not useful for quantitative analysis, but provides a framework for assessing knowledge-based industries. It therefore also provides guidance for policy-design. The interactions between the actors within a NIS can be seen at three levels.

The first level encompasses the four most important types of actors, the firms, the universities and research centres, policy instruments and important complementary elements (see figure 3).

At the heart of level 1are companies and firms, which innovate to seek rents. The importance of research institutes and universities (which perform the dual role of research and providing human capital), however, is equally important. At the same time, the goals of a research policy and the political instruments occupy an additional independent role. A country can perform innovation policy for example to advance its economy, or it can direct research into environmental or defence issues. Finally, a heterogeneous collection of complementary elements is important. They include for example the financial markets situation, availability of venture capital or preferences developing out of the specific education system.

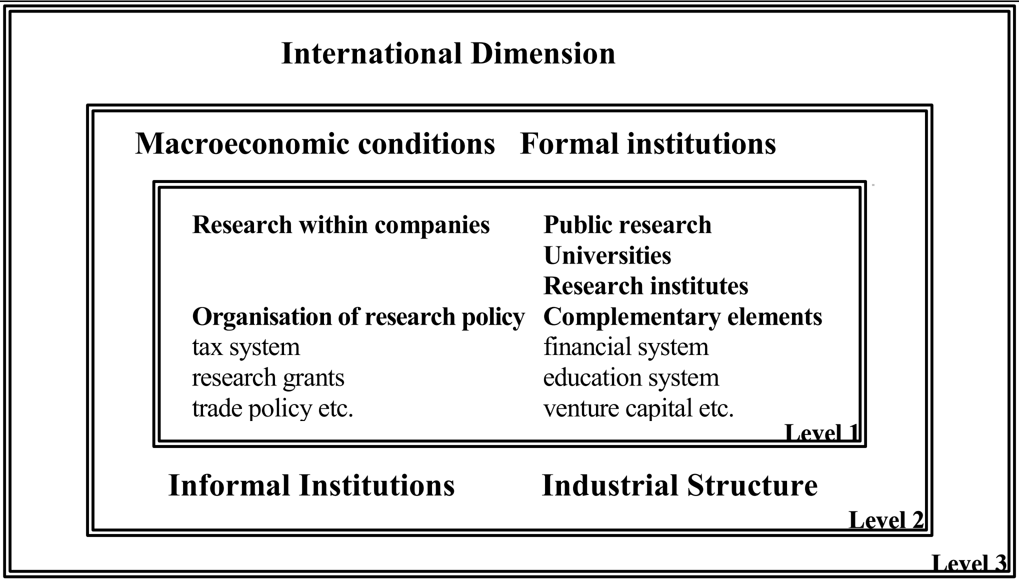
The second level includes the general macroeconomic condition, the existing formal (e.g. intellectual property right protection, rule of law) and informal institutions (norms, values) and the general industrial orientation.

Finally, the international dimension plays an important role and defines the last level. It makes a difference how open a country is, if it is a technological leader or follower and if its economy is comparably large or small.

With this framework, it is clear that there are different channels for knowledge creation. The creation and diffusion of knowledge takes place between all actors of the NIS; industries absorb knowledge that has been created at universities and public research institutes, but they also create knowledge.

Innovation (marketable application of knowledge or invention), however, is only produced by firms. For that reason, the interaction between actors within firms, inter-firm relations and institutions-firms relations can be seen as three individual sublevels of the NIS and are given special attention in the next section.

Figure 3: **The National Innovation System**



Aspect	**Role in the NIS**
Innovator	The firm
Process	Systemic, evolutionary Also stochastic Interdependencies between actors Searching and Learning
Determinants	R&D competence, rent seeking, marketing, regulations Internal incentives Institutional framework Networks
Geographic dimension	Transaction costs of knowledge diffusion reduced by geographic proximity
Role of Government	Large Provides Infrastructure, supports knowledge diffusion Creates knowledge, absorbs knowledge Provides human capital Funds research efforts, in particular basic research Provides risk capital Coordinates and defines national efforts
Goal	Innovation

Source: Adapted from Blum (2002)

3.2 The three levels of innovation creation within the NIS

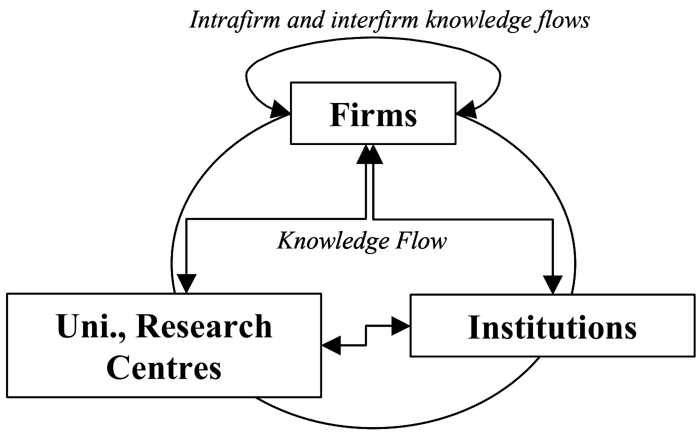
Since the study is interested in the process of innovation creation, a firm-based microeconomic view is apt. As mentioned, innovation is created by firms, important are the internal organisation of firms, inter-firm linkages, as well as firm-institutions relations. Policies that seek to promote innovation processes should bear these in mind.

Concerning the internal organisation of firms (see also figure 4), innovation can be described in three dimensions:[10]

1. Technological innovations – e.g. shift in usage or production of technology
2. Organisational innovations – e.g. change in production processes, logistics, data handling
3. Social innovations – e.g. reduction in hierarchies, change in transparencies, knowledge flows between workers

In research-intensive start-up firms, the internal organisation and the research usually is in the hands of a few founders. They often need a certain level of external expertise to benefit from all types of these three types of innovation. For this reason, a certain level of supporting services may be useful and could be provided either by private actors, or by governmental institutions.

Figure 4: Levels of Innovation Creation



Source: Adapted and modified from Blum (2002)

10 This section follows Altenburg (2002).

Arguably as important, however, is the inter-firm level. One can differentiate predominantly between two types:

1. Horizontal linkages – Arise between firms on the same level of the value chain of a product, usually competitors

2. Vertical linkages – Between firms on different levels of the value chains, usually suppliers and buyers.

Understandably, *horizontal linkages* are generally less common, the fear to lose knowledge to a competitor is large. Cooperation could, however, increase the economies of scale and lead to focussing of scarce research funding. In the biotechnology industry, horizontal cooperation is possible if the firms cooperate in using similar technology, for example expensive proteomics tools. Otherwise, competition for one specific product market, given the very high costs of development, is perhaps too strong for competitors to cooperate. Here, legal and financial institutions could provide a safety net for aspiring entrepreneurs.

Vertical linkages occur more often, in particular also between small biotechnology-firms. Suppliers and buyers are in very close connection to one another and respond accordingly. A supplier of one product may also feed into different value chains and therefore benefit from economies of scale. The presence of a centre of genetic sequencing, for example, in an industrial biotechnology cluster is very common and serves all researching firms.

The third location of innovation creation describes the general relationship between firms and institutions. Institutions can be either *formal* or *informal*.

Formal institutions help reducing uncertainty in legal and economic issues. What is more, the flow of knowledge depends on the cost of knowledge transaction, institutions and infrastructure reduce these costs.

Informal institutions, such as habits, rules and norms provide the soft framework within which firms operate. They can as well be very important in technology transfer.

From the policy point of view it may be a daunting task to engage nationally to provide the framework of all layers of the NIS. Furthermore, many interventions may turn out to be market distorting. Finding the balance is difficult. For this reason, it may be easier to instead concentrate not on a National Innovation System, but a subset, a Regional Innovation System (RIS). What is more, many of the requirements for innovation by firms, be it inter-firm linkages or firm-institution linkages, flourish in geographic proximity. This idea has been introduced to explain the clustering of industries, a theory that will be dealt with in turn.

3.3 Introduction to different cluster-theories

As geographic proximity enhances many aspects of the NIS, one can extend the concept of the NIS by the cluster-theory to explain the regional agglomeration of industries. Inter-firm interactions, as well as firm-institutions interactions provide a starting point for conceptualising the development of clusters.

The term cluster, however, is used in many different ways. An industrial cluster describes a local agglomeration of firms within the same industry; a regional cluster usually an agglomeration of different industries in a geographically defined space. The two, however, can even co-exist: *Boston's Route 128*-region covers a large number of industries, but also contains areas in which firms of a specific industry are found.

The benefits from clustering can be further described in two dimensions.[11] According to the *horizontal cluster* theory, firms producing at the same step of a value chain, i.e. usually competing firms, benefit from clustering due to geographic proximity. This allows them to respond to product innovations and to imitate the products of the competition (for some, however, this may also be a reason not to be too close to the competitor). Clustering therefore allows the capture of spillovers, specialisation, easy flow of information, industrial economies of scale and, through competitive imitation, advances innovation.

Vertical clustering, on the other hand, describes the agglomeration of firms at different stages of the value chain. Supplier and buyers can respond more easily, as they are in close proximity. Often, vertical clustering follows a lead firm, which groups all relevant suppliers around it. Vertical clustering thus leads to a social division of labour. In the long run, however, vertical integration does not allow the capture of spillovers present in horizontal cluster, that is, the ability to respond to the competition. To benefit from this aspect, vertical clusters must either grow and also become horizontal clusters, or the knowledge flow into and out of the cluster concerning competitive products must be very open.

3.4 Porter's definition of clusters – a mix of horizontal and vertical linkages

One of the principal representatives of cluster theory is Porter,[12] who developed a framework for explaining the evolution of clusters. He defines a cluster as a "geographically proximate group of companies and associated institutions in a particular field, linked by commonalities and complementarities".[13]

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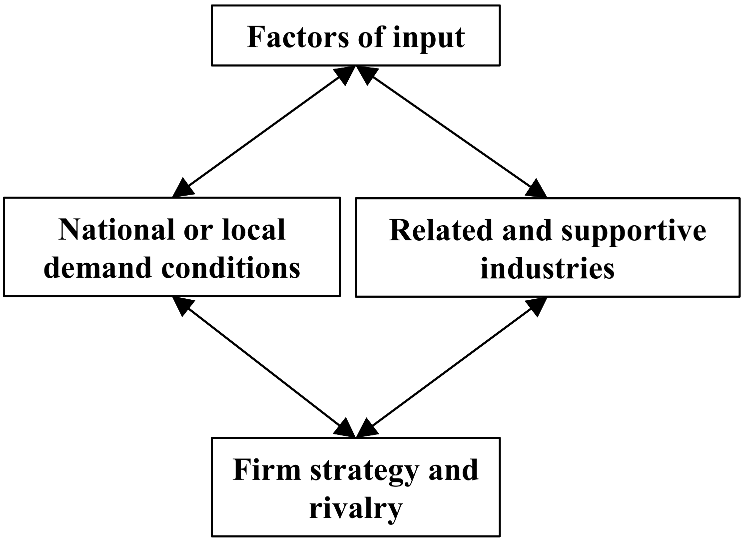
11 This section follows Bathelt, H. and Glückler, J. (2002).

12 Porter, M.E. (1990).

13 Porter, M.E. (1998), p. 199.

To describe clusters, he concentrates in his “diamond analysis”, based on the interplay of essentially four factors: 1. Factors of input 2. National or local demand conditions 3. Related and supportive industries and 4. Firm strategy and rivalry (figure 5).

Figure 5: Diamond Analysis of Clusters



Source: Porter (1990)

Input factors have to be specific and be a distinguishing factor, this can be specific human capital in form of graduates from near-by universities. Product demand conditions are important in two ways: they guide the early development of the cluster and the strength of demand determines the dynamics of the cluster evolution. Related and supportive industries provide cost and cooperation advantages and through networking activities push innovation. Firm structure and rivalry are especially important according to Porter: Strong domestic pressure stream-lines the firms and pushes the innovative frontier (box 2).

Porter predominantly considers horizontal clustering of competing and imitating firms. He assumes a market situation in which competing firms in a cluster engage in a race towards innovation (horizontal competition) while both benefit from specialised suppliers.

Porter’s analysis is often criticised as being too simplistic. For example, he pays little attention to the institutional context of an industry. He also neglects the social aspect of industry evolution, such as the historic orientation of a region towards innovation or the networking aspects of industries. What is more, Porter aims to provide an evolutionary explanation of cluster development, but he concentrates almost exclusively on static parameters such as the current input factors.

Box 2: The relative importance of Porter's diamond analysis factors
Porter devised a cluster databank which categorises a large number of international clusters (http://www.isc.hbs.edu/). A meta-analysis based on his and published research, covering 833 clusters in 49 nations (25 developed, 24 developing) revealed some interesting characteristics of the demography of clusters. The medium number of firms per cluster is 150, even though these numbers vary strongly. Clusters have no predetermined ´life cycle´, there are some very old and some very young clusters. The age is also not related to the degree of competitiveness. For developing countries this is motivating: It suggests that clusters can still be successfully formed today. To explain competitiveness of a cluster, factor conditions were most important (in 47 % of all clusters), followed by related and supporting industries (13.3 %) and the context for strategy and rivalry (13.3 %). Competitive clusters rely on all four factors of the diamond analysis. Interestingly, uncompetitive surviving clusters are dependent almost exclusively on factor conditions and demand conditions (little demand for products of uncompetitive clusters). Notably, rivalry was significantly absent in uncompetitive clusters, suggesting indeed that rivalry is a good stimulus for a cluster. Also, 66.7 % of all clusters in developing countries predominantly relied on factor conditions, compared with only 35.5 % in developed countries. In order to start a cluster, factor conditions were again most important, this was the case in 39.8 % of all clusters, usually simple factors such as raw materials, cheap labour or special growing conditions; more importantly even than specialised labour or knowledge in near-by universities. The second most important reason was "other reasons" (26.3 %), such as coincidences or influence by foreigners. Demand conditions came third with 18.8 % and related and supporting industries fourth with 15.1 %.
Source: Linde, van der, C. (2003)

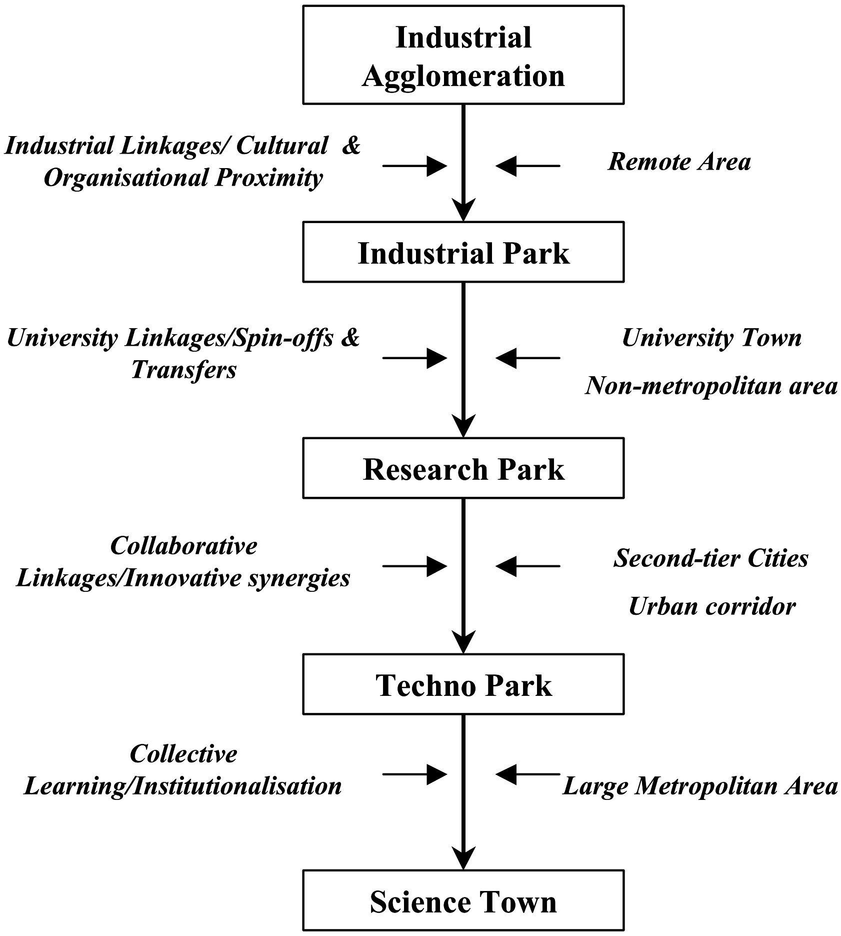
It is tempting to apply Porter's cluster-theory to analyse biotechnology industry-clusters in Asia. However, as will be apparent, this framework is not sufficient, as the Asian experience describes a much more evolutionary development of clusters. An extension of the cluster theory seems therefore apt.

3.5 The evolution of science parks

In Porter's theory of industry-cluster development conditions for research and development are not decisive. Yet the young biotechnology industry relies more than most industries also on basic research. It seems plausible to extend the cluster-theory and to emphasise research opportunities and collaborations.

Indeed, a number of biotechnology cluster, for example *Boston Route 128*-region, the *Research Triangle Park* (RTP) in North Carolina or the *Innovations- und Gründerzentrum* (IZB) near Munich, Germany certainly benefited from the interaction with universities and research institutes. In an industry where human capital is *the* most important asset, proximity to producers of human capital pays. This new type of cluster is then also defined by the interaction between firms and institutions, called a *triple helix*: A combination of *firms*, *universities* and *research centres.* It provides thus a meaningful combination of the concept clustering and the NIS, without, however, asserting a strong direct governmental role. This approach was extended (figure 6) to describe the evolution of Science Parks.[14]

Figure 6: Evolution of Science Towns



Source: Kee-Bom, not dated

14 Kee-Bom (---.).

In phase 1, districts with industrial agglomerations turn into *Industrial Parks* by increasing linkages and the establishments of informal institutions such as trust and social interactions. It is tempting to equate *Industrial Parks* with Porter´s early Industrial Clusters.

In phase 2, the concept is extended to *Research Parks*. The presence of universities and research institutes can lead to linkages to firms, perhaps spin-offs and limited transfer of knowledge. Furthermore, universities contribute with their cultural activities.

In phase 3, universities and firms engage in collaborative research and very high technology transfer activities, thereby forming *Techno Parks.* This is often the case where professors not only teach, but are also heading a company. Firms, universities and research institutes share the same research facilities and there is active management of the interaction between the industry and the other actors.

In phase 4, the final form, a *Science Town* is created. The interactions in a Techno Park are extended to include institutionalised learning and an embedding of the interactions into the local community. All activities are supported by a community providing a very rich supply of services, a strong setting of informal institutions and a creation of social capital conducive for further innovations. Science Towns are set in a metropolitan area, or create these themselves, since only such settings can provide the rich bundle of infrastructure which is conducive for further firm development and which leads to a positive feedback loop. Boston's *Route-128* is a rare example where this has really worked. Here, a cluster that once benefited from military research contracts developed the strength to evolve and support a nascent biotechnology industry, which now constitutes the strongest growing industry. Worldwide, however, there is only a handful of successful Science Towns.

The evolutionary framework of clustering does not emphasise governmental intervention. It starts with an Industrial Park which forms without a direct governmental role. Except for possibly funding by the government of universities and research centres (which could also be private), all further stages also evolve independently of a specified governmental action.

3.6 The role of government in the frameworks

Within the NIS, the government is an important actor. Not only does it define the international position and stability of the economy, it is also largely responsible for many institutions and interacts with firms. It is one source and recipient of knowledge flow, without, however, influencing directly selected industries or firms. Nonetheless, the NIS does provide a reference for policy-makers for decision-making.

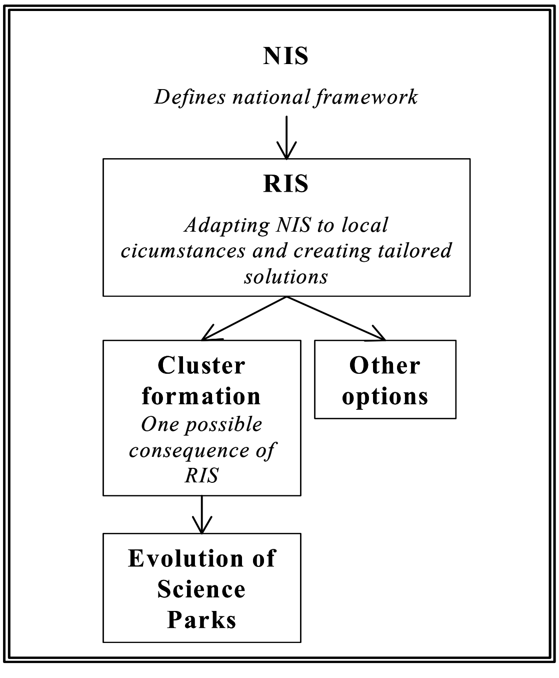
In the cluster theories, in particular in Porter´s theory, the government does not feature much. Clusters start and grow independently, the government fulfils only a minor role. In Porter´s diamond analysis, the government does not feature at all.

This is similar in the extension of cluster theory, the evolutionary framework. Governments at most interact indirectly through university funding or infrastructure for example, but they do not guide or even initiate the cluster development.

For a policy-maker that wants to boost a new industry, the concepts therefore create a certain tension. If he wants to regionally focus industry development the limitations become obvious. The theories speak against far-reaching governmental intervention at this level. This conclusion, however, may be frustrating for countries with no industry, as it essentially calls for a wait-and-see strategy. In dynamic industries, however, waiting may be prohibitive and it may be tempting for government officials to take initiative.

For this reason, an empirical analysis of a nascent and dynamic industry in aspiring economies may shed light on the question if the government should indeed remain passive. South-East Asia provides a particularly good natural experiment for these ideas. The evolutionary framework is used to analyse the development of the biotechnology industry (see also figure 7) in three countries: Taiwan, South Korea and Thailand.

Figure 7: **From NIS to Science Parks**



Source: Own Illustration

4 Biotechnology cluster in Taiwan, South Korea and Thailand

4.1 Taiwan's Science Parks – A success in governmental planning?

4.1.1 The Start –The Hsinchu Science Park[15]

This science park, the first in Taiwan, is often cited as the most successful attempt by a government to create a cluster from scratch. In its profile it resembles more a regional cluster, that is, it is a collection of different industries. Located between Hsinchu and Hsinchu county, the park lies about 70 kilometres from Taipei. It was founded some 24 years ago and supported by the government with about US $ 620.5 million in particular for infrastructure for high-tech industries. Accordingly, the Forbes magazine nicknamed the park "Silicon Island". By the end of 1998, the Hsinchu Science-based Industrial Park (HSIP) had 272 companies with a combined annual sales revenue of about US $ 13.7 billion. Since HSIP slowly reached its geographical limits, it expanded in an extension area in the near-by Tungluo, which served also as the location for some biotechnology firms, as well as the optoelectronics and telecommunication industries. The HSIP also served as the role-model for the new Tainan Science-based Industrial Park (TSIP), which was commenced in 1998, and which by now is the second important comparable science park in Taiwan.

4.1.2 Development and Industry Overview

The government combined infrastructure, human capital and industrial support to form a competitive and innovative park. The HSIP is located close to two important universities, the National Tsing Hua University and the National Chiao Tung University, which together educate about 15,300 students and maintain close contacts with industries. Professors are encouraged to participate in industries, representatives of the industry teach at the universities. The universities and industries are further supported by the near-by Industrial Technology Research Institute (ITRI), which includes research facilities for aerospace, chemicals, computer communications and consumer electronics, electronics, energy and resources, environmental protection, industrial safety and health, machineries, materials, measurement standards and technology, medical devices and instruments and opto-electronics. Recently, biotechnology has also been given its own research facilities. The ITRI forms an important third pillar of the HSIP, next to universities and industries and is key for technology transfer into industries; it also engages in founding its own spin-offs (so far, 31 companies). Furthermore, there are three National Laboratories, the National Center for High-Performance Computing, the Synchronous Radiation Research Center and the National Space Program Office. Some would describe this as an example of a successful *triple-helix* of cluster formation: A joint effort by universities, industries and governmental research.

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15 SIPA (2004).

The administration of the park is in the hands of the Science Park Administration (SIPA), which not only coordinates the development of the industrial park with all its required infrastructure, but it also provides recreational value for the employees; for example it maintains a large sport complex and many large gardens with lakes. Given the expansion of the HSIP into the Tungluo area, as well as the maturity of HSIP, the park authority now concentrates on developing the new site and on creating a network between the Hsinchu and the Tungluo site. It is also responsible for further developing the infrastructure for the families of workers, such as schools and even language and integration courses for the families of foreign expatriates. What is more, it grants Innovative Product Awards, Awards for Innovative Technology Research and awards for R&D on Key Components and Products (see also appendix A for financial benefits and further incentives).

The firms in the park spend a very significant percentage of their sales revenues on R&D, biotechnology tops the ranking as it spends 30.3 % of its revenue on R&D. On average, the firms spend about 6.7 % of their sales revenue on R&D, compared with 1 % for the rest of the country. A very significant part of Taiwan's patents are also filed by firms in the park, over half of the top 10 companies that filed patents in Taiwan were situated in the park. These numbers highlight the high share of research-dependent activities in the park.

In 1998, there were 272 companies in the HSIP, 50 of which were foreign-owned. The sales were a combined US $ 13.7 billion, while the aggregate investment in 1998 was US $ 15.3 billion. Domestic sources accounted for 90.1 % of this investment, while foreign sources accounted for the remaining 9.9 %. The firms have a largely international client base; the international manufacturing and environmental standards (ISO 9000, ISO 14000) are compulsory for all firms. Some 47 firms have also foreign dependencies and the number of foreign investments into HSIP is increasing.

The park authority differentiates between six industries: Integrated circuits, computer and peripherals, telecommunications, optoelectronics, precision machinery and materials, as well as biotechnology. In terms of number of firms and employees, "integrated circuits" tops the 1998 ranking, with 112 firms (out of 272) and 41, 253 employees (out of 72,623); sales were US $ 6.932 billion. Biotechnology is comparatively small, with only 15 firms, 366 employees and US $ 17 million in sales, but biotechnology experienced the largest growth in percentage since 1997. However, due to size limitations it was decided to find new sites for the booming biotechnology sector, which found strong support by the government.

The HSIP therefore provides an interesting example of a science-based industrial park that commenced in one industry and which, over time, developed capacities in a completely different industry: A centre for mostly integrated circuits and computers created an innovative surrounding which was conducive to the development of the biotechnology industry. In this respect, the HSIP is similar to the Boston *Route 128*-region. The further expansion of the biotechnology industry in Taiwan is dealt with in turn.

4.1.3 Further Development of Biotechnology - Three main biotechnology industrial clusters in Taiwan[16]

Since the HSIP proved too small to hold the booming biotechnology industry, the government decided to concentrate its support for biotechnology in three biotechnology industry parks: In the South in the Tainan Science-based Industrial Park (TSIP), east of Taipei in the Biotechnology Plaza of the Nanking Software Park and in a further expansion of the HSIP, the Hsinchu Biotechnology and Pharmaceutical Park.

These clusters are then supposed to be merged in a network spanning from north to south. In the north, the Nanking Site specialises in biopharmaceutical research. The new development of the HSIP will focus on medical supplies and biochips, while in the south, biotechnology in the TSIP will conduct research for agricultural purposes.[17,18]

The newly-developed Nanking Software Park, located east of Taipei, is home to a large number of software development and computer enterprises. In 2003, the Biotechnology Plaza was also founded at this site and is the first important R&D-focused biotech centre in Taiwan. This state-of-the-art facility is found near R&D resources and institutes such as Academia Sinica, the Development Center for Biotechnology (DCB) Hsichih facilities, and the many major medical centres in nearby Taipei City. Furthermore, the National Health Research Institutes (NHRI), the National Science Council and the Biotechnology & Pharmaceutical Industries Program (BPIPO) will also have a presence in the park. The Nanking Site will focus on biopharmaceutical research is expected to be the key biotechnology cluster in Taiwan.

The new Hsinchu Biotechnology and Pharmaceutical Park, an extension of the old HSIP, is scheduled to be fully operational by August, 2004. At its operational peak, around 10,000 highly skilled professionals will be expected to work at this site. Its biomedical zone covers general hospitals, integrated hospitals and a cancer centre, clinical experiment chamber facilities, and biotechnology industry lots. The park will be dedicated primarily to medical education and research.

In the south, the Tainan Industrial Park will be further expanded to hold biotechnology companies. Among the operation facilities to be built are manufacturing areas for the agricultural and biomedical biotechnology industries, enterprise service centres, and clinical trial centres.

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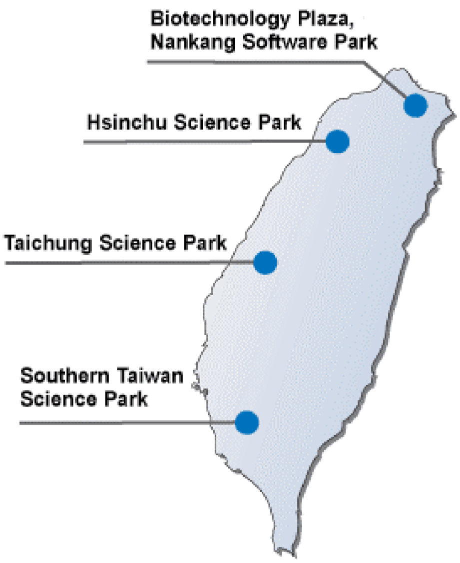
16 biotecheast.com (---.).

17 http://www.corp-compass.com/contact.htm.

18 In addition, a number of regions within Taiwan have started to develop their own biotech areas. Local governments of Taipei City, Kaohsiung and Pintung County, Changhwa County, Tainan County, Ilan County, Nantou County, and Hualien County, among other localities have all been very supportive of their own biotech parks.

It is estimated that the Taiwan biomedical industry will experience an average annual growth rate of 25 % in turnover over the next five years. It is hoped that the three linked clusters will propel Taiwan's biotechnology capabilities into the world's premier league. What is more, the government decided to develop another Science-based Industry Park akin to HSIP and TSIP, located more in the centre of the country near Taichung city and Yunlin county. With this step, the government shows a surprising risk-attitude, as the National Science Council vice-chairman Huang Wen-Hsiung puts it: "In recession, we must prepare for boom time". The map (figure 8) demonstrates the geographical location of the science and biotechnology clusters.

Figure 8: Taiwan's Science Parks



Source: www.biotecheast.com

4.2 The South Korean experience

4.2.1 The Start – The Taedok Science Town

South Korea experienced high economic growth during the 1960´s with the aid of foreign investment and capital. During the 1970´s, however, the South Korean government realised that in order to maintain economic growth, the country would have to establish its own research capabilities. For that matter, it devised a mostly R&D-based park, the *Taedok Science*

Town (TST)[19] (sometimes also called Daedok Science Park, DSP), near Taejon, about 150 km south of Seoul. The planning of TST commenced in 1973 and the first research institutes were located into this park in 1978. Its main purpose was indeed to perform research, not to develop industries; by the mid-1990s, the park hosted 68 research institutions employing about 12 000 scientists and technicians and another 5000 supporting staff. Of these, 19 were Industry Research Laboratories, employing a total of 7393 workers, with the aim to conduct research supportive of South Koreas large industries. The size and importance of these laboratories, however, varies: The largest is the LG Chemical Research Park with 650 employees, the smallest the Kohap Taedok R&D Institute for bio-products and drugs with only 19 employees. It can therefore be said that the TST was not designed as large incubator for the development of small and medium-size R&D-based companies, but instead a large governmental research park with the purpose of conducting basic research. In recent times, however, this has changed somewhat.

4.2.2 Development and Industry Overview

The development of the park was in the hands of the *Taedok Science Town Administration Office* (TAO), itself being regulated by the *Ministry of Science and Technology* (MOST). Since the MOST had little interest to develop industries, the TST remained a science park for most of its time. The R&D concentrated on the following fields: New materials, precision chemistry, electronics, informatics, aerospace machinery, life engineering and energy resources. The basic science is supported by a plenitude of science foundations, such as the Korea Science and Engineering Foundation (KOSEF) and the Korea Basic Science Institute (KBSI). Furthermore, teaching is important; the Korea Advanced Institute of Science and Technology (KAIST), the Electronics and Telecommunications Research Institute (ETRI, a large research institute employing more than 2000 people) as well as local universities, such as Chungnam National University and Hannam University, are actively involved in educating researchers.

In 1994, 21 years of TST´s inception, KAIST established the first program for business incubation and provided small high-technology firms with spaces for RD activities, business services, computer networking services and opportunities for taking advantage of KAIST´s research staff and facilities. The effect was astounding. Until 1994, the ETRI was the most important source for company spin-offs, with a total of 42 firms. Within months, KAIST saw its 30 spaces rented out and until 1999 expanded to 116 firms. The success must have inspired others, in 1998, nine other institutes set up business incubator schemes; within one year, all ten business incubators reported a combined number of 289 firms.

19 Ministry of Science and Technology (2004).

A study[20] that examined the linking of these companies to the institutional landscape came to the conclusion that most of the firms benefited strongly from the local research institutions, universities and related firms (it is not stated whether these are competitors or cooperators), as well as the internet infrastructure. Surprisingly few stated that the local financial institutions and the government offices and authorities had been helpful. A large number of employees had been recruited from the local area, and not, as might be expected, from the capital. This is a sign that the local education efforts by the institutes and universities had been successful over time.

The same survey also uncovered that the source of initial capital was predominantly private savings and loans, friends, family or former employers. Banks provided in 15 % of all cases the initial money, venture capitalists only in 7 %. This suggests that the financial environment of the TST is not geared towards the creation of new firms.

It should be noted that this development occurred in the midst of the Asian financial crisis, which hit South Korea's large companies particularly hard. The effect was that since 1997 a large number of technically able and entrepreneurial employees were laid off. They looked for an opportunity to start their own company. Furthermore, the South Korean government apparently realised that the large South Korean firms were too inflexible to respond to the fast-changing international market and therefore engaged in supporting small- and medium size companies.

The TST therefore provides a different route to the establishment of industry clusters. It was designed to be a hotbed for basic research and education with the hope that this knowledge would find its way into the hands of the large South Korean firms. This concept led to high technological capabilities. When the potential for small and medium size firms was finally realised, combined with the consequences of the Asian crisis, this large knowledge base was finally plugged and very quickly led to the establishment of an industrial base at the TST.

In view of the aim to use a scientific base to advance a country's economy, the TST has not been as successful as the HSIP for example. From the beginning, TST lacked almost completely an industrial dimension, which led to lack of local linkages, difficulty to recruit skilled labour and insufficient business services. In the eyes of many, TST is therefore not really a success.

Furthermore, the TST has played little role in attracting foreign capital, nor has it spawned a healthy biotechnology industry. With the Osong BioHealth Science Technopolis (OBST), the South Korean government sought to learn from its mistakes.

20 Dong-Ho Shin (2000).

4.2.3 Further Development of Biotechnology – The Osong BioHealth Science Technopolis

The Osong BioHealth Science Technopolis (OBST)[21] was designed with a different aim than the TST: To compete not just scientifically, but also on an industrial level. The OBST project was approved in 1997, in 2001 the first important governmental research institutes relocated to the area and in 2002 a ceremony marked the start for attracting firms. OBST is located north from the TST, linked by two highways and a railway to the capital and aims to recruit much of its personnel from the TST. The proximity to 13 universities, KAIST and the establishment of the new Korea Advanced Institute of Health and Medical Technology (KAIHMT) will provide OBST with human capital. OBST is further located close to Chungju International Airport. This places OBST also in the middle of Koreas "Industrial Belt". Since the park is located far from any major city, however, a whole new city is planned to be developed, a condition that is certainly not ideal given that most planned cities take a long time to be attractive for workers as a living environment.

Under the guidance of the Science and Technology Board and the Korea Land Corporation, which develops the area and the infrastructure, important governmental research institutes were first located at OBST. The National Institute of Health (NIH), the Korea Health Industry Development Institute (KHDI), the Korea Food and Drug Administration (KFDA) and the National Institute for Toxicological Research (NITR) first established their offices at OBST.

To raise awareness for the newly developing site, the 2002 Osong International Bio Expo was held, a biotech-based fair for the public.

The establishment of the governmental research institutes and the Bio Expo was aimed to attract firms to OBST. They are further attracted with a whole range of incentives, in particular to attract foreign firms (see appendix B).

It is too early to evaluate the success of OBST, it was only recently opened to firms. It seems, however, that the government has learned from its shortcomings when planning the TST. OBST has a much more aggressive policy for attracting firms, including foreign firms. It can rely more than the TST on components of a triple helix by governmental research, universities and attraction of firms. Unlike the Taiwanese government, Korea has not actively tried to establish a specific sub-type of biotechnology; it is also unclear how big OBST is designed to be and if it can compete with Taiwan's more advanced plans. According to recent news, OBST is intended to remain the only biotechnology industrial cluster in South Korea, but the government plans a whole host of industrial clusters from scratch (see box 4 and figure 9).

21 Osong BioHealth Science Technopolis (2004).

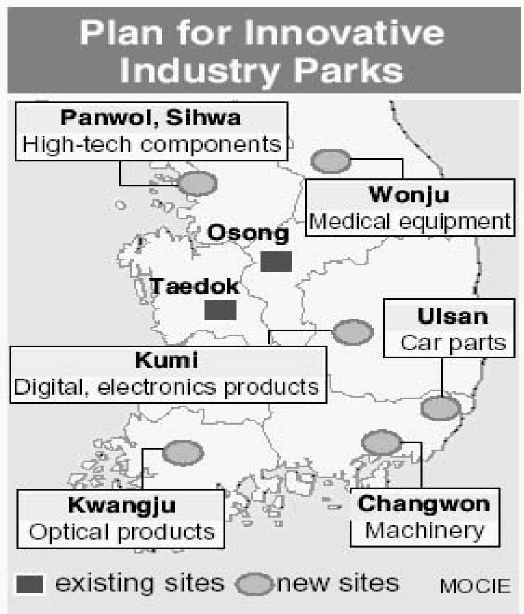
Box 3:	**Innovative Clusters Nationwide in South Korea**

One of the lessons of the Asian financial crisis was that South Koreas firms were too inflexible and the government saw the provision of industry clusters as a good way to attract the forming of small and medium size companies. OBST was attempted first to plug into the lucrative biotechnology industry. Recently, however, the government announced to create six more innovative clusters, geographically spread across the country.

The new clusters will concentrate on high-tech components (in Panwol, Sihwa), medical equipment (Wonju), digital electronics products (Kumi), car parts (Ulsan), machinery (Changwon) and optical products (Kwangju). Kang Nam-hoon, representative of the Ministry of Commerce, Industry and Energy (MOCIE), said: "we will foster the six regions to become Korean versions of the Silicon Valley, which will play a significant part in propelling the nation to reach $20 000 per capita GDP". By 2008, the six complexes are expected to create 37000 new jobs and reach $116.1 billion in exports. It is notable, perhaps, that the planning of the clusters is no longer in the hands of the Science and Technology board or the Ministry of Science and Technology (MOST), but instead the MOCIE.

Source: Kim Tae-gyu (2004)

Figure 9: South Korea's plan for industry parks



Source: Kim Tae-gyu (2004)

4.3 Thailand: Clustering with a mission

4.3.1 The Start – Demand-driven initiatives

Taiwan and South Korea have realised the great economic potential that lies within biotechnology. Neither government, however, aims to develop a specific product.

This is somewhat different in Thailand. The Thai government sees biotechnology as a tool to achieve the aim of boosting its agricultural output. As described below, biotechnology serves only as one of many, albeit perhaps the most potent, tool to increase productivity in one of Thailand's most important economic sectors: Export-oriented agriculture.[22] Conceptionally, this is a different approach than the one used by Taiwan or South Korea. While the Asian Tigers support a supply-driven approach to boost biotechnology, by pushing any general biotechnology industry, the Thai government uses a demand-driven approach. The demand is provided by the agricultural sector that requires increased productivity.

Thailand was hit particularly hard by the Asian financial crisis.[23] After years of high growth, the Thai economy shrunk in 1998 by -7.8 %. Efforts aimed at reviving the economy targeted the technological capabilities in the Thai economy. Despite the rapid industrialisation, agriculture has remained a very significant part of the economy. Thailand has shifted from basic agriculture to industrial agriculture, with special emphasis on postharvest and processing technologies. Among Thailand's top 10 export products in 1998 were rice, canned food, rubber, frozen shrimp and prawn. In the aftermath of the crisis, the weak currency helped exports, but the economy now relies more on R&D to stay competitive.

For example, rice productivity averages only 2.42 metric tons/hectare compared to 6.3 in the USA. Its sugarcane is, in international comparison, not ´sweet´ enough and many plants have to be made resistant against drought, salty soil and diseases.

Before describing the vital role of biotechnology in tackling agricultural problems, it should be noted that the government sees biotechnology only as part of a greater strategy. Other strategies to boost export revenues from agriculture include:

- The establishment of integrated agricultural export zones.
- Encouraging farmers to use less chemical fertiliser while promoting the use of natural and organic alternatives.
- Improving farm methods and technology.
- Improving management of land use and ownership, natural resources, irrigation and coastal areas.

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22 Pearsley, G.J. (---.).

23 Tanticharoen, M. (---.).

4.3.2 Development and Industry Overview – Biotechnology to promote the shrimp industry

Biotechnology is used in shrimp production, rice production, dairy cow development and others. In the field of medical biotechnology, Thailand concentrates on combating tropical diseases, such as Malaria. The shrimp industry,[24] however, serves as a particularly good example of how biotechnology is employed by government agencies to tackle a specific problem.

In 1983, the National Center for Genetic Engineering and Biotechnology (BIOTEC) was founded. It later became part of the newly established National Science and Technology Development Agency (NSTDA). BIOTEC provides all the resources for the country to develop capabilities in national biotechnology R&D. It not only funds research, it is also actively involved in promoting technology transfer from abroad, human resource development, institution building, information services and the development of public support for biotechnology.

BIOTEC[25] granted about 70 % of its R&D budgets to various universities and research institutes around the country and 30 % to in-house-projects. In 2002, the BIOTEC Central Research Unit was relocated to the first science park in Thailand situated in Rangsit, Pathunthani.

BIOTEC´s support focuses on shrimp diseases and improvement of feed supply. The aim is to use biotechnology to control shrimp pathogens, particularly yellow-head disease (YHD) and white-spot syndrome (WSS) disease. Biotechnology found early use in the diagnosis of the diseases. In the time from 1995-1997, YHD caused losses of US $ 40 million, WSS of US $ 500 million. Due to rapid diagnostics, an even worse spread of the disease could be prevented. Another problem is declining fertility of the broodstock. The USA, Venezuela and French Polynesia have already introduced specific pathogen-free (SPF) and pathogen-resistant (SPR) strains (*Penaeus stylirrhostries* and *P. vannamei*) with higher fertility. For that reason, a program has been initiated with genetically improved *P. monodon* stocks in Thailand by BIOTEC. So far, biotechnology is estimated to have saved the Thai economy about US $ 1 billion by combating shrimp diseases.[26]

The national research effort is flanked by an industrial, governmental and university-based research effort. The state-supported firm *Shrimpbiotec* provides diagnostic and research services for the shrimp industry. What is more, BIOTEC promoted the formation in 1996 of an industry consortium (the Shrimp Culture Research and Development Company) that works together with the industry to conduct required research. BIOTEC further supports the Center for Shrimp Molecular Biology and Biotechnology, Centex Shrimp, at the Mahidol University (one of the leading Thai universities). Finally, BIOTEC maintains its own important Central Research Unit. At this research unit, a special food section conducts agricultural biotechnology research.

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24 See also Altenburg (2002).

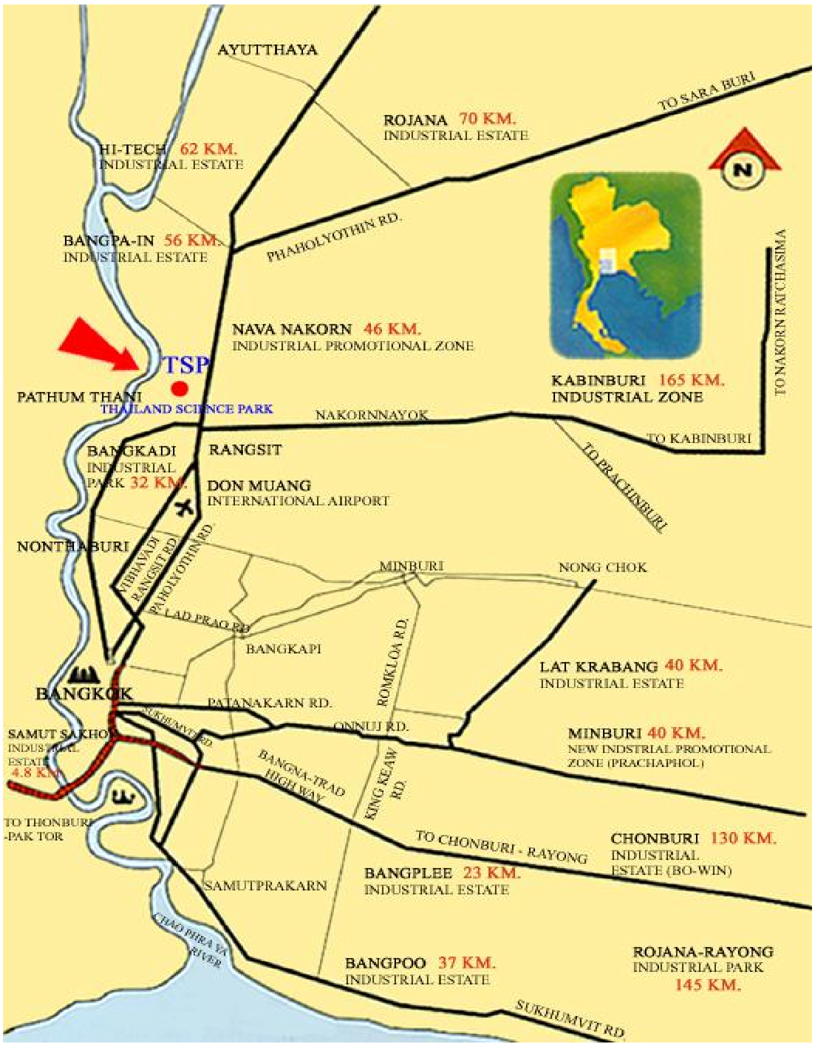
25 see under http://food.biotec.or.th/

26 ---. *Opportunities for Biotech Research in Thailand.*

As mentioned, the BIOTEC Central Research Unit is located in the newly founded Thailand Science Park[27] (figure 10). Here, BIOTEC is joined by the NSTDA office building, along with the two other National Research Centres – National Metal and Materials Technology Centre (MTEC) and National Electronics and Computer Technology Centre (NECTEC).

The Park is located next to Thammasat University (TU) and the Asian Institute of Technology (AIT). Also located at the Park will be the Technology Information Access Centre (TIAC), a provider of on-line information services, including access to relevant databases.

Figure 10: Location of Thailand's Science Park



Source: www.nstda.or.th/sciencepark/

27 see under http://www.nstda.or.th/sciencepark/

The emphasis in the park is on research in the area of genetic engineering and biotechnology, even though there is an industry park in the vicinity. A range of incentives to attract firms exists, including tax relieves, grants, import duty relief and others (little information available).

4.3.3 Further Development of Biotechnology

The 80-acre Science Park is located 20km from Bangkok and was built with an initial investment of US $ 175 million. TSP provides main laboratories, incubator units, pilot plants, greenhouses and accommodations as well as financial, management and legal support for NSTDA, BIOTEC and private customers. In addition, the TSP offers long-term leases of land for construction and ready made wet-lab space for rent.

Information of biotechnology companies in the Science Park is scarce online. However, the BIOTEC central Research Unit provides a number of research services, suggestive of the presence of other biotechnology companies. What is more, Thailand apparently has particularly lax laws concerning research with genetically modified organisms and a well-educated, but cheap research labour force. With its location close to Bangkok, the TSP is well located to a major Asian airport. Also, Thailand is home to a large percentage of the world's known animals and plants, providing a genetic base for many biotechnological firms.

Unfortunately, the information available online in English is not sufficient to establish whether Thailand's strategy of demand-driven and state-led clustering of firms in a Science Park with associated business activities has had convincing success. It does, however, provide a conceptual alternative. One of the key parameters is the size of the target market. The agricultural sector in Thailand is large and important. The demand for biotechnology-based solutions is therefore relatively large and the agricultural biotechnology is much cheaper than the costly pharmaceutical biotechnology.

The approach further confirms the experience that developing countries have made in other industries. Thailand is unable to be at the front of biotechnology advance; instead, the country will usually use methods and technologies developed elsewhere and adapt them for their own shrimp research.

5 The theories of innovation-creation in the light of the Asian experience

This section reviews the applicability of the theories of chapter 3 in light of the Asian experience for biotechnology industries of chapter 4. The section therefore summarises that:

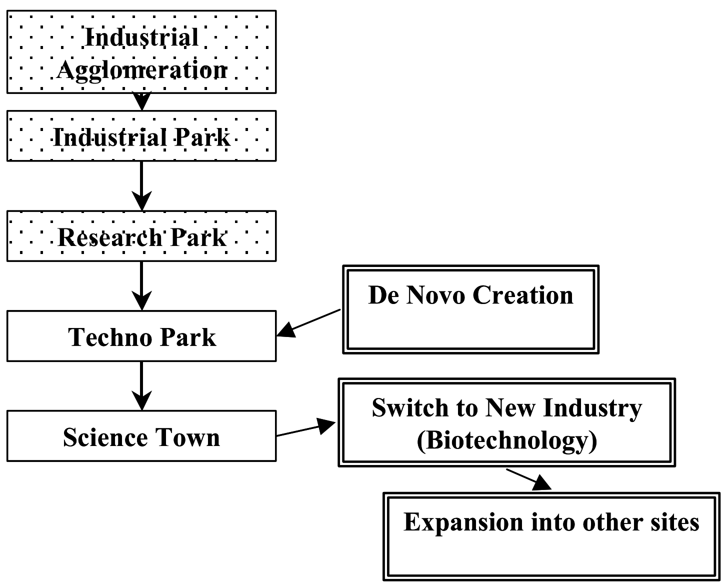
- None of the theories from chapter 3 can fully account for the role of the government.
- Governmental intervention in the biotechnology industry in Taiwan, South Korea and Thailand was instrumental and large.

- The industry-development showed country-specific patterns of governmental interaction.
- These country-specific ways of intervention can possibly be explained by different economic conditions in the examined countries.
- In light of the described Asian experience, the frameworks are not sufficient.

As described in chapter 3, there is a tension between the role of the government in providing the general framework for innovation and the absence of a governmental role in supporting the regional agglomeration of industries. Porter, as one of the principal scholars of cluster-theories even stresses a notable absence of governmental intervention and instead emphasises interfirm-competition as the key driver of innovation. Governmental intervention would only distort this competitive character. The extension of the cluster-theory under evolutionary aspects did see a role of the government, but only in a passive sense (by financing universities and research centres and by providing infrastructure in cities). Within the concept of the NIS, the government is more active, but remains in the background (e.g. by providing institutions or macroeconomic conditions) and does not directly promote industries.

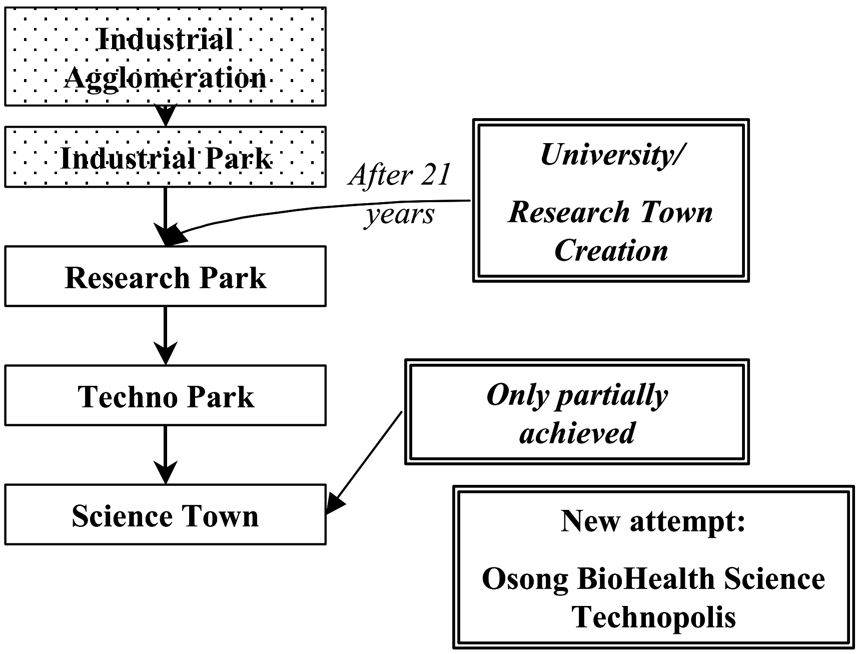
The presented case-studies provide anecdotal evidence that the role of the government in boosting biotechnology-industries in selected Asian countries was quite considerable. It is apparent that due to different historical capacities and needs, the three presented countries pursued different strategies.; the strategies are thus briefly discussed in turn and compared in figures 11, 12, and 13.

Figure 11: Evolution in the case of the Hsinchu Science Park



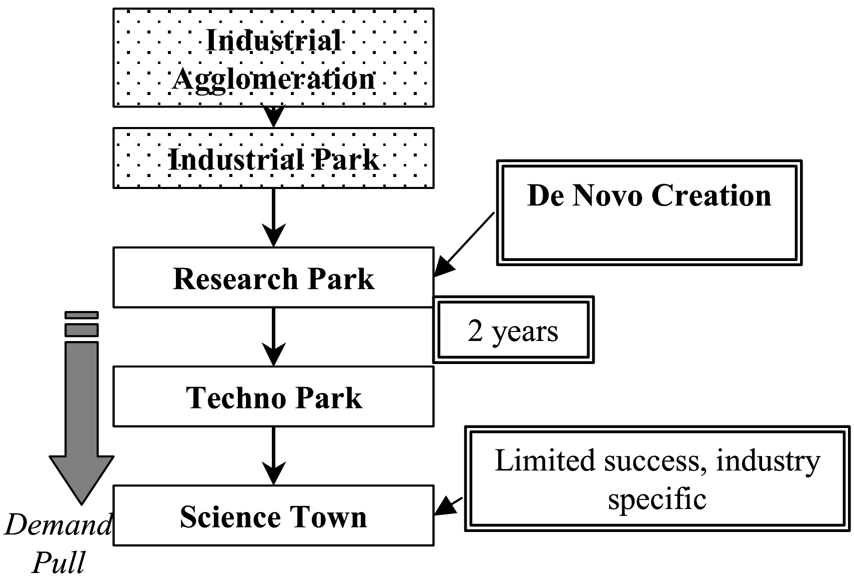
Source: Own Illustration

Figure 12: Evolution in the case of the Taedok Science Town



Source: Own illustration

Figure 13: Evolution in the case of the Thailand Science Park



Source: Own illustration

In none of these countries an industry agglomeration existed that evolved independently into a biotechnology cluster. For this reason, the framework of the evolution of a Science Town does not apply directly. For the same reason, a clustering in the sense of Porter, with firms embedded in a mostly horizontal cluster with growth due to imitation and comparative innovation does also not apply. Instead, the science town development was pushed governmentally in all cases. These efforts supported firms, universities, research centres and all types of infrastructure and institutions. The efforts had at their heart a vertical value chain approach; the biotechnological firms did not compete directly but instead built supplier and buyer-relationships.

It is tempting to speculate about reasons for the different ways of governmental intervention. The underlying causes will be manifold and a detailed analysis why the governments chose to pursue exactly the path they eventually took remains beyond the scope of the study.

Nevertheless, the differing economic and political structures of the countries may provide clues. Compared to South Korea, the Taiwanese government was always more supportive of SME development. It started with this strategy already in the 1950s, linked with an import-substitution strategy. The strategy was to build independent research capabilities, located in small firms. Since these required funding for the research, the government was always very supportive of private R&D, the government finances about half of R&D in Taiwan[28] In some cases, the government also played a *direct* role in developing technologies, exemplified by the Taiwanese semiconductor industry. The success of the Hsinchu Science-based Industrial Park (HSIP) thus relies on the successful combination of interventionist policies conducive to spawning a new biotechnology industry. The start was made by laying out directly all components necessary for a multi-industry Techno Park, which then evolved into a Science Town, with its own rich resources of services and institutional learning. When the global biotechnology boom started, the HSIP was then in ample position to switch to this new industry. Biotechnology then expanded into new sites.

The Korean government, instead, had for long supported its large, multi-industry corporations, the *chaebol.* The Korean technology policy was designed to foster autonomous research capabilities by controlling imports, product reverse engineering and spending large amounts on research (South Korea spends 53 % of total private sector R&D in the developing world[29]). The Taedok Science Town (TST) was therefore designed predominantly to support the *chaebol*, not to spawn new enterprises. With its strong emphasis on research centres, linked to universities, the early TST was therefore more a university town with basic research. Only when the large Korean enterprises suffered in the Asian crisis, efforts were on their way to promote a new industry with small start-up firms. This is the moment when the Research Park evolved into a Techno Park. Unfortunately, however, a Science Town, with its own reinforcing learning was only partly achieved. The young biotechnology industry needed other environments.

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28 UNCTAD (2003).

29 UNIDO (2002).

The Osong BioHealth Science Technopolis (OBST) in proximity to the TST represents an approach more tailored to a nascent industry. Time will tell if OBST will indeed flourish, given that a whole new city had to be planned to house the workers.

Finally, Thailand was technologically far less developed than either Taiwan and South Korea, with few large and small firms and a focus on agriculture. Technologically, it lies between mature Tigers such as Korea and Taiwan on the one side and countries such as Indonesia and India on the other side. Struggling with a poorly educated population and little research expertise,[30] Thailand has little chance to build autonomous technology-industries. Instead, it relies on considerable capabilities in adopting and mastering imported technologies at best-practice levels. It is therefore no surprise that the Thai government sought first to use biotechnology more as a tool to help another industry, not as an industry in its own right. This is partly reflected in the industry-development. After a transition period, in which the Thailand Science Park (TSP) relied on the research centres, firms (e.g. *Shrimpbiotec*) with links to customers and research units, were also established. With its proximity to Bangkok, the final status is a Techno Park with, perhaps, the required service infrastructure, institutional learning and vertical linkages to qualify as a Science Town for this specific industry. The low number of qualified personnel (for example, 49 % to 64 % of university faculty have less than a Master´s degree[31] and in 1995 Thailand had only 119 scientists and engineers per million population, compared to more than 2 500 in South Korea[32]), however, does not paint a positive picture for the future development of a competitive biotechnology industry.

While the causes of varying ways of governmental intervention remain, in this study, mostly elusive, the study does show that for the biotechnology industry the government did play a very instructive role.

In this respect, the theories described in chapter 3 seem applicable only in parts, in particular Porter's cluster-theory appears too narrow in its definition of instrumental factors of cluster-development. The extension of the theory into an evolutionary framework also left too little space for a direct governmental role, but at least mapped the later stages of a Science Town development. The concept of the NIS, in turn, does consider a greater role for the government. In light of the Asian experience, though, in particular in Taiwan and South Korea, the experience has shown that state actors not only interacted with firms (as would have been described by the NIS), but also actively attracted domestic and foreign firms (see also appendix A and B).

Yet it is not clear if the counterfactual, that of governmental absence, would not have equally led to a blossoming of a biotechnology industry. This counter-argument can be weakened by the fact that in none of the three countries a competing, independent biotechnology also

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30 UNCTAD (2003).

31 ibid.

32 Middleton, J. and Tzannatos, Z. (1998).

evolved in parallel. On the other hand, the governmental effort could have produced a significant crowding out effect, which would have negated an additional industry development in these countries. A study about the biotechnology-industry in more free-market developing countries (possibly Latin America) could perhaps shed more light on this question. The study presented here simply illustrates that some Asian countries did use interventionist tools and did so with different strategies and with varying success.

The alternative to such a strong governmental role, however, is not necessarily a total absence thereof. The German experience with the BioRegio contest provides an example where the government undoubtedly was instructive in the development of the biotechnology industry, even though its direct role was minimal compared to the examined Asian countries. The contest is described in the next section.

6 The German BioRegio contest

The German BioRegio contest,[33] initiated in 1995, was intended to support the biotechnology industry by means of a governmentally-induced competition for private and independent development. Aim of the contest was to promote three biotechnology regions in Germany financially, selected as the winners of a contest.

6.1 Background situation in Germany

Until the 90´s, Germany's biotechnology industry was not well established compared to the UK or the USA. Germany, however, was internationally envied for its variety of internationally competitive basic research centres, for example the Max-Planck-Gesellschaft for basic research or the Fraunhofer-Gesellschaft for industrial research. The Deutsche Forschungsgemeinschaft (DFG), coordinated financial support of research. Germany lacked, however, biotechnology clusters which would concentrate on bringing the principal actors of research institutes, local or regional governments and industry together.

To boost the biotechnology industry, the Federal Ministry of Education and Research designed a competition; it was intended to select and support the three regions with the most competitive biotechnology industry development plan. Any region could apply.

33 The information about the BioRegio contest follows largely a talk with Dr. Stöffler, formerly responsible for the BioRegio contest at the Federal Ministry of Education and Research and now Deputy Director General for New Technologies at the Ministry.

It should be noted, however, that in the 1980´s, the Federal Ministry of Research[34] had promoted the establishment of six ´Gene-clusters´, research institutes, which, as it turned out, would also form the most competitive applicants for the BioRegio contest. Those were the region Munich, Cologne and the Rhine-Neckar triangle. The ´gene-centres´ were promoted for 10 years, but had to establish independent means of funding; the ministry would not extend the funding. Those centres developed into the first nuclei of biotechnology in Germany.

6.2 The concept of the contest

The Ministry used a limited amount of money in order to achieve a multiplying effect. Applying regions were given 100 000 DM (~50 000 Euro) for the application process, in which they would have to present a concept of how to become a competitive cluster.[35] Twenty regions applied and soon realised that the 100 000 DM were not sufficient; the application process already spawned successful attempts to recruit funding from elsewhere. Furthermore, the chances of winning were slim, the Ministry would pick only three winners. Nevertheless, the response was overwhelming.

The contest, however, faced some political obstacles. In Germany's Länder, different parties were in power and enviously vied for support for ´their´ Land and Party affiliation. To avoid any complains, a very high profile and balanced jury was employed, consisting of scientists, economists, labour union representatives and politicians (box 4).

Box 4: Criteria for the BioRegio contest
A panel of high-profile judges evaluated the competing candidate regions according to the following criteria: •Existence of a prolific scientific scene, the existence of biotechnology-oriented research centres in vicinity? •Quality of communication infrastructure in the region •Number and size of existing firms oriented towards biotechnology •Location of supporting facilities, such as patent office, information networks, consulting support, local financing banks •Strategies for converting biotechnology know-how into new products, processes and services, including marketing strategies •A concept and support for start-up of biotech-firms •A financial market structure and risk-capital availability for start-up firms •Cooperation between research institutes and hospitals in respective region

34 It only later turned into the Federal Ministry of Education and Research.

35 See also Marquardt (2000) and Ernst & Young (2003, B).

6.3 The result of the contest

Three regions were selected directly: Cologne, Munich and the Rhine-Neckar triangle. All three had already been promoted as Gene-centres in the 80´s. For political reasons, Jena was also supported. In hindsight, these regions had looked like the most likely winners before the onset of the competition anyway, but the contest stimulated the efforts of all competing regions. In total, the Federal Ministry supported each region with 50 million DM (about 26 million EUR), Jena received another 30 million DM (15 million EUR). The financial support was paid over a period of five years. In the end, all three regions developed very well, both scientifically and economically.

Somewhat surprisingly, perhaps, all the other regions that had competed also developed well (figure 14). This can be seen as the consequence of the application process, which stimulated the conception of successful business-plans. The region Hamburg subsequently even attracted more financial support than any other region, even though it had not been picked as a winning region, while the Berlin-Brandenburg region spawned the largest number of Biotech companies. Thus, it is estimated that by 1999 about 165 million EUR were governmentally invested, which in turn generated about 292 million EUR in additional investment and created 850 jobs. However, the general biotechnology industry experienced also a push through this contest and awareness-building; today there are about 360 SMEs with 14 000 employees. Considering further the supplying industry, it is estimated that about 300 000 jobs are dependent on the biotechnology industry.

Figure 14: The biotech regions that developed out of the BioRegio contest

Source: http://www.bioregio.com/karte.htm

The largest number of new firms were involved in Pharma & Healthcare (42 %), followed by environment and genomics firms. The focus was generally on R&D-intensive firms (41 %), followed by service and suppliers firms (29 %) and producing firms (20 %).

It should be noted that the financial situation was certainly very conducive at the time of the contest: Worldwide, biotechnology was booming, the international stock markets were looking for investment opportunities and in the year 2000 alone, ten biotechnology firms were listed at the stock market, with more than 400 million EUR market capitalisation.

What is more, the venture capital market had become very active; an internal evaluation of the Ministry estimated that for each DM/EUR of support, 14 DM/EUR were added by venture capitalists.

6.4 A BioRegio contest for Developing Countries?

One has to remain sceptical about the prospect of using the BioRegio contest as a way of stimulating the development of similar clusters in South-East Asia. Some countries, such as South Korea or Taiwan may have the required infrastructure and preconditions, but most countries lack these. The BioRegio contest built on the following preconditions:

1. A previously existing potential of a biotechnology, including the Gene-Centres, universities and a large and varied number of independent research institutes.

2. A sense of competition among independent and decentralised authorities and research centres.

3. Abundance of human capital, entrepreneurs and industry representatives.

4. Sufficiently large financial, stock exchange and product markets so as to support also regions that do not win the contest (i.e. that led to the positive development of all other 17 competing regions); if these markets are not present, the incentives to compete are not great enough as losing the contest would be equivalent to losing out completely.

5. An international financial situation conducive to risk-capital (as found before the stock exchange crash).

6. Limited political problems (avoided in Germany by use of jury and by compromising on taking Jena) of implementation and choosing the winners.

Bearing these factors in mind, most developing countries in South-East Asia must probably be excluded. The most likely candidates remain Taiwan and South Korea. Even in these countries, however, the total numbers of pre-existing possibilities is limited, except, perhaps, in

Taiwan.[36] With only a limited number of potential regions, the idea of a contest remains dubious; the lack of a financial market to support a number of different clusters is equally problematic. Furthermore, it has to be established if these countries are conducive to the idea of interregional competition, or if they prefer governmental guidance.

7 Conclusion

The study presented frameworks of industry-clustering and the evolution of science parks as subparts of the NIS. It further introduced the importance of biotechnology for developing countries in Asia. The study then analysed the growth of biotechnology clusters and compared it to the discussed theories. This showed the following:

- The growth of biotech-industries in these countries were always accompanied by considerable governmental intervention.
- The paths taken, analysed with the evolution framework, was different in all three cases.
- While the reason underlying the different cluster development paths remains undefined, it seems clear that the described theories are not sufficient to explain any of these and should be extended.
- The German government promoted its biotechnology industry differently, but the applicability of its contest model to most countries is doubtful.

The study provided a framework-based introduction. Due to the lack of local contacts and site-visits, however, the study had to remain undefined in several areas:

- Even though prominent theories have been criticised, the study does not provide an alternative.
- The NISs of the examined countries have hardly been explored.
- The study did not focus on the overall economic significance of the biotechnology industry for the selected countries.
- In addition to the selected countries, the study could have focussed further on a country less technologically advanced than Thailand, for example Indonesia; that way a more complete spectre of developing economies in Asia could have been presented.

Despite these shortcomings, the study has given a good introduction to the development of one of the most important industries in some of the most dynamic economies in the world. It remains to be seen if the experience in Taiwan, South Korea, Thailand and Germany can lead to new theories that act as role-models for other countries.

36 As referred to in chapter 4.1.4., there are now a number of regions in Taiwan that aim to boost their own biotechnology industries, a competition among them may be possible.

Appendix A

Examples of incentives for firms to establish themselves in Taiwan’s Science Parks:

Financial Benefits

- Accelerated depreciation on equipment
- Tax deduction on the equipment, technology, expenses for R&D and personnel training
- Shareholders' investment credit
- Five-year tax exemption
- Duty free for imported machinery and equipment
- Tax exemption for 50 percent of the royalty for personal creation or innovation
- Encouragement of merger or consolidation of companies
- Land-value increment tax incentives for plant relocation
- Outward investment loss reserve
- Exemption of income tax on technical royalty payment
- Separate tax rate of 20 percent for dividend or partnership's profit distributed by a foreign profit-seeking enterprise of a non-resident individual
- Exemption of income tax of the overseas salary of expatriates
- Other tax incentives

Government Investment Participation

- Executive Yuan Development Fund and Chiao Tung Bank investment key points for high-tech enterprises
- Five-year Investment Plan for Biotechnology by the Executive Yuan's Development Fund
- New Product Development Assistance

A. Methodology for encouraging the development of new industrial products by private enterprises

B. Assistance in the development of innovative products

C. Technology project management system of private enterprises

D. Small- and Medium-Sized Business Innovation Research

Appendix B

The Korean government devised a number of incentives to attract firms to OBST, including:

- National tax exemptions for the first five years and 50 % reduction for the next 5 years
- Exemption of property tax and comprehensive land tax for 5 years
- Partial funding for research and long-term low-interest loans
- Ample access to office and research space
- Administrative support for certification, approval services
- Use of governmental research space and networking systems
- 50 % reduction of special surtax and transfer tax for the movement of headquarter and plant to local area
- Low interest support: Settlement fund (6.25 %) and company support fund (3 %)

These incentives are much more extensive than what had been found at TST.

In addition, the government attracts foreign firms with almost paradisiacal conditions for foreign investors, for example:

- Exemption of corporation tax, local tax and income tax for 10 years (more than for domestic firms)
- Reduction of property, acquisition, registration and land tax by 50 %-100 % for maximally 15 years
- Partial financial support for R&D activities
- Right to use, profit from, and rent real estate, plant or other properties of the national or local government
- Exemption of tariff, special consumption tax and added value tax for the amount of investment
- Permission to acquire any lot in the park and to cooperate freely with any domestic firm
- Permission of foreign M&A
- Free use of foreign currency
- Significant reduction of administrative registration burden

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