Business ecosystem dynamics

a research into R&D ecosystem dynamics in China for Philips Research Asia Shanghai

van den Berg, R.A.J.

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Shanghai, June 19th 2009

Roel van den Berg Bsc.

TU/e Technische Universiteit Eindhoven University of Technology

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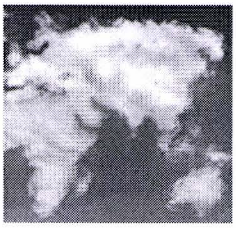
Shanghai, June 12th 2008

Author: R.A.J. van den Berg BSc
Studentnumber: 522626
Company Mentor Philips Research Asia Shanghai:
Ms. Sherry Yu
Initiator and project owners:
Dr. Ir. Frans Greidanus
Ir. Reinoud Selbeck
University supervisor:
Dr. Allard Kastelein
Innovation, Technology, Entrepreneurship & Marketing
2nd supervisor:
Dr. Ir. Isabelle Reymen
Innovation, Technology, Entrepreneurship & Marketing
Education program:
Innovation Management
Industrial Engineering & Innovation Sciences
Eindhoven Universiteit of Technology

Key words: business ecosystem, competitive advantage, location factors, location theory, China

To Toon van den Berg

To Jup van Gerwe



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Management Summary

Context and developments

One of the most profound outcomes of economic growth in its modern day, read globalized, context is its geographical unevenness. On the one hand is the "flat world" (Friedman, 2005) spreading economic functions around the planet. On the other, the world is "spiky", with a tendency for activity to cluster in relatively small numbers of locations (Florida, 2008). Apparently these spiky locations offer local companies competitive advantage through e.g. skilled labor, infrastructure and accumulated know-how.

The term business ecosystem refers to dynamic structure which consists of interconnected organizations including small firms, large corporations, universities, research centers, public sector organizations, and other parties which influence the system. Spikes in the economic geographical distribution of a certain business represent locations with competitive advantage for that business and thus a mature business ecosystem.

For manufacturing but also R&D activities, being in such a competitive place can greatly enhance economic outcome in terms of profitability, returns on investment, patent filings, etc. In the future, success will come to those companies, large and small, that can meet global standards and tap into global networks. And it will come to those cities, states and regions that do the best job of linking businesses that operate within them to the global community (Kanter, 2003).

Research goal and questions

In this graduation project a research approach has been designed and implemented to analyze the dynamics of R&D ecosystems.

Research goal:

> *"Develop and implement a method to analyse dynamics in business ecosystems in China"*

And management question:

> *"How can PRAS cope with their R&D ecosystem dynamics in China?"*

In order to reach the research goal and answer the management question, the following research questions have to be answered:

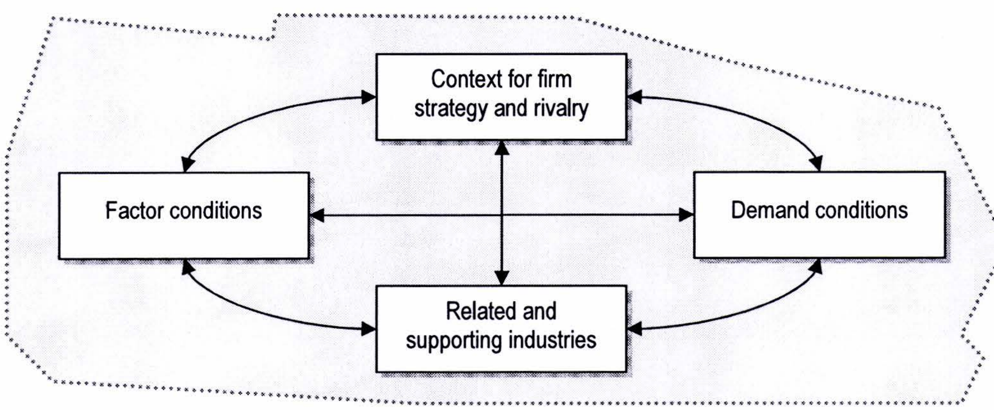
1. How does science explain business ecosystems and (re)location of businesses?
2. Which variables affect R&D location decisions?
3. What are the current values of these variables in China?
4. How will these variables change in time?
5. What will be the resulting R&D ecosystem dynamics?
6. How can the PRAS cope with modeled R&D ecosystem dynamics?

Literature review

In a literature survey on business ecosystems as an approach to complex business environments (Peltoniemi, 2004) a conclusive definition is provided in which a business ecosystem is considered to be:

"A dynamic structure which consists of an interconnected population of organizations. These organizations can be small firms, large corporations, universities, research centers, public sector organizations, and other parties which influence the system."

These definitions of business ecosystem are very close to the concept of clusters, a term introduced by Michael Porter (1990) in his famous book "The Competitive Advantage of Nations". In his work he defines clusters as "geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions in particular fields that compete but also cooperate" (Porter, 1998: 197–198).



In this thesis, Peltoniemi's definition of a business ecosystem is acknowledged and the Porter Diamond is used to describe the forces that affect the state of a particular instance of business ecosystems. No matter what the geographical area of interest, be it nations, states, cities or even neighborhoods, the Porter Diamond can be used to describe the business ecosystem in place in terms of four determinants.

Business (re)location theory is the science that studies why business locates where it does, the process that essentially shapes business ecosystems. Profitability of a location is identified (Hoover & Giarratani, 2006) as the most important measure of competitiveness of alternative locations. But even when the profit motive is paramount there are other significant considerations. Although the definitions of benefits or costs may differ in substance across individual businesses or firms, the goal of seeking to increase net benefit by a choice among alternative locations is common to all.

The basis for locational preferences can be expressed generally in terms of a limited set of location factors. These factors can be categorized into a standard set of a few elements defining competitevens of locations. The Porter Diamond categorizes the location factors into the four determinants to describe a business ecosystem.

Studies on location decision making by individual firms started as early as 1929 with Alfred Weber's theory on the locations of industries. His neoclassical location theory interprets the firm as a 'Homo Economicus' who has the perfect economic information and perfect rationality to compute an optimal location in the sense of minimizing costs or maximizing profits. In terms of the Porter Diamond the neoclassical approach focuses on quantifiable determinants, like certain factor- and demand conditions and transportation related factors, in explaining competitiveness and business location decisions.

The neoclassical view is that firm location is driven by powerful forces of economics and industry can only ignore economic reality at their own peril. This view has had a pervasive influence in business location theory. Practically, the neoclassical approach has a strong 'common sense' appeal in that it stresses the axiom that for firms to be viable revenues must exceed costs and that decisions for firm locations should be made accordingly. Moreover, at a time of rapidly globalizing competition, the neoclassical emphasis on the relentless and rational pursuit of lower costs and more profits captures an essential dimension of contemporary economic dynamism (Hayter, 1997).

This neoclassical theory is useful as a benchmark that defines the 'optimal' behavior of the firm in economic terms, under the assumptions of rationality and perfect competition. But the use of the neoclassical approach as the sole explanation of business location has been criticized since the 1960s because of its ignorance of historical events, imperfect information and uncertainty which all do seem to effect the locations of firms. Apart from this, the application of a more 'behavioral' approach in location theory was also motivated by limiting discriminating power of regional economic conditions in determining the optimal location of industries or, equivalently, the spatial margins of profitability (Hayter, 1997). If regional economic conditions show limited variation, this leaves many profitable sites to choose from. Then firm-specific economic factors or non-economic factors may become of more importance for the explanation of firm locations.

The behavior approach adds to the neoclassical approach by exploring the many motives, economic and non-economic, that are important in the decision making process of a particular firm. The approach seeks to understand the actual behavior of businesses and focuses on the decision making process. Although a useful approach to understanding firm relocations, critics say that it focuses too much on sociological, psychological and other 'soft' variables (Scott, 2000); in the same way the neoclassical approach relies heavily on purely economic locational factors. A combination of the behavioral and neoclassical approach seems to be more fruitful.

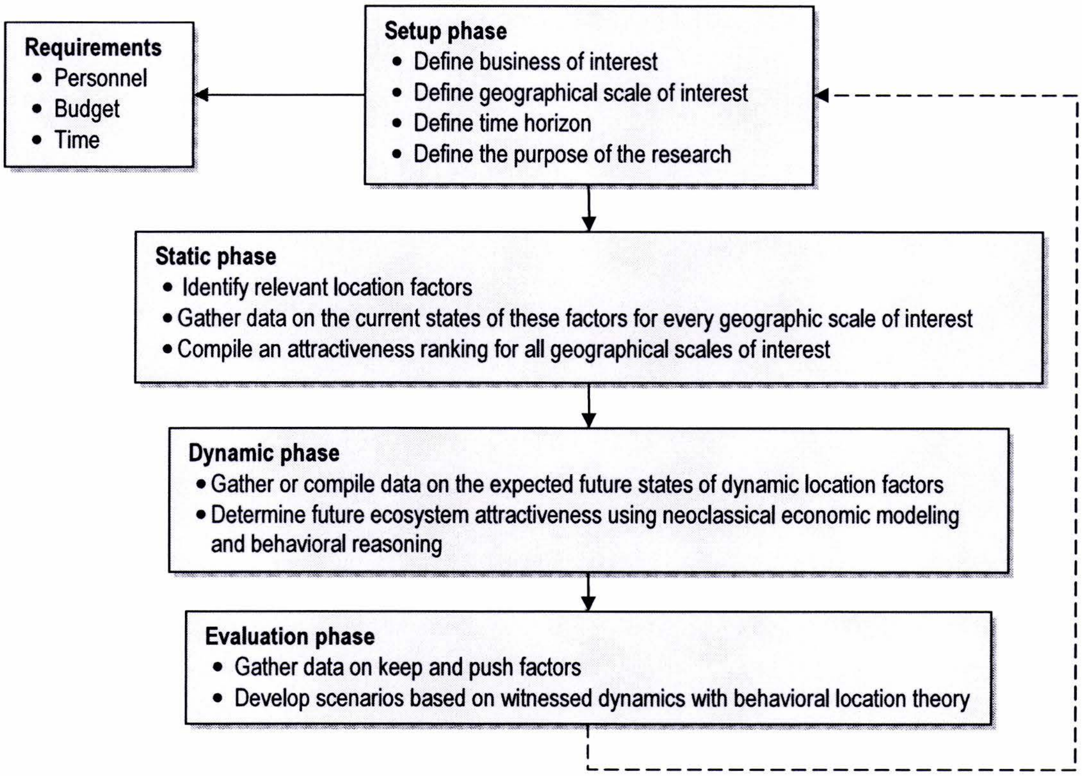
Management decision making itself can be envisaged as an ordered process. Simon (1977) was the first to outline three phases in the managerial decision process. The first phase is about intelligence activity, which involved recognition of the need for a decision by investigating internal performance indicators and external conditions. The second phase is directed towards design of a method to gather relevant data to define alternative solutions. The third phase is the about actually choosing the alternative and implementing it.

In line with Simon's study (1977) describing managerial decision processes as ordered three phase processes, a few investigators have identified different stages in the location decision making process (Schmenner, 1982; Kotler et al., 1999). The starting point of these frameworks is a need to (re)locate a factory or shop and as such it the frameworks work well for individual firms that have to make a physical (re)location decision. Yet this outset makes them intrinsically non optimal for application in a business ecosystem dynamics research. A business ecosystem dynamics research does not necessarily start with an identified need to (re)locate parts of a firms business. Rather the objective is to analyze how the industry is likely to evolve geographically. Methods to conduct the second phase of Simon's (1977) decision process on business ecosystems dynamics have not been found during this literature study.

In this master thesis, the research goal has therefore been achieved by first designing a research method tailored for analyzing business ecosytems. It has subsequently been used to answer the management question. The core of the research model is based on three main pillars: business ecosystems, location theory and location decision making.

Research method

To conduct the research a four phase research method has been proposed:

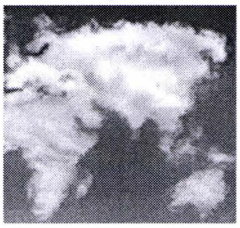


The process is sequential from the setup to the evaluation phase. After evaluation of the results of previous phases the company can decide to perform another loop on a different geographical scale. During its application in the analysis of Chinese R&D ecosystems at PRAS, the business of interest has been defined as open innovation based research and development activities conducted by corporate multinational enterprises. The geographical scale of interest is capitals of Chinese provinces, capitals of autonomous regions and the four municipalities. We did not include Hong Kong, Macau and Taiwan. The time horizon was set to five years and the purpose of the research is to get insights to what China's R&D competitive landscape will look like in five years.

Conclusions

From 1994, when the first foreign R&D centre was registered, the number of them has rapidly increased to over 750 by the end of 2007. So far, foreign R&D centers have located in major Chinese cities, such as Beijing and Shanghai, and in locations with high concentrations of FDI such as Guangzhou and Tianjin. Recently, 2nd tier cities like Suzhou, Nanjing, Shenzhen and Dalian are witnessing the setup of MNE labs as well.

Currently Beijing and Shanghai offer the most competitive locations for MNE R&D activities. Their location factors are most favorable to support the business and this will not change in the next five years. 2nd tier cities near Shanghai and Beijing will see the first spillover effects before cities further inland will. Four types of scenarios have been proposed for Philips on how to deal with the predicted R&D ecosystem dynamics. None of these have been developed subsequently as PRAS moved into its new location in Shanghai during the course of this master thesis project.



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Preface

This thesis is written in Shanghai at Philips Research Asia Shanghai (PRAS), the Chinese laboratory of Philips Research which aims at developing new technologies and products for the East Asian market. The principals for this thesis are Ir. Reinoud Selbeck, former CPO of China and Dr. Ir. Frans Greidanus, GM of PRAS and CTO East Asia.

Supervised by Dr. Allard Kastelein and Isabel Reymen from the Innovation, Technology, Entrepreneurship and Marketing (ITEM) group within the Industrial Engineering and Innovation Sciences department of Eindhoven University of Technology, the goal of the research is to provide Philips insight in the dynamics of China's provincial R&D ecosystems. To reach this goal, a research design and a mathematical model have been designed and implemented. Both the approach and model can be reused and customized to various other Philips businesses that are interested in business ecosystem dynamics.

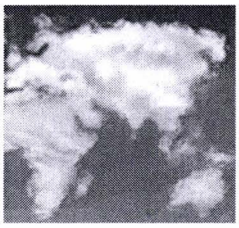
Through here I'd like to first of all thank both Frans Greidanus and Reinoud Selbeck for granting me the assignment and putting faith in me. Also, I'd like to thank all the people of PRAS for the warm welcome they gave me, Allard and Isabel for their valuable input, Hans Oerlemans with whom I travelled to Beijing and my colleagues in Project Leapfrogger: Berend Luger, Paul Wang and Arjan Petten.

A great word of thanks goes to Serge Aluker, my highly appreciated former colleague and dear friend, without whom I couldn't have done an equally good job. And finally I want to say thank you to Khoby. Our marriage is by far the most unexpected and beautiful outcome of this project. I thank her for her patience, support and understanding.

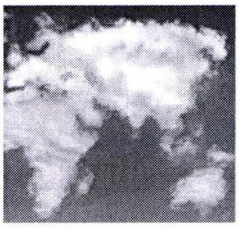
Have fun reading this!

Roel van den Berg

Shanghai, June 2009



Index



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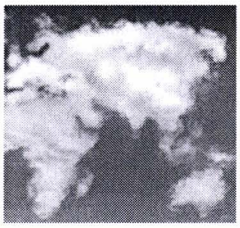
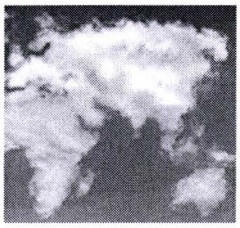
Glossary

BOM	Bill of Material
CTO	Chief Technology Officer
CPO	Chief Purchasing Officer
(F)CS	(Final) Competitiveness Score
DLF	Dynamic Location Factor
FDI	Foreign Direct Investment
FOP	Factor of Production
FTE	Full Time Employee
GDP	Gross Domestic Products
GERD	Gross Expenditures on R&D
GIO	Gross Industrial Output
GSI	Geographical Scale of Interest
IP	Intellectual Property
IPR	Intellectual Property Rights
MBA	Master of Business Administration
MNE	Multinational Enterprise
MP	Market Potential
OECD	Organization for Economic Cooperation and Development
PGP	Philips General Purchasing
PRAS	Philips Research Asia Shanghai
R&D	Research and Development
S&T	Science and Technology
SEZ	Special Economic Zone
SKL	State Key Laboratory
SRI	Supporting and Related Industries
WIPO	World Intellectual Property Organization
WTO	World Trade Organization
YOY	Year-on-Year



List of figures

List of tables



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List of digital documents

Digital document 1: Static phase GSI and region raw statistics.xlsx

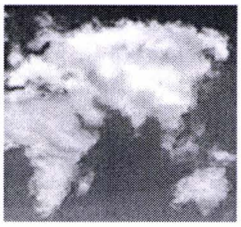
Digital document 2: Static phase GSI scores.xlsx

Digital document 3: Computer model.zip

Digital document 4: Computer model manual.pdf

Digital document 5: Dynamic phase GSI scores.xlsx

Digital document 6: Master thesis – Roel van den Berg – final.pdf



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1. Introduction

This master thesis was written at Philips Research Asia Shanghai (PRAS) and its aim is to provide Philips Research a better insight into the research and development (R&D) ecosystems in China. Emphasis in this master thesis research project is on the development of a structured research design to investigate business ecosystem dynamics.

This chapter serves as an introduction to this thesis and provides short descriptions of the concepts globalization and business ecosystems as well as the goal and objectives of the research. This chapter is written based on literature reviews and interviews with field experts within Philips as well as with external parties.

1.1. Context and developments

Throughout history people have expanded the variety of resources, products, services and markets available to them by establishing contacts over a wider geographic area. It's a century long process that really took off with the establishment of the ancient Silk Road, an interconnected series of trade routes through various regions of the Asian continent. Trade on this route was a significant factor in the development of the great civilizations of China, Egypt, Mesopotamia, Persia and Rome, and in turn helped lay the foundations for the early modern world.

Later, the 15th century voyages funded by European monarchs in search for new trade routes to India led to the discovery of many new lands. The quest for variety continued with imperial expansion and the colonization of these lands. In the mercantilist era, companies such as the VOC even served as surrogate colonial governments, all primarily for the purpose of trade. This trade flourished through privatization and the use of intercontinental railways and transoceanic steamships until the process halted early 20th century due to the two World Wars.

After World War II international trade and investments were driven mainly by advances in technology that lowered the cost of trade and liberalization of cross border trade due to changing political situations. Organizations such as the World Bank, the International Monetary Fund and especially the World Trade Organization were also founded to foster global corporate trade again. As a result the level of global trade increased 14-fold in the period from 1950 to 1997 (World Bank, 2003).

International trade, investments and human interaction have increased the worldwide integration of economic, cultural, political, religious, and social systems and it is this integrating process that is often called globalization. This term, presumably first used in an economic context by Theodore Levitt in 1983, means different things in different contexts (Osland, 2003) and has been defined in many ways in contemporary sciences. Although the author recognizes that globalization has had various effects on our everyday lives, the emphasis in this thesis is on the economic and demographic effects of globalization.

In time this process was driven by different entities with different motives. In early modern times feudal governments were looking to acquire greater wealth through trade but gradually their motives became more diverse. As the political situations in Western civilizations changed, so too did the actors in the globalization process. By the late 19th century globalization was driven mainly by multinational enterprises (MNEs) that internationalized their businesses to expand sales, acquire resources and minimize risks or a combination of these. Since then, many multinational enterprises like Philips have increasingly shaped our world by setting up factories and offices around the world, thus driving globalization, international business and people's interdependence.

Today Philips operates in 60 countries, employing approximately 116,000 people that generated annual sales of 26 billion Euros in 2008. The history of one of the world's biggest enterprises in the fields of health care, lifestyle and technology dates back to 1891 when two brothers Gerard and Anton Philips founded Philips & Co in Eindhoven to serve the growing demand in incandescent light bulbs. From Eindhoven the company then expanded its product range as well as its geographical reach by setting up business in European countries, the US and finally emerging economies in Asia such as China.

In this geographical expansion Philips has helped the formation of "new industrial spaces", a term coined by Allen Scott (1988) to denote concentrations of business activities in regions that are situated well beyond the long established industrial regions of Western Europe and America. This geographic evolution of competitive advantage and industrial location is a long term, complex process and the most significant feature of its outcome is its unevenness. The process is geographically selective, resulting in highly variable rates of manufacturing growth among countries. Moreover, as Pollard (1981) notes in a European context, within countries, industrialization has been a profound regional phenomenon.

Never before in human history did one country have such a profound effect on the geography of manufacturing as China did since it opened its economy to the world in 1978. Thanks to its competitive advantage in labor intensive production it was able to set up an incredible amount of green field manufacturing activities through unprecedented inflows of foreign currency and foreign direct investments. But not all Chinese provinces succeeded equally in this (Wei, 1999). In the case of China this wave of industrialization was regional as well. Most of foreign MNE's established their activities in the Yangtze and Pearl River deltas.

Apparently geography matters! There seem to be two sides of globalization. On the one hand is the "flat world" (Friedman, 2005) spreading some economic functions around the planet. On the other, the world is spiky, with a tendency for activity to cluster in relatively small numbers of locations (Florida, 2008). Once established, these regional centers of industry offer huge advantages to further economic growth through their pools of skilled labor, infrastructure and accumulated know-how. Surely these result not of inherent differences between locations but of some set of cumulative processes, necessarily involving some form of increasing returns, whereby geographic concentration can be self-reinforcing (Krugman, 1991). Dubbed economies of scale, clusters or spatial economies, these agglomerated business activities have been sources of economic growth and regional competitiveness.

The term ecosystem is multifaceted and a difficult concept to effectively grab in one definition that serves everyone's purposes. In biologic terms, Odum (1971) states that any area that includes living organisms and non-living substances that interact to produce an exchange of materials between the living and non-living parts is an ecological system or ecosystem. In this thesis the term business ecosystem is used to describe an area's competitiveness in a certain type of business, where competitiveness is a result of the way companies there are able to operate and interact with their environment.

The aim of this thesis is to provide a method to structurally investigate and gain insights into dynamics of business ecosystems and to apply that method to R&D ecosystems in China. Globalization has brought Philips' R&D activities to China. Now how will it geographically evolve inside this country? Which centers of industry are likely to evolve into high tech centers like Philips' campus in Eindhoven and which regions will lag behind because of uneven economic growth?

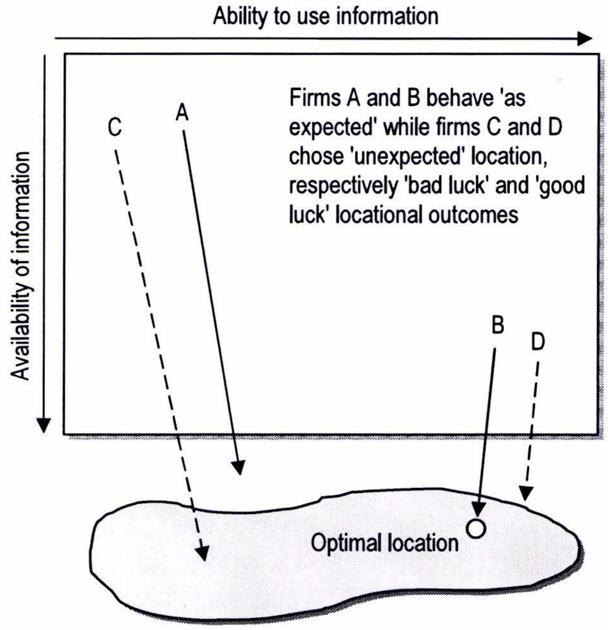
1.2. Reason of the research project

Due to the complexity of a business ecosystem and the external forces that affect it, providing definite answers to these questions will prove impossible, however gaining insights into the geographical dynamics behind such questions are essential in making strategic decisions on resource (al)location in China. For manufacturing but also R&D activities, being in the right place can greatly enhance economic outcome in terms of profitability, returns on investment, patent filings, etc. This is in accordance with a statement by Harvard professor Kanter (2003):

"In the future, success will come to those companies, large and small, that can meet global standards and tap into global networks. And it will come to those cities, states and regions that do the best job of linking businesses that operate within them to the global community."

According to this statement, identifying the most competitive states and regions is crucial for being successful. Being able to identify and choose those locations depends on an interplay between factors influencing 'the availability of information' to firms and another group of factors influencing 'the ability to use' information by firms (Pred, 1967). In summary, a firm with a high ability and a high level of information would typically be in a better position to make a 'good' locational choice than a firm with low ability and a low level of information (see figure 1.2).

Figure 1.1: Behavioral Matrix



With slow economic growth in the Europe and the US and the booming transformational economy of China, that leads the way in emerging East Asia, it is now especially important for Philips management to understand the geographical dynamics in China as it will increasingly be part of that global Excelling in China will allow a company like Philips to also excel in the greater region of East Asia. And to do so it needs insights into the dynamics of business ecosystems.

And right now, it needs those insights more than ever. Internally, Philips' organizational structure is basically divided in the three core sectors: Lighting, Healthcare and Consumer Lifestyle (see appendix Faced with their evolving business these sectors make investment decisions in China mainly based on their individual product life cycles (Vernon, 1966). The central thesis of this product life cycle model is that over time production shifts from skilled, labor intensive activities to capital intensive activities employing unskilled labor. The geographical point is that as products evolve through various stages, underlying input conditions change which in turn may potentially lead to shifts in ideal production locations. At the same time, input conditions in a certain location can change, altering that location's attractiveness for different business activities.

And the input conditions are indeed changing in China. Many electronics companies like Philips have relocated parts of their businesses to China in the early 1990s because of its cheap labor pool, used in the mass production of their products and later research and development activities. Recently though, these companies are facing increasing operating costs in their existing China bases. This, combined with government incentives to boost investments in the less developed provinces, has caused many foreign companies to look "west" for opportunities to expand or relocate operations to such provinces.

Besides these core product sectors, Philips has also set up support departments in China like Philips Research Asia Shanghai and Philips General Purchasing (PGP). PRAS is Philips' R&D headquarters in East Asia and besides generating patents, translating global trends in innovation into directions to help shape the strategy of Philips is part of their mission (see Appendix II). PGP's mission is to leverage Philips' buying power by purchasing non bill-of-material (BOM) products and services used throughout the global organization. As such, part of PGP's job is to continuously look for new supply opportunities.

Because of PRAS- and PGP's similar exploratory tasks, and fueled by the rising operating costs in the existing bases, a decision was made to set up a joint research project, called project Leapfrogger, to investigate business ecosystem dynamics and help the organization move towards the lower right corner of the behavioral matrix (figure 1.2).

1.3. Research goal and questions

The goal of this master thesis project is to come up with a research design to structurally analyze business ecosystem dynamics and to apply this design in project Leapfrogger at Philips. Because of the differences in the nature of activities performed by PRAS and PGP the design has to be general and well documented, so that it is flexible and customizable.

Research goal:

> *"Develop and implement a research design to analyse dynamics in business ecosystems in China"*

And management question:

> *"How can PRAS cope with their R&D ecosystem dynamics in China?"*

In order to reach the research goal and answer the management question, the following research questions have to be answered:

1. How does science explain business ecosystems and (re)location of businesses?
2. Which variables affect R&D location decisions?
3. What are the current values of these variables?
4. How will these variables change in time?
5. What will be the resulting R&D ecosystem dynamics?
6. How can the PRAS cope with modeled R&D ecosystem dynamics?

1.4. Research audience

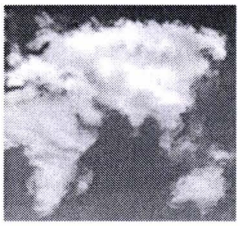
Besides providing answer the management question expressed by PRAS about R&D ecosystem dynamics this research has also developed a structured research design to analyze business ecosystem dynamics in general. This research report therefore serves an audience beyond PRAS. It can also be used to analyze the dynamics of other business ecosystems relevant to PGP or other departments within Philips. Parties external to Philips that want to perform similar investigations into their business ecosystem dynamics can also use the research design for application in their research.

During the literature study, no prior research into the analysis of business ecosystem dynamics could be found. So this thesis will hopefully initiate a branch of contemporary practical applications of the many theories that are involved to business ecosystem dynamics such as regional economics, knowledge spillovers, business location decision making, etc. This way the report will hopefully serve an academic audience as well.

Finally, the research report may be of interest to government bodies in China. All regions and many cities in China run a foreign investment promotion office and their better understanding of business ecosystem dynamics and the logic behind the research design proposed here might help them attract more foreign multinationals and facilitate regional economic growth.

1.5. Thesis layout

After this chapter which has introduced the research, chapter two continues with the literature review. First the literature on business ecosystems is reviewed after which two major schools of thought on business (re)location decision making shall be addressed. After this decisions are made on which theories to include in the research design which is presented in chapter three. This concludes the first part of the report. The second part consists of several chapters each describing the different phases of the research design, as applied in the analysis of R&D ecosystem dynamics in China for PRAS. The final chapter of this second part answers the management question by providing scenarios for PRAS based on the identified dynamics. The last part of this report reviews the designed approach, its limitation, the lessons learned and suggestions for further research.



2. Literature review

In this chapter, the literature in regional science, economics, location theory and other related fields that explore core theoretical concepts on the geography of economic activity are reviewed. But first, we begin by laying out the working definition for business ecosystems.

2.1. Business Ecosystems

The term business ecosystem is relatively recent and was first used by Moore (1993, 1996). He defined the concept as "an extended system of mutually supportive organizations; communities of customers, suppliers, lead producers, and other stakeholders, financing, trade associations, standard bodies, labor unions, governmental and quasigovernmental institutions, and other interested parties."

In a literature survey on business ecosystems as an approach to complex business environments (Peltoniemi, 2004) a conclusive definition is provided in which a business ecosystem is considered to be:

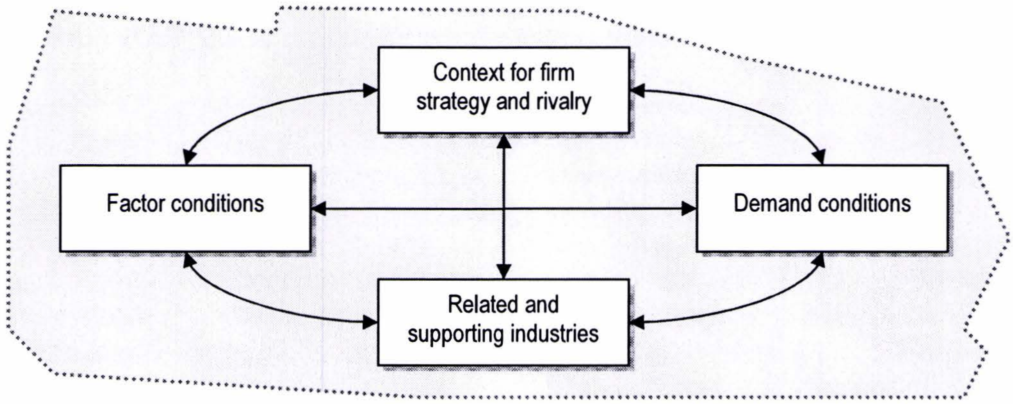
"A dynamic structure which consists of an interconnected population of organizations. These organizations can be small firms, large corporations, universities, research centers, public sector organizations, and other parties which influence the system."

These definitions of business ecosystem are very close to the concept of clusters, a term introduced by Michael Porter (1990) in his famous book "The Competitive Advantage of Nations". In his work he defines clusters as "geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions in particular fields that compete but also cooperate" (Porter, 1998: 197–198). Thus, a clear condition for the existence of a cluster was the presence of linkages between companies and institutions. In particular, these linkages were considered important for productivity growth.

Originally, Porter argued that there are four determinants that define the competitiveness of a nation, but in later publications looser consideration was instead given to inter-firm geographic proximity, since 'the geographic scope of a cluster can range from a single city or state to a country or even a network of neighboring countries' (Porter, 1998: 199).

His model which shows the interconnected determining factors of competitive advantage of clusters has become known as the Porter Diamond. It suggests that the location in which a firm operates plays an important role in shaping the extent to which that firm is likely to be competitive. The location factors, categorized under the four determinants, support or hinder organizations from building competitive advantages to excel in global competition. The Porter Diamond is depicted in figure 2.1.

Figure 2.1: Porter diamond



In this thesis, Peltoniemi's definition of a business ecosystem is acknowledged and the Porter Diamond is used to describe the forces that affect the state of a particular instance of business ecosystems. No matter what the geographical area of interest, be it nations, states, cities or even neighborhoods, the Porter Diamond can be used to describe the business ecosystem in place in terms of the four determinants. Factor conditions refer to the basic endowments on which the firm seeks to compete. Examples of factor conditions are human-, natural- and capital resources and physical- and IT infrastructure. Context for firm strategy and rivalry refers to the local context and rules that encourage investments (e.g. intellectual property protection) and vigorous competition among locally based rivals. Demand conditions refer to the presence of sophisticated, specialized demand from local customers whose needs anticipate those of customers elsewhere. Related and supporting industries refer to the presence and access to capable, local suppliers such as banks, law firms, venture capitalists and firms in related fields.

Competitiveness is a comparative concept. The state of one local business ecosystem relative to that of states of business ecosystems elsewhere is a measure of local competitiveness in that particular business. In practice, a competitive business ecosystem is one in which the four determinants are favorable to that type of business and relatively well developed. This results in a geographical competitive advantage. There is a geographical attribute to competitiveness which is related to localization of the business of interest. A location's competitiveness in furniture retailing for example is more localized (city or district level) than corporate R&D (country or global level). Sustained geographical competitive advantage often results in very high concentrations of related and supporting industries. Examples of such business ecosystems are "furniture malls" for the furniture retail business and Silicon Valley in California and the Eindhoven High Tech Campus for corporate R&D.

So how do such concentrations of business activity come into existence? With globalization in full swing, and a world both flat and spiky, this is one of the most interesting questions for economists and social scientists today. So interesting even that Paul Krugman was rewarded a Nobel Prize for economics in 2008 for his contributions to analysis of international trade. If trade is largely shaped by economies of scale, as Krugman's trade theory argues, then those economic regions with most production will be more profitable and will therefore attract even more production which results in a few countries, regions or cities with high shares of the total business

Marshall (1920: 277) was the first to introduce the concept of such an industrial district as a concentration of 'large numbers of small businesses of a similar kind in the same locality'. The basic cause for agglomeration according to Marshall back then was the presence of increasing returns to scale which are external to the firm. These external economies of scale are generated by the presence of the following three factors:

- Labor market effect
- Input-output dependency
- Knowledge spillovers

When firms cluster they will demand and attract similar specialized labor force which will at the same time be cultivated and become more skilled by the presence of the cluster. Because the skills of the labor force will benefit from learning by doing and by spillover effects created by the rotation of personnel between firms.

In the same way the clustering of industries induces the specialization of firms which supply inputs and intermediate products. Firms tend to cluster when there is vertical disintegration or outsourcing of parts of the production process or by providing specialized services (Venables, 1996). Thus, firms start clustering by supplying to one firm and end up trading goods and technology with each other thus forming a network.

In such presence of a pool of skilled labor as well as of companies that supply each other with intermediate goods knowledge spillovers are created which are best transmitted, in turn, when firms are geographically close to each other.

Other arguments that explain the presence of clusters are borrowed from the development economics literature which state that firms will tend to agglomerate in those places where transport systems are more efficient (e.g. harbors) and/or where the necessary infrastructure is more developed (e.g. urban centers), an idea already noted by Adam Smith (1776) in his book Wealth of Nations. In this way, firms which do not have anything in common in their production process will cluster in order to be able to share overheads, financial and physical capital, infrastructure, natural resources or a large local demand (Fritz, 1997).

Once established, these agglomerations offer huge advantages to companies through the geographical competitive advantage. But competitive business ecosystems can disappear as well. Studies by e.g. Watts (1987) and Yeates (1990) show that socio-economic change caused many established manufacturing areas to decline because firms decide to move to more other locations. The socio-economic changes come in many forms. Technology can radically change industry requirements, governments can install new policies, factor of production (FOP) costs can structurally change, external economies of scale can diminish and market demographics can shift. All these can have a profound effect on local ecosystem competitiveness to a certain type of business.

Because of all this, clusters have been the object of interest for researchers from many different disciplines, especially economists and policy makers. In this thesis though, the firm is at the center of analysis. Here, the question is how firms like Philips look at business ecosystems as locations for their operations.

2.2. Business (re)location theory

Business (re)location theory is the science that studies why business locates where it does, the process that essentially shapes business ecosystems. So what constitutes a "good" location? Subject to some important qualifications to be noted later, profitability is identified (Hoover & Giarratani, 2006) as the most important measure of competitiveness of alternative locations. But even when the profit motive is paramount there are other significant considerations, including security, amenity, and the manifold political and social aims of public and institutional policy. Although the definitions of benefits or costs may differ in substance across individual businesses or firms, the goal of seeking to increase net benefit by a choice among alternative locations is common to all.

The basis for locational preferences can be expressed generally in terms of a limited set of location factors. The ways firms look at locations vary considerably. Location conditions and location factors are characteristics which vary from place to place and which directly or indirectly affect the viability of firms. Nishioka and Krumme (1973) define location factors as the specific interpretations made by individual firms of more general location conditions. This distinction between location factors and conditions is a potentially useful one for understanding the highly divergent locational reasoning offered by firms in explaining their location decisions. Despite the great variety of types of businesses, all are sensitive in some degree to certain fundamental location factors. That is to say, the advantages of locations can be categorized (for any type of business) into a standard set of a few elements. The Porter Diamond presented earlier categorizes location factors into the four determinants to describe a business ecosystem.

Throughout post industrial revolution history the process of location decision making, which evaluates the location factors of alternative locations, has proven to be complex. Studies on location decision making by individual firms started as early as 1929 with Alfred Weber's theory on the locations of industries. This pioneering theory marked the beginning of a school of thought that is called neoclassical location theory.

In essence, neoclassical location theory interprets the firm as a 'Homo Economicus' who has the perfect economic information and perfect rationality to compute an optimal location in the sense of minimizing costs or maximizing profits. Williamson (1975) identified general characteristics of neoclassical explanations of business locations:

- It focuses solely on economic variables, especially transportation and labor cost.
- It analyses economic factors in an abstract, deductive manner to derive generalizations as to where industry should locate.
- It assumes economic laws based on universal notion of rationality governing behavior.

In terms of the Porter Diamond (see figure 2.1) the neoclassical approach focuses on quantifiable determinants, like certain factor- and demand conditions and transportation related factors, in explaining competitiveness and business location decisions.

In Weber's approach (1929), the transportation costs of industry inputs and outputs determine a least-transportation-cost surface. Other location factors, such as labor and raw material costs or external economies, determine similar least cost surfaces. By adding up the cost surfaces of all relevant location factors a total-cost surface is derived. In a similar vein, a spatial-revenue surface may be calculated. The firm is able to make a profit in any location where total revenues exceed total costs. By subtracting the total-cost surface from the revenue surface an optimal location can be found and the total area is divided into profitable and unprofitable areas. This concept is defined as the firm's spatial margins of profitability (Smith, 1966; Taylor, 1970). As both firm and environment change over time, this leads to changes in the shape of the cost and the revenue surfaces and thus in the optimal location and the shape of spatial margins of profitability. Nakosteen and Zimmer (1987) provide a theoretical framework in which firms continuously monitor these dynamics. In practice few companies do this so stringently but insights in these dynamics are important because a possible outcome may be that the current location soon will be outside these spatial margins of profitability.

The neoclassical view is that firm location is driven by powerful forces of economics and industry can only ignore economic reality at their own peril. This view has had a pervasive influence in business location theory. Practically, the neoclassical approach has a strong 'common sense' appeal in that it stresses the axiom that for firms to be viable revenues must exceed costs and that decisions for firm locations should be made accordingly. Moreover, at a time of rapidly globalizing competition, the neoclassical emphasis on the relentless and rational pursuit of lower costs and more profits captures an essential dimension of contemporary economic dynamism (Hayter, 1997).

Indeed, by moving to low labor cost regions like China, Philips as well as many other electronics companies have shown business location decision behavior that appears to have been dictated by changes in abstract economic forces. Constructed as a form of economic determinism in which these economic forces dictate the location of firms, neoclassical location theory has often been used to link business location decisions to measurable economic variables (Watts, 1977; Howland, 1988) in an attempt to explain location dynamics.

This neoclassical theory is useful as a benchmark that defines the 'optimal' behavior of the firm in economic terms, under the assumptions of rationality and perfect competition. But the use of the neoclassical approach as the sole explanation of business location has been criticized since the 1960s because of its ignorance of historical events, imperfect information and uncertainty which all do seem to effect the locations of firms. Apart from this, the application of a more 'behavioral' approach in location theory was also motivated by limiting discriminating power of regional economic conditions in determining the optimal location of industries or, equivalently, the spatial margins of profitability (Hayter, 1997). If regional economic conditions show limited variation, this leaves many profitable sites to choose from. Then firm-specific economic factors or non-economic factors may become of more importance for the explanation of firm locations.

The behavior approach adds to the neoclassical approach by exploring the many motives, economic and non-economic, that are important in the decision making process of a particular firm. The approach seeks to understand the actual behavior of businesses and focuses on the decision making process. Although a useful approach to understanding firm relocations, critics say that it focuses too much on sociological, psychological and other 'soft' variables (Scott, 2000); in the same way the neoclassical approach relies heavily on purely economic locational factors. A combination of the behavioral and neoclassical approach seems to be more fruitful.

2.3. Business (re)location decision making

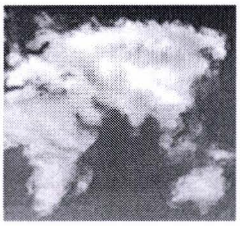
Management decision making itself can be envisaged as an ordered process. Simon (1977) was the first to outline three phases in the managerial decision process. The first phase is about intelligence activity, which involved recognition of the need for a decision by investigating internal performance indicators and external conditions. The second phase is directed towards design of a method to gather relevant data to define alternative solutions. The third phase is the about actually choosing the alternative and implementing it.

In line with Simon's study, a few investigators identify different stages in the location decision making process (Schmenner, 1982; Kotler et al., 1999). Both of them places emphases on different parts but essentially these are the stages companies go through regarding location decision making:

- Need recognition
- Establishing a research team
- Information search
- Evaluation of alternatives
- Choose an alternative

So the second phase starts with the information search, as research team members gather data on location factors. Location alternatives then essentially consist of the aggregated information on each location factor. Evaluation of alternatives is a trade off and means putting weights on the location factors that make up an alternative to identify the optimal location.

The starting point of these frameworks is a need to (re)locate a factory or shop and as such it the frameworks work well for individual firms that have to make a physical (re)location decision. Yet this outset makes them intrinsically non optimal for application in a business ecosystem dynamics research. A business ecosystem dynamics research does not necessarily start with an identified need to (re)locate parts of a firms business. Rather the objective is to analyze how the industry is likely to evolve geographically. Methods to conduct the second phase of Simon's (1977) decision process on business ecosystems dynamics have not been found during this literature study. The next chapter will therefore present a research design as a general method that firms can employ when analyzing their business ecosystems of interest.



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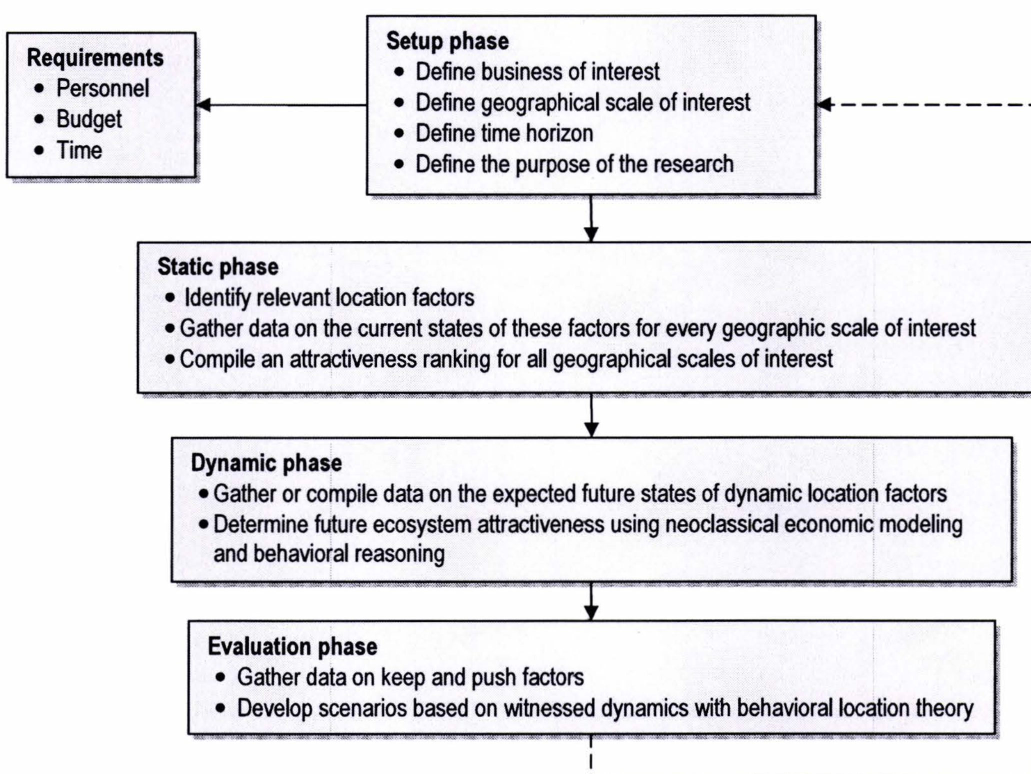
3. Research design

Now that a business ecosystem is defined and the general approaches to business location and location decision making have been presented, the next paragraph will present the research design as a general approach that a firm can employ when analyzing their business ecosystems of interest.

3.1. Research method

In this section the research design is presented as a general method on how firms can conduct a research into business ecosystem dynamics. Since the state of a business ecosystem in a location is defined by the state of location factors that define the business, a research into business ecosystem dynamics is essentially a research into relevant location factor dynamics. To conduct such a research a four phase research method is proposed as depicted in figure 3.1.

Figure 3.1: Research method



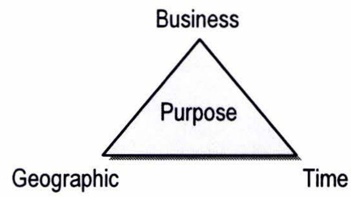
The design is similarly structured as the location decision processes proposed discussed earlier. The process is sequential from the setup to the evaluation phase. After evaluation of the results of previous phases the company can decide to perform another loop on a different geographical scale.

In the next paragraphs each of the different phases will be addressed in greater detail.

3.1.1. Setup phase

The first phase in a business ecosystem research should be a naming and framing phase. This is done through qualifying four dimensions (see figure 3.2). To do this, interviews with the most important internal stakeholders are likely the most efficient research methodology.

Figure 3.2: Four dimensions to a business ecosystem research



Each type of business and firm is unique and looks at a location differently (Nishioka & Krumme, 1973). This results in a different set of relevant location factors to describe business ecosystems. Is the business in question the production of television sets or is it about R&D activity? And is the R&D focused on generating new patents or is it developing products? The exact definition of the business is a very important first step.

Defining the geographical scale of interest (GSI) is also very important. Does the company want to know high level ecosystem dynamics inside a country or investigate it at a city level and evaluate business ecosystems in different districts? And which instances of the defined geographical scale of interest are taken into account during the research[1]? The definition of geographical scale of interest and the set of instances can have great implications for project resource requirements and is therefore very important.

Time horizon is another important characteristic of the research. Is the firm only interested in analyzing existing business ecosystems and their dynamics over a time span of two years, ten years or fifty years? The time horizon states how far the research tries to look into the future. Long time horizon forecasts are often not available from external sources and inherently more ambiguous than short term predictions. Due to these difficulties, the time horizon should be considered with great care.

Last but not least, the purpose of the research. What is it that the firm intends to do with the knowledge on business ecosystems? Is it for looking for potential future suppliers, for marketing purposes only or is it part of a study into relocation or the setting up of a sales office? The purpose will impact the level of detail and precision required in subsequent phases of the research.

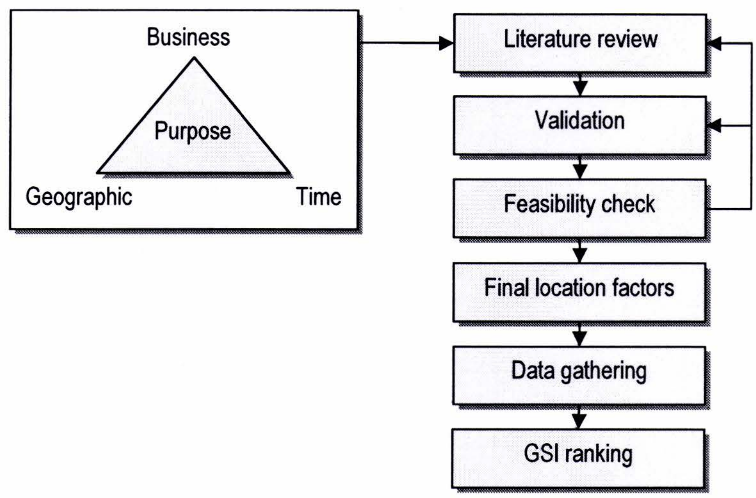
All these dimensions have implications for the subsequent phases because they all influence the set of relevant location factors, the availability of data on the location factors and the methodologies that can be employed to get the information. Furthermore the answers frame the research in terms of its personnel, time and budget requirements.

[1] From now on, when referring to the complete set of instances of the geographical scales of interest, the words "all GSI" shall be used.

3.1.2. Static phase

This phase is dubbed the "static" phase. The goal of this phase is first to identify the final set of relevant location factors and then gather data on each of them in all GSI. Once this all information is gathered, the GSI should be ranked to determine their attractiveness to the business of interest. The process of identifying the set of location factors is depicted in figure 3.3.

Figure 3.3: Static phase process



The final set relevant location factors first of all depend on the results of the previous phase. Sometimes, business ecosystem dynamics studies are primarily interested in market related location factor dynamics such population, disposable income or GDP. In other cases, FOPs such as labor, energy and raw materials also play an important role so that location factors such as wages and kW/h price have to be taken into account.

In general, this phase of the research starts with a literature review with the results of the previous phase in mind. A lot of research has been done into general location factors and this will help compile a preliminary list of important factors. A BOM review for the business of interest in most cases also yields a set of straightforward FOP related location factors that can be added to the preliminary list. The next step is to validate the preliminary list. This can for example be done by a round of interviews with relevant people within the organization. Often, less obvious or more case specific location factors can also identified during this validation step; others might be discarded. After these first two steps the preliminary set of relevant factors is more accurate but the process is iterative so another literature or company document review can be necessary. When the preliminary set is satisfactory and agreed upon at the appropriate level of management a feasibility check is needed to ensure that data on these factors is available or collectable within the projects time, budget and personnel constrains set earlier. Again the result can be that the set needs refinement. If not, the set is final and data gathering can begin.

For data gathering a multitude of sources can be utilized. Depending on the GSI, various levels of government bodies might have official databases that contain macro economic statistics on location factors. Specialized human resources-, logistics- or finance consultancy firms might have statistical packages for sale that contain information and forecasts on certain location factors. Data can of course also be gathered in the field by through observations, interviews with experts from other companies or governments, or through the collection and aggregation of various independent data sources. The availability and set of sources varies case-by-case and depends on the set of location factors chosen.

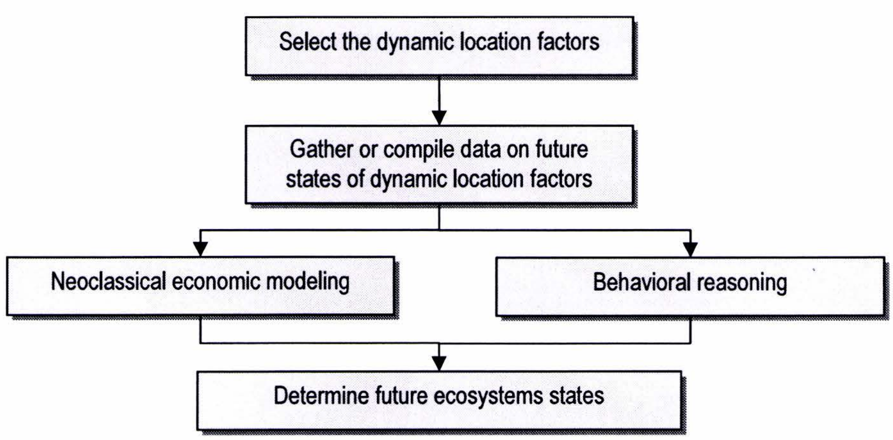
When location factors are quantified for each of the GSI, the GSIs can be scored on an ordinal scale or classified on an interval scale e.g. using stars to represent competitiveness. Ranking can be done in an objective way using structured mathematical models or more subjectively. Quantitative data lends itself more for the prior while qualitative data sometimes forces one to subjectivity. Often a mix of both makes the most amount of sense. It is important to do this initial ranking because it can identify big gaps which could alter the further course of the study.

To compose a final static phase GSI ecosystem competitiveness ranking, a weight can be assigned to each location factor, for often not all location factors are equally important. The final GSI score is then a sum of location factor scores times the weights associated with each location factor.

3.1.3. Dynamic phase

The "dynamic" addresses the future states of the location factors in the GSIs and the resulting future competitiveness of GIS to the business of interest. The first step in this phase is to select dynamic location factors. These are location factors that will be taken into account to assess future dynamics of the ecosystems. Not all of the static location factors selected earlier qualify as dynamic. Some of them are known not to change, show very limited change or change equally in every GSI. As such these are not going to cause any dynamics and don't need to be taken into account. Once a list of dynamic location factors is complete, data has to be gathered or compiled once more (see figure 3.4).

Figure 3.4: Dynamics phase process



The availability of data and methodologies used in this step depend on the research scope, as defined in the setup phase. For some location factors, official government or industry forecasts are available. If not, the future values can be forecasted. Depending on the nature and qualities of the knowledge sources, a number of different types of forecasting methods are available. Appendix III shows the methodology tree for forecasting taken from Armstrong (2001), which classifies all possible types of forecasting methods into categories and shows how they relate to one another.

One of the primary conclusions drawn from a study by Makridakis and Hibon (2000), which involved thousands of time series, was that beyond a modest level, complexity in time series extrapolation methods produced no gains. Complex models are often misled by noise in the data, especially in uncertain situations. Thus, using simple methods is important when there is much uncertainty about the situation. Simple models are often easier to understand, less prone to mistakes, and more accurate than complex models. This should be taken into account in this phase of the research.

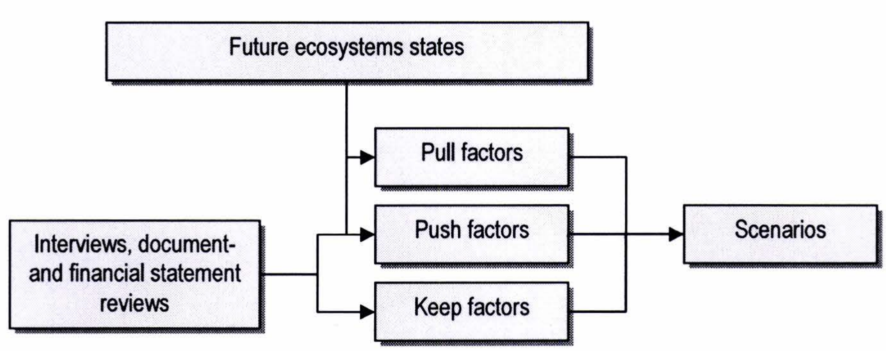
After data is gathered it can be fed into neoclassical economic models to generate future cost and revenue curves. These costs and revenues incurred in a location play a very important role in the competitiveness of that location but are not only determinants of competitiveness.
Sometimes less quantifiable dynamic location factors are thought to play a role as well. For those location factors, there are often no sensible statistical data sources are available for forecasting so one has to judgmental forecasting (see Appendix III).

When the dynamic location factors are quantified for each of the GSI, the GSIs can again be ranked on an ordinal scale or classified on an interval scale e.g. using stars to represent competitiveness. To compose a final dynamic phase GSI ecosystem competitiveness ranking, a weight can again be assigned to each dynamic location factor. The final GSI score is then a sum of dynamic location factor scores times the weights associated with each dynamic location factor.

3.1.4. Evaluation phase

The final phase is the "evaluation" phase. The research has generated insights into the dynamics of the business ecosystems and now it is time to analyze these observations and develop scenarios about how to cope with the witnessed dynamics. Such scenarios should be built with the behavioral approaches to business location decision making in mind. So far the analysis has focused on revealing *pull* factors, factors that are external and pull a business to a certain geographical area. But in order to develop scenarios the internal processes within the firm have to be taken into account as well. This means the important *keep* and *push* factors (Pellenbarg, 2002) have to be identified through interviews and document- and financial statement reviews. Investments and contracts with local governments may limit the viability of a geographic move are examples of factors called keep factors. Push factors explain why a firm wants to move from an internal perspective. When all these relevant pull, push and keep factors are known, scenarios can be developed.

Figure 3.5: Evaluation phase process



After all this, scenarios can be implemented. Implementation details are beyond the scope of this research design. Worth noting is that in some cases, the results from all the evaluation phase might indicate that another round of research is desired, perhaps on a smaller geographical scale in which the organization zooms in on the optimal location identified in the prior study for more detailed understanding. The exact same proposed research design can then be used one more time.

3.2. Research process

Early 2007, Philips' higher management faced a dilemma when confronted with questions regarding business ecosystems in China and the need arose within Philips to conduct a serious research into business location dynamics in East Asia. A decision was made to set up a joint research project, called project Leapfrogger, to investigate business ecosystem dynamics. In the beginning of April 2007, first contact between the graduate student and Philips was established and on May 7th 2007 the project started in Shanghai.

Translating the management dilemma into subsequent management- and research questions is an important step in the research (Cooper & Schindler, 2003) and this has been especially true for this research. The initial management dilemma was stated in quite ambiguous terms. The term ecosystem is such a broad concept and East Asia is such a vast geographical area that this translation required a lot of attention monitored by a well planned process. This process relied on desk research and literature reviews but interviews were by far the most productive and insightful method used in fine-tuning the research questions. Appendix IV provides a list with many of the interviewees that were interviewed in the course of the project from both within as well as outside of Philips.

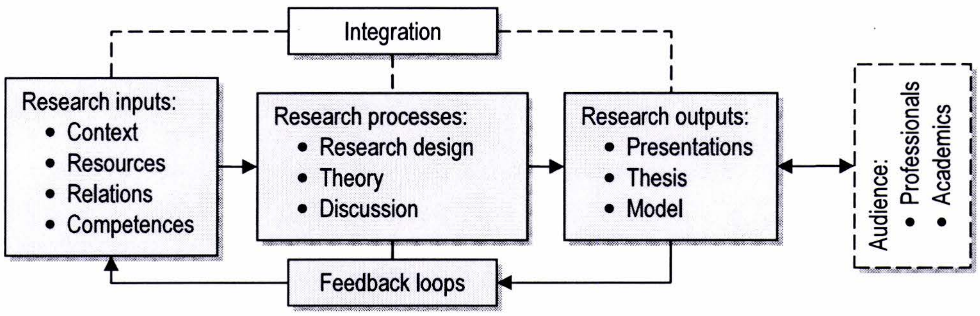
Soon after these initial efforts it became clear that location factors are at the core of business ecosystems and their dynamics. From July to halfway October, data on the past and present states of each location factor were gathered. During this static phase three MBA students joined project Leapfrogger to gather data on business ecosystems from an industrial and sourcing perspective.

Then from October to December, a customizable model was developed to graphically visualize business ecosystem dynamics on a provincial scale in China. Also, further data on the future states of location factors was gathered. The evaluation phase process was executed from December 2007 to February 2008 in which scenarios for the witnessed R&D ecosystem dynamics were developed. The final presentation was held on 28th of February 2008 and after that, from March 2008 to June 2009 the reports and this thesis were finalized.

3.3. Quality of the research

Quality has been assured by meeting quality criteria on all facets of the research endeavor, i.e. its inputs, processes, outputs and the overall research integration (van Fenema, 2002). Figure 3.6 depicts the interconnection of all facets:

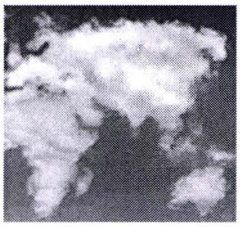
Figure 3.6: Quality assurance system



The input of the research is the context in which the research takes place, the resources, relations and gathered competences. The research has been initiated by Ir. Reinoud Selbeck, CPO of China and Dr. Ir. Frans Greidanus, General Manager of PRAS and CTO East Asia. Their expertise is in supply chain management and corporate R&D management respectively and both men have extensive experience in doing business in China. They also served as excellent guides through the Philips organization thanks to their long working history in the company. The university assigned Dr. Kastelein and Dr. Ir. Reymen as the university supervisor and second supervisor respectively. They were responsible for coaching the graduate student during the project. Both have extensive experience in supporting students during their graduate projects.

But there were also difficulties, especially during the data gathering phase, when some of the work was done by people that temporarily joined the project. The names of the MBA students that joined the team in the summer of 2007 were already chosen such that the competences of the people working in this phase of the project were thus outside the graduate student's control. The quality of their final deliveries was therefore difficult to manage. Also, since the research was conducted in China with Chinese GSIs as the subject of research, a lot of data was in Mandarin or had to be gathered with help of Chinese people. For the graduate student, who couldn't speak or read any Chinese at the beginning of the project, this was a huge disadvantage. Often, great trust had to be put in the hands of translations made by fellow Chinese team members, dictionaries or official translators. Furthermore, being located in China limits the contact moments with the supervisors and access to all Dutch university libraries which combined accumulate a great availability of resources, relations and competences.

The second quality criterion is the research process that consists of the methodologies used in- and the realization of- the research design. As mentioned earlier, the research is built on existing scientific theory and uses official government- or academic sources wherever possible in both the empirical and theoretical parts of the research to assure high quality research results. Finally regarding the output of this research, reports, this final thesis, presentations as well as the developed computer model are quality measures for this final quality criterion.



4. Setup Phase

This chapter of the report describes the first phase of the research design and its application at PRAS to help frame the R&D ecosystem dynamics research as part of project Leapfrogger. This decisions made during this phase are made based on literature reviews but mainly on interviews with field experts within Philips as well as with external parties.

4.1. Business of interest

In this phase the research design is applied to the business of PRAS which is corporate research and development activities. The phrase research and development (R&D), according to the UNESCO, refers to:

"Creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications".

Three types of R&D are generally identified. Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. Applied research is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective. Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, that is directed to producing new materials, products or devices, installing new processes, systems and services, or improving substantially those already produced or installed. The activities within PRAS can be classified as basic or applied research rather than experimental development.

In general, R&D activities are conducted by specialized units or labs, belonging to companies, universities or state agencies. Corporate commercial R&D normally refers to future-oriented, longer-term activities undertaken by companies for the purpose of discovering or developing new products, including improved versions or qualities of existing products, or discovering or developing new or more efficient processes of production. The successful implementation or introduction of these outputs of R&D is often called innovation. Innovation these days relies more on collaboration than ever before. This trend for Open Innovation (Chesbrough, 2003) is also embraced by Philips Research.

An R&D lab usually employs personnel working directly on R&D activities, as well as those providing services such as research and development managers, administrators and clerical staff. The prior are generally highly educated professionals, with master- or doctorate degrees, engaged in the conception or creation of new knowledge, products processes, methods, and systems. Their fields of expertise generally vary depending on the nature of the company's products or ambitions but because of the complexity of modern day market needs and the products that serve them, a mix of skills and theoretical backgrounds are often present in single lab. In PRAS as well, where R&D is conducted for all three of Philips' sectors, the range of scientific background amongst personnel needed is very wide; from medical to math to physics and psychology and economics.

Even though R&D is traditionally one of the last corporate activities to spread geographically, the share of R&D carried out by MNEs outside their home country headquarters has increased rapidly in recent years, especially in the connection to the recent phase of globalization. This close relation of the internationalization of R&D and production is because of the fact that the large companies engaged in foreign direct investment (FDI) also are key players in the creation of innovations and their global diffusion. The dominance of MNEs in international R&D investments is evident and it is these investments in labs like PRAS that are the business of interest in this ecosystem dynamics study.

4.2. Purpose of the study

Philips opened up its China laboratory in 2000 which has since grown steadily. During the graduation research the whole department moved into their new location in the south west of the downtown Shanghai area. The purpose of this study is therefore not to serve as a preliminary investigation with the ultimate aim to relocate the lab. Rather the purpose is to provide Philips Research senior management an up-to-date overview of where corporate R&D is located in China, and provide insights into which regions will host China's most competitive R&D ecosystems in the future.

4.3. Geographic scale of interest

The Constitution of the People's Republic of China provides for three levels: the province, county, and township. However, two more levels have been inserted in actual implementation: the prefecture, under provinces; and the village, under townships (see appendix V)[2].

In this research, the municipalities and capital prefecture level cities of provinces and autonomous regions are chosen as the geographical scale of interest (see Appendix VI), for a few reasons. First of all, the special administrative regions Hong Kong and Macao are not taking into account because the research is focused on R&D ecosystem dynamics on mainland China. Secondly, the management dilemma was not about intra city, district scale R&D ecosystems but answers are sought on the dynamics of a bigger scale e.g. in light of China's "Go West" policy. Capitals prefecture cities are chosen to represent their provinces or autonomous regions to make these more comparable to municipalities as they are all the most urbanized, economically advance and populous areas within their region. If a similar research would be set in Europe or the United States the research subjects would be countries and states respectively. In China, the capitals that are very similar to country or state capitals in Europe and the United States respectively, both in size and their share in economic activity.

Thirdly, the prefectural level is the lowest level on which comparable data is made available by the Chinese government on a yearly basis through the various statistical yearbooks. Because regional competitive advantage is in itself a comparative concept it is important to make assessments of this competitiveness based on comparable data, to ensure validity of the conclusions as much as possible.

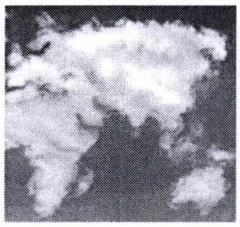
Occasionally, in light of the above, data availability required the research to use provincial level data to determine location factor states in the capitals; other times it made more sense to use provincial level data rather than prefectural level. In these cases a clear mention is made.

Essentially, the capitals represent their provinces or autonomous regions so the names of these provinces and autonomous regions shall be used throughout this report when referring to the GSIs for ease of reference; unless explicitly mentioned. The GSI and their provinces are classified in four groups. The currently most developed provinces located on the east coast shall be referred to as coastal provinces throughout the rest of the report. The other provinces have been classified as either northern, near-western or far-western (see appendix VII).

[2] For more information: http://en.wikipedia.org/wiki/Political_divisions_of_China

4.4. Time horizon

In addressing future dynamics of a regional R&D ecosystem the time horizon has been set to five years. A shorter time horizon is not relevant for PRAS because it is not considering relocation. R&D labs take relatively long to become mature and efficient IP generating entities so a shorter time horizon is also not very insightful because as a result dynamics tend to be quite slow. Also, assessing all the location factors on every province, necessary to provide accurate answers to short term dynamics would be too much of a time consuming effort. A longer time line would make assessing the future location factor values less reliable and more ambiguous since extrapolations and predictions need to be used in determining future states of dynamic location factors.



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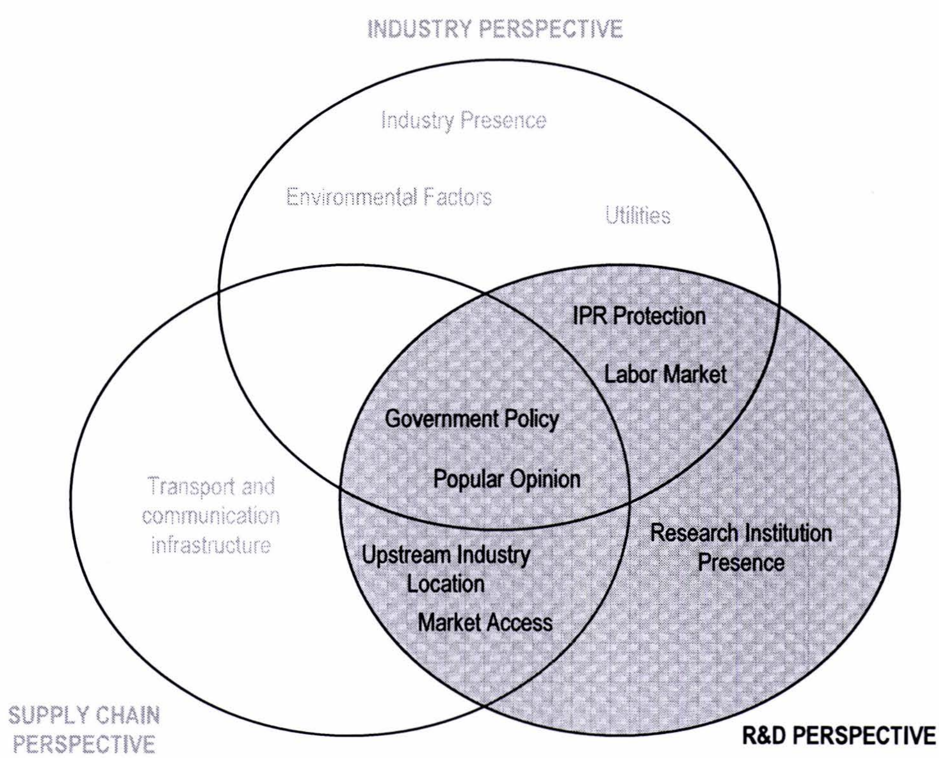
5. Static Phase

In this part of the report the second phase of the research design as implemented at PRAS is presented. This "static" phase focuses on the "now" and it addresses research questions two and three. The chapter is based on book and literature reviews, expert interviews and various sources of statistical data. First the research methodology is explained after which all the relevant location factors are identified. Then this chapter will zoom in on each factor relevant to R&D activities and present the data collected.

5.1. Research framework

Figure 5.1 presents the framework for data collection used in this static phase of the research. Given the aim and organization of the project, it's cross departmental setting and the research design used, a decision was made to make a generic static phase research model that incorporates three perspectives, i.e. R&D, industry and supply chain. In this model, each perspective is represented by a circle with its relevant categories of location factors captured inside the circles. One can see from the model that many categories of factors overlap. In some cases the same sort of factors are important from more than one perspective. This doesn't mean that the different perspectives value the factors the same way.

Figure 5.1: Three Perspectives Model



Location factors have been considered and classified in a variety of ways (Epping 1982, Barkley & McNamara, 1994; Badri, 2007) and even though the relevance of various factors may change significantly over time, due to e.g. political and technological changes, a list of most important location factors categories can easily be distilled from the papers presented above (see appendix VIII).

For R&D activities these categories of location factors or forces are in play, motivating companies to set up labs in an area. These categories of forces can easily be mapped on the determinants of competitiveness used in the Porter Diamond.

In this research, seven categories of factors have been identified as important and for each category a set of specific location factors are identified. The chosen location factors are the result of many interviews with experts in- and outside Philips and reviews of studies on location factors by Christy and Ironside (1987), Bathelt & Hecht (1990), Badri et al. (1995) and studies on factors influencing R&D location decisions by Jones & Teegen (2003) and Cadil et al. (2007). The resulting set of location factors are presented in table 5.1 and cover both quantitative and qualitative aspects of the business ecosystems and include operational, strategic, economic, political, social and cultural dimensions.

Table 5.1: R&D location factors

Location factor category	Location factors
IPR	IPR regulatory framework
	Court IPR experience
	Number of IPR cases
Research Institution Presence	Number of universities
	Quality of universities
	Number of state key labs
	Number of MNE labs
	Gross expenditure on research and development
Labour Market	Number of students
	R&D labor pool
	Quality of graduates
	R&D wages
Market Access	Population
	Average level of education
	GDP
	GDP / capita
Upstream Industry Location	FDI stocks
	FDI stocks in region
	Gross industrial output of foreign invested firms
	Exports from region
	High tech exports from region
	Philips supplier location
	Philips departments location
Government Policy	Local R&D tax incentives
	Local government science and technology expenditure
Popular Industry Opinion	Quality of living

The next paragraphs will address each category of location factors. Firstly an explanation is given as to why the location factors should be taken into account when analyzing R&D ecosystems. Then relevant prior research into the relationship between the location factors and R&D activities is presented. After that, the current location factor state of each GSI is described with qualitative and quantitative data.

Clearly, a lot of data has been gathered during this static phase of the research. In total, information had to be gathered on twenty-one locations factors for each of China's thirty-one provinces yielding an astonishing: 31 x 21 = 651 combinations. China is hot at the moment so a lot of news and data is published almost every day. On one hand this is an advantage but this abundance of data sometimes contradicts each other. Also, one should not forget that China is a transitional economy with a communist central government that sets targets for various regional governments. Some say, Chinese government statistics are therefore not the most reliable (Huenneman, 2001). In this thesis, all data gathered but Chinese government statistics especially, is double checked where possible using both Chinese sources as well as international ones e.g. The World Bank, WTO or private research firms to maximize data validity. The data from Chinese Statistical Yearbooks used in this chapter can be found in digital appendix "Digital document 1: Static phase GSI and region raw statistics.xlsx" for your reference.

5.2. IPR protection

The goal of corporate R&D activities is to increase the stock of knowledge within the company and to use this stock of knowledge to devise new applications for future competitive advantage. The result of corporate R&D activity is intellectual property (IP) which is a legal field that refers to inventions, symbols, names, images, and designs used in commerce, including copyrights, trademarks, utility models and patents, and related rights.

Intellectual property rights (IPR) are a bundle of exclusive rights over such creations of the mind, both artistic and commercial. The former is covered by copyright laws, which protect creative works such as books, movies, music, paintings, photographs, and software and gives the copyright holder exclusive right to control reproduction or adaptation of such works for a certain period of time. The second category is collectively known as "industrial properties", as they are typically created and used for industrial or commercial purposes. A patent may be granted for a new, useful, and non-obvious invention, and gives the patent holder a right to prevent others from practicing the invention without a license from the inventor for a certain period of time. A utility model is very similar to the patent but usually has a shorter term and less stringent patentability requirements. A trademark is a distinctive sign which is used to prevent confusion among products in the marketplace.

Over the last decennia, with globalization in full swing, almost all countries put IPR laws in place and signed international IPR treaties (initiated by e.g. the WTO and WIPO) aimed at protecting the forms of IP described above. The effects of these IPR legislations on a country's economy have been an increasing topic of research. Among others, Gould (1996), Park (1997), Kwan (2003), Schneider (2005) all reveal positive correlations between IPR protection laws and economic growth.

IPR facilitates economic growth in many ways (Falvey et. al., 2006) but in relation to R&D ecosystems, its positive effect on innovation, a major force of economic growth (Grosman & Helpman, 1991), is the most important. Innovation is the result of R&D activity and refers to successfully creating or introducing something new, especially a new product or a new way to increase productivity. Intellectual property rights stimulate innovation and spurs economic growth by providing incentives for firms and individuals to invest in R&D, especially where the returns from investment are longer term, where the investment involves significant costs or risks, and where the invention or creation may be easy to copy or imitate. As such the level of IPR protection is an important determinant for competitive advantage in R&D ecosystems (see figure 2.1).

Yang (2003) provides a very good overview of the history of IP development in China and demonstrates the evolutionary change before and especially the revolutionary change after, the Open Door Policy from 1979. The resulting changes in China's IPR regime and legal framework, aimed at protecting the forms of IP described above have been clearly documented by Liao (2006) and WIPO (2007). Just for a glance, China now is a member of the World Intellectual Property Organization Convention, Paris Convention for the Protection of Industry Property and Berne Convention for the Protection of Literary and Artistic Works. Notably, with its accession to the World Trade Organization in 2001, China IPR system was brought into line with the Agreement on Trade-related Aspects of Intellectual Property Rights. Most recently, on June 9, 2007, the WIPO Copyright Treaty and the WIPO Performances and Phonograms Treaty both came into force within China.

All of these laws on IPR in China apply to every province and as such there is no geographical difference on this category factor other than the following. Many of the interviewees believed the courts in big cities like Shanghai and Beijing have more qualified and experienced judges whose decisions are more just. "These cities host most of China's high-tech related industries and thus get more opportunities for IPR cases to arise in the courts. Their size also renders these cities to possess larger government institutions in which domestic protectionist influences may find harder to pervade."

These beliefs are backed up by Wang (2006). In her very extensive research she shows that the intellectual property courts outside major city centers such as Beijing and Shanghai continue to be staffed with a majority of judges who remain unfamiliar with intellectual property law. Depending on the region, many judges of intellectual property divisions at lower level courts may also lack the general educational and professional background needed for intellectual property cases. The supply of qualified candidates for the judiciary who are willing to serve courts in these more rural and isolated regions of China continue to be limited and recent reforms to the judicial system does not resolve this matter.

Finally, the China Intellectual Property Yearbook 2005 also showed that in 2004, nearly two thirds of all the intellectual property cases were concentrated in six major areas – Guangdong, Beijing, Shanghai, Shandong, Zhejiang, and Jiangsu (see Appendix IX) .

China has improved its IPR legislation significantly since it opened up its economy in 1989. The government has implemented an IPR framework comparable to many Western countries. Although the same IPR framework is in place in every province, in practice, the developed regions and especially the cities Beijing, followed by Shanghai and Guangdong are ahead of the others thanks to their experience in dealing with IPR cases and the quality of judges and law enforcement. This results in the following star ratings on the IPR location factor category.

Table 5.2: Static star ratings: IPR

Stars - IPR			
Beijing	★★★★★	Anhui	★
Shanghai	★★★★	Fujian	★
Guangdong	★★★★	Jiangxi	★
Tianjin	★★	Henan	★
Liaoning	★★	Hubei	★
Jiangsu	★★	Hunan	★
Zhejiang	★★	Guangxi	★
Shandong	★★	Hainan	★
Chongqing	★★	Sichuan	★
Shaanxi	★★	Guizhou	★
Hebei	★	Yunnan	★
Shanxi	★	Tibet	★
Inner Mongolia	★	Gansu	★
Jilin	★	Qinghai	★
Heilongjiang	★	Ningxia	★
		Xinjiang	★

5.3. Research Institution Presence

From the Porter Diamond (figure 2.1) one can see that the co-location of supporting and related industries (SRIs) is an important determinant of ecosystem competitiveness. Drawing on location theory one could argue that there are both demand and supply forces at work that result in the clustering of related firms. The theory of agglomeration economics emphasizes knowledge spillovers and enhanced benefits and lowered costs caused by the presence of multiple organizations and the externalities they create (Baptista & Swann, 1998).

The stronger the SRI determinant, the more attractive an R&D ecosystem is. Empirical support for this agglomeration effect is provided by Audretsch & Feldman (1996, 1999), Jaffe & Trajtenberg (2002) and Rothaermel & Thursby (2005). Silicon Valley in California and the Eindhoven Leuven Aachen triangle in Europe are examples of R&D ecosystems in which high concentrations of SRIs operate.

For Philips' corporate R&D business in China the related firms are mainly private R&D labs, universities and state laboratories. Supporting businesses like law firms, venture capitalists and investment banks play an important role for some R&D intensive start up firms but are less important to Philips due to its size and in house capabilities. Because of this, supporting businesses will not be addressed in great detail. The next paragraph will briefly present an overview of the entire Chinese high tech sector taking into account all three kinds of R&D entities. After that the R&D activities and the locations of each of these entities will be quantified in greater detail.

Research and development activities in China

Table 5.3 provides an overview of the Chinese high tech sector. China is already a major S&T player in terms of inputs to innovation, with similar GERD/GDP ratios as Italy and the UK, but looks smaller on the output side. The GERD/GDP ratio has more than doubled in a decade and reached 1.41% in 2006 compared to 0.6% in 1995. China's innovation system has undergone some fundamental changes. In the past, public research institutes and universities were the dominant R&D actor but today these have been replaced by the domestic and foreign MNE business sector (see table 5.4).

Table 5.3: Gross Expenditures on R&D (GERD)

	GERD	GERD/GDP	Government S&T appropriation	Share in total expenditure
	(billion yuan)	(%)	(billion yuan)	(%)
2001	104.3	0.95	70.3	3.7
2002	128.8	1.07	81.6	3.7
2003	154.0	1.13	94.5	3.8
2004	196.6	1.23	109.5	3.8
2005	245.0	1.33	133.4	3.9
2006	300.3	1.42	168.9	4.2

Table 5.4: S&T Sources of funds and performing institutes in 2006 (billion Yuan)

		Performance sector				
		Research institutes	Business	Higher Education	Others	**Total**
Sources of funds	Government	48.1	9.7	15.2	1.3	**74.2**
	Business	1.7	194.6	10.1	0.9	**207.4**
	Abroad	0.3	4.2	0.4	0.0	**4.8**
	Others	6.6	5.0	2.0	0.3	**13.9**
	Total	**56.7**	**213.5**	**27.7**	**2.5**	**300.3**

When looking at a provincial level (see Appendix X) one can see that many Chinese provinces are now larger R&D performers than several Western countries. But significant differences exist within China. The coastal provinces account for two thirds of China's national GERD in 2007. Here the GSIs represent a clear group of top performers in terms of R&D intensity.

Higher education system

There is a long history of analysis of the impacts of universities on regional economies; Florax (1992) provides a list of over 40 studies. The existence of geographically mediated spillovers from university research to commercial innovation was first proven by Jaffe (1989) and very recently again, a study by Abramovsky, et. al. (2007) shows strong evidence for the co-location of corporate R&D and university research.

The roots of a formal system of education in China can be traced back at least as far as the 16th century BC in the Shang Dynasty (1523 – 1027 BC). Until the Communist Party ascent to power in 1949, the education was heavily influenced by Confucian philosophy. Shortly after the founding of the People's Republic of China, a new educational system was imported: the Soviet model. Most of the government's efforts during this period were devoted to the development and restructuring of higher education. The number of comprehensive universities diminished and the amount of specialized colleges showed a huge increase. Although this change facilitated the construction of industry and the development of science and technology, producing a large amount of specialized talents for the economic development of the 1950s, it also resulted in various problems. First, the number of comprehensive universities and departments of humanities were drastically decreased, leaving less options for interdisciplinary experiences and cross-disciplinary research. Second, since universities were divided and specialized in constricted fields, the graduates tended to become more narrow minded (Chen, 2003). By 1961, the failed policies of the Great Leap Forward, an epidemic of natural disasters, and the breaking of relations with the Soviet Union thwarted further progress along these lines. With the Soviet model no longer the paradigm; the government attempted to introduce a system at a balance between Confucian and Western-style education.

In 1995, the Chinese central government launched Project 211 with the idea to establish a specially funded group of 104 universities that will considerably improve the quality in teaching, research, management and institutional efficiency. It is hoped that from this group, standards for quality will derive. Later, Project 985 was initiated and aimed at developing 10 to 12 so-called world-class universities which are able to compete with the premier league of universities worldwide. These top universities would help China get highly educated people with capabilities for "indigenous" or "home-grown innovation". Appendix XI shows a list of all of these 104 leading universities and Appendix XII shows how all institutions of higher education and the subset of top universities are distributed across GSIs.

Although as many as 700 of the universities in China are registered as active in R&D, only few of those enjoy international reputation. This is the result of government policy to concentrate about two-thirds of total funding to the top fifty universities that have the greatest potential to become world class research institutes. This concentrated funding has had quite an impact in terms of scientific publications. In 2005 China ranked fifth in the Science Citation Index with a share of 6.5% of the world's publications compared to only 2% less than a decade before (OECD, 2007). The quality however doesn't seem to keep up with the quantity so citation rates and other indicators of quality remain low. Appendix XIII shows a table of the top 10 universities 2008 and appendix XIV shows the most prolific university sources of scientific publications.

From looking at appendixes XII, XIII and XIV a clear picture emerges: the majority of China's top higher education system, an important partner in R&D and the source of PRAS's most important factor of production are located in the coastal provinces and in Beijing, Shanghai and Nanjing particularly, followed by Wuhan and Xi'an.

Chinese State Key Laboratories

State Key Laboratories are top equipped open laboratories in a specific research direction and there is usually only one in each discipline. They are all affiliated to top universities and theoretically everyone can submit their research proposal to these labs and compete for experimenting time. Their mission is to carry out fundamental research to meet the social, scientific and economic needs. They are approved and constructed as platforms to attract outstanding young scientists and carrying out advanced research at international competitive level. In 2006, there were over 9000 full time employees in these 199 SKLs accounting for almost half of the Chinese publications in national and international first class journals (Hong & Tong, 2006).

Appendix XII shows the geographical distribution of the current 199 SKLs across the GSIs. SKLs are roughly similarly distributed across China as the top universities. Beijing, Shanghai and Nanjing host the most closely followed by Wuhan and Xi'an.

Corporate MNE R&D activity in China

China's innovation system has undergone some fundamental changes. In the past, public research institutes and universities were the dominant R&D actor but today these have been replaced by the domestic and foreign MNE business sector (see table 5.4).

The time when foreign multinationals like Philips invested in China only to take advantage of its cheap labor pool is over. Inward FDI increasingly includes R&D operations. As a best guess given the limitations of available data, foreign R&D now accounts for 25-30% of total business R&D in China (OECD, 2007). Foreign R&D labs established by MNEs are highly concentrated in the ICT industries including software, telecommunications and semiconductors but pharmaceuticals, biotechnology, as well as automotive industries also attract a large amount of R&D related FDI (Lan, 2006).

Unfortunately there is no adequate official database on MNE FDI and in particular on MNE R&D investments that can be used directly. Fortunately Prof. Von Zedtwitz from Tsinghua University in Beijing was able to provide me some data from his GLORAD database in which he accumulated data on MNE R&D investments. Appendix XII shows the geographical distribution of MNE R&D labs across the GSIs.

In the GLORAD database, Beijing and Shanghai account for 26 and 41 percent of all MNE R&D labs, respectively. A very recent study by the OECD showed that Beijing and Shanghai account for 48 and 33 percent of all MNE R&D labs in China. Clearly there is a strong concentration in both these cities. Sun (2007) argues that this is the product of imitative behavior by foreign MNE decision makers faced with uncertainties and multiple risks. More recently cities like Suzhou, Guangzhou, Hangzhou, Xi'an, Tianjin and Dalian have appeared on the map of foreign R&D investments but still the distribution is very skewed compared to US distribution (see appendix XV).

All in all a very clear conclusion can be drawn; R&D activity in China is currently mainly located in the Beijing, Shanghai, Nanjing and Guangzhou. Wuhan and Xi'an both score relatively well in the near and far West, respectively. Corporate R&D by foreign MNEs shows a spectacular concentration in Beijing and Shanghai.

Table 5.5: Static star ratings: RIP

Stars - Research Institution Presence			
Beijing	★★★★★	Chongqing	★
Shanghai	★★★★★	Lanzhou	★
Nanjing	★★★★	Nanning	★
Guangzhou	★★★	Shijiazhuang	★
Wuhan	★★★	Zhengzhou	★
Xi'an	★★★	Nanchang	★
Jilin	★★	Changchun	★
Fuzhou	★★	Taiyuan	★
Harbin	★★	Kunming	★
Changsha	★★	Guiyang	o
Shenyang	★★	Haikou	o
Chengdu	★★	Hohhot	o
Tianjin	★★	Yinchuan	o
Hangzhou	★★	Xining	o
Hefei	★	Lhasa	o
		Urumqi	o

(Giuliani 2005)5.4. Labor Market

Talent is the most important factor of production for R&D labs like PRAS and one of the main driving forces behind the establishment of foreign R&D activities in China (Gassmann & Han, 2004). Corporate R&D laboratories like PRAS employ highly educated people with various backgrounds. China, with its immense population, is thought of as a great source for such talent.

The Chinese education system has come a long way. Once an "elite education" system, with only very few students lucky enough to enter, it now serves more than 23 million students according to China's Minister of Education. But this number is heavily debated especially in light of science and engineering students (Bracey, 2006 and appendix XVI). There is much controversy about the real number of full time students in China and it is often said that the definition of a "student" in Chinese statistics deviates considerably from the definition used in other countries. However, since this discussion is ongoing and since this research is mainly focused on regional differences that result in attractiveness, the official Chinese statistics shall be used in this paragraph.

The differentiation between the different types of education is quite remarkable. In 2007 there were around 1 million graduate students and 19 million undergraduate students (see appendix XVII) which is a rather different ratio compared to Western countries like Germany or the Netherlands where the same ratio is approximately 1:4½ and 1:3 respectively. Of these roughly one million graduate students, 50% studies engineering or science related degrees (see appendix XVIII). Although this ratio is declining is still is a lot higher than in OECD countries (OECD, 2007). A subsequent breakdown of students enrolled in universities, funding and number of teachers per GSI is provided in appendix XIX. Using the statistics on funds and teachers per student as a proxy for the quality of education one can conclude that Beijing and Shanghai offers best quality education. Provinces like Yunnan, Tibet and Xinjiang in the West of China are clearly getting a boost in educational funds in the government's effort to upgrade those regional economies.

Combining these statistics with ones presented in the previous paragraph yield a clear picture: China's highly educated talent pool is located in coastal provinces. It is here that most of China's top talent graduates and where almost all top talent goes to work (Wang, 2006 and see appendix XII) at high quality universities, MNE R&D labs and national and state laboratories. Very few of the top students decide to stay in e.g. Harbin or Xi'an when higher salaries and more metropolitan lives awaits in places like Shanghai, Beijing and cities abroad. In other words, MNE labs in China are not only competing for the best talent with other R&D institutes in China but also with top research institutes in the US and Europe (Von Zedtwitz, 2007).

This situation and the continuing increase in corporate and public R&D activities in China puts a lot of pressure on the R&D human resource market. Annual salary increases are very high and so is voluntarily staff turnover in the high tech sector (see appendixes XX and XXI respectively). Today's salaries in different sectors across the various provinces are presented in Appendix XXII. The data here comes from China's Statistical Yearbooks and is an average of all wages across all types of business entities. As such is not the most accurate representation of absolute wages paid by MNE labs in various provinces. In depth studies of MNE R&D salaries are available but are extremely costly. For the purposes of this study, which is the comparison of provinces, the figures suffice since the relative differences between the provinces are most important. Wages in Beijing and Shanghai are the highest, followed by the other coastal provinces.

Although the geographical distribution of this salary component of the labor market is completely opposite of the labor supply component, in terms of attractiveness, these salary costs are still very low in comparison to the costs of hiring high quality R&D personnel in e.g. The Netherlands or Silicon Valley. The salary component is therefore not the highest priority for many of the MNE R&D labs. Also, if the reason for conducting R&D is market driven, as most MNE R&D activity is, one needs local talent regardless of their wages.

Because of the contradictory nature of the location factors that compose the labor market attractiveness, two scales should be made. Each GSI is thus scored on labor supply and labor costs:

Table 5.6: Static star rating: labor supply

Stars - Labor market: Supply			
Beijing	★★★★★	Fuzhou	★★
Nanjing	★★★★	Shijiazhuang	★★
Shanghai	★★★★	Zhengzhou	★★
Tianjin	★★★★	Changsha	★★
Guangzhou	★★★	Taiyuan	★★
Harbin	★★★	Chengdu	★★
Wuhan	★★★	Lanzhou	★
Nanchang	★★★	Nanning	★
Changchun	★★★	Guiyang	★
Shenyang	★★★	Haikou	★
Xi'an	★★★	Hohhot	★
Jilin	★★★	Kunming	★
Hangzhou	★★★	Yinchuan	O
Hefei	★★	Xining	O
Chongqing	★★	Lhasa	O
		Urumqi	O

Table 5.7: Static star rating: wages

Stars - Labor market: Wages			
Hefei	★★★★★	Yinchuan	★★★★
Lanzhou	★★★★★	Xi'an	★★★★
Guiyang	★★★★★	Chongqing	★★★
Haikou	★★★★★	Fuzhou	★★★
Changsha	★★★★★	Shijiazhuang	★★★
Nanchang	★★★★★	Shenyang	★★★
Changchun	★★★★★	Jilin	★★★
Taiyuan	★★★★★	Chengdu	★★★
Urumqi	★★★★★	Nanjing	★★
Kunming	★★★★★	Xining	★★
Nanning	★★★★	Tianjin	★★
Harbin	★★★★	Lhasa	★★
Zhengzhou	★★★★	Hangzhou	★★
Wuhan	★★★★	Beijing	★
Hohhot	★★★★	Guangzhou	★
		Shanghai	★

5.5. Upstream industry location

The results of activities performed by a MNE R&D lab often find their commercial application in different parts of the firm, e.g. product divisions, or get completely spun-out to other, often newly found organizations or competitors via the high tech marketplace. Upstream industry location refers to the presence of such users of R&D results.

R&D investments in China generally follow prior investments and co-locate at manufacturing sites (Lu, 2004) and / or sales offices. Philips itself had factories, assembly plants and a national sales office long before PRAS was set up. They located mainly in Guangdong, Jiangsu, Shanghai and Beijing. According to Philips' internal accounting system it is also in these provinces that all of Philips' top one hundred suppliers are located.

Since China decided to accept foreign investment in 1978, China has received a large part of international direct investment flows but its impact was moderate until the early 1990s. China moved from restrictive to permissive policies in the early 1980s, then to policies encouraging FDI in general in the mid-1980s to policies encouraging more high-tech and more capital intensive FDI projects in the mid-1990s (Fung et al., 2004). Since then the stream of incoming FDI turned into a flood and over the past decade, China has become the second largest recipient of FDI in the world after the United States. FDI flows to China have increased massively in recent years.

A lot of research has been conducted into the effects of FDI on regional development in general and its impact on regional innovation in China more particularly (e.g. Cheung (2004)). FDI can benefit innovation activity in the host via spillover channels such as reverse engineering, skilled labor turnovers, demonstration effects, and supplier-customer relationships. These benefits are even greater when FDI is colocated in close proximity as Orlando (2004) and Madariaga (2007) show.

Foreign MNEs account for roughly 80% of China's high tech exports (OECD, 2007). Exports and high tech exports especially are therefore a good indicator of where users of R&D are located. Appendix XXIII shows an overview of recent total annual exports per region and appendix XXIV shows their high tech export component. The relative shares of the high tech export in total exports are presented in appendix XXV. All conclude the same. Coastal provinces rule, accounting for 87% and 97% of China's total exports and high tech export respectively.

Appendix XXVI shows each region and GSI's accumulated FDI and the gross industrial output (GIO) of foreign invested companies per GSI. Clearly, Guangdong and Jiangsu have the highest FDI stocks followed closely by the other coastal provinces. Foreign invested GIO is by far highest in Shanghai. Combined with the figures on exports, a clear conclusion can be drawn again; production and exports are located in the coastal regions with their high tech component being mainly located in the GSIs Shanghai, Tianjin, Guangzhou, Beijing and Nanjing.

Table 5.8: Static star rating: Upstream industry presence

Stars - Upstream industry presence			
Guangzhou	★★★★★	Zhengzhou	★
Nanjing	★★★★	Wuhan	★
Shanghai	★★★★	Changsha	★
Beijing	★★★	Nanchang	★
Fuzhou	★★★	Changchun	★
Jilin	★★★	Xi'an	★
Tianjin	★★★	Taiyuan	★
Hangzhou	★★★	Chengdu	★
Shenyang	★★	Lanzhou	O
Hefei	★	Guiyang	O
Chongqing	★	Hohhot	O
Nanning	★	Yinchuan	O
Haikou	★	Xining	O
Shijiazhuang	★	Lhasa	O
Harbin	★	Urumqi	O
		Kunming	O

5.6. Market access

The market access category contains location factors that refer to the demand conditions determinant in the Porter Diamond. Sophisticated demand for high technology and high tech products in an area will make the local firms devote more attention to those products than do firms outside that area, leading to a competitive advantage when the local firms begin exporting the product. Also, a strong trend-setting local market helps local firms anticipate global trends.

Different approaches have been used to classify motivations for R&D internationalization. One approach broadly distinguishes between demand-oriented and supply-oriented drivers for R&D internationalization (see Granstrand, Hakanson and Sjölander, 1993). Demand-oriented motivation factors include the local market needs localized products, and this factor has been a strong driver behind the openings of R&D labs in China (Gassman, 2004). In fact, according to Motohashi (2006) most of the R&D related investments by MNEs in China is market driven.

Due to the differences in need, behavior and preference between consumers in Eindhoven and China it is difficult for Philips to design products for the Chinese market from a R&D lab in Eindhoven. The opening up of PRAS in China was a strongly influenced by Philips' need to better understand socioeconomic tendencies and local market needs to make the innovation funnel more efficient in generating products to serve the local Chinese market.

Even though PRAS typically develops technologies or applications instead of final consumer products, the upstream industries discussed in the previous paragraph are not the final customers. Most of Philips' products are bought by high market segment customers and it is important to be in touch with these final customers from a design and marketing perspective. These customers live in urbanized areas rather than rural villages so population, urbanization rate and average education level are the most important market related location factors besides the obvious GDP and GDP per capita statistics. Appendix XXVII provides an overview of these most important market related location factors. Even though Beijing, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian and Guangdong account for only 36% of China's total population, their combined GDP is 60% of the whole China pie.

Again, the coastal GSI score highest on this determinant of competitive advantage, especially Guangzhou, Shanghai and Beijing. Their consumer markets are big; their population is very urbanized, relatively rich and well educated. Shanghai scores higher than Beijing and Guangzhou for its central location and the fact that it has a more cosmopolitan and vibrant lifestyle and grandeur.

Table 5.9: Static star rating: Market access

Stars - Market access			
Shanghai	★★★★★	Shijiazhuang	★
Beijing	★★★★	Zhengzhou	★
Guangzhou	★★★★	Wuhan	★
Nanjing	★★★	Changsha	★
Tianjin	★★★	Hohhot	★
Hangzhou	★★★	Nanchang	★
Fuzhou	★★	Yinchuan	★
Harbin	★★	Xi'an	★
Changchun	★★	Taiyuan	★
Shenyang	★★	Chengdu	★
Jilin	★★	Urumqi	★
Hefei	★	Lanzhou	O
Chongqing	★	Guiyang	O
Nanning	★	Xining	O
Haikou	★	Lhasa	O
		Kunming	O

5.7. Government policy

This category of location factors refers to the all relevant government related factors. Technological progress has long been seen as the engine of economic growth which is why governments try to stimulate R&D activities. Local governments can stimulate R&D by providing incentives like tax exemptions, tax rebates and other preferential policies (Griffith, 1995). The Chinese communist government has been very active is steering the domestic economy. In the past it has used incentives based legislation to stimulate growth in certain areas through export zones and it is now investing heavily in physical infrastructure in the Western provinces to promote economic growth there (Goodman, 2004).

Today many governments in almost every country of the world try to stimulate R&D activity within their borders because of its positive effect on economic growth (Hall, 2000). So too in China where one of the targets set in the National Guidelines for the Medium- and Long-term Plan for Science and Technology Development (2006-20) is to raise the ratio of R&D to GDP to 2% by 2010 and to 2.5% or more by 2020. It is hard to gather accurate field data on the effects of local government policy in the forms of tax cuts and other financial incentives on MNEs R&D labs. Negotiations between MNEs that want to set up an R&D lab and the host government are very timely and senior level and the results very case sensitive.

As a proxy to governments policy in terms the government science and technology appropriation in absolute and relative terms are used. When governments have big absolute and relative budgets for S&T they are likely more experienced in dealing with R&D investments. Appendix XXVIII provides the latest statistics on GSI government science and technology (S&T) appropriation. Top performers here again are Beijing and Shanghai, followed by Hangzhou, Tianjin and Guangzhou.

Table 5.10: Static star rating: Government policy

Stars - Government policy			
Beijing	★★★★★	Wuhan	★
Shanghai	★★★★★	Changsha	★
Guangzhou	★★★★	Hohhot	★
Hangzhou	★★★★	Changchun	★
Tianjin	★★★★	Xi'an	★
Nanjing	★★★	Chengdu	★
Fuzhou	★★	Urumqi	★
Shenyang	★★	Kunming	★
Jilin	★★	Hefei	O
Chongqing	★	Lanzhou	O
Nanning	★	Haikou	O
Guiyang	★	Nanchang	O
Shijiazhuang	★	Yinchuan	O
Harbin	★	Xining	O
Zhengzhou	★	Taiyuan	O
		Lhasa	O

5.8. Popular industry opinion

This final category of location factors refers to less quantifiable factors and physical location factors that have no direct effect on the business of interest but are still important to firms making investment decisions. Surveys of industrialists and decision-makers, such as those conducted by across Europe, provide evidence the importance of e.g. the quality of living. In their study of the 500 largest companies in the European Union, about 10 per cent include quality of life factors amongst the three most important attributes in their location decisions (Rogerson, 1999).

In the US, surveys of the late 1980s also concluded that, in industrial location, quality of life issues were a primary consideration in locating a plant or new business (Love, 1999) especially for high technology industries (Malecki & Bradbury, 1992). It furthermore seems that even though the principal "push" factors in location decision making are often financial, the final selection of where to locate is heavily influenced by quality of life and related factors (Rogerson, 1999).

A recent study by Horinzon in China, the coastal city Dalian in Liaoning province was selected as China's most suitable city for living, followed by Xiamen in Fujian province. Following were Mianyang and Chengdu in Sichuan province, Wuhan, the provincial capital of Hubei, Hangzhou, the capital of Zhejiang, Shanghai, Nanjing, provincial capital of Jiangsu province, Qingdao in Shandong province and Chongqing.

Big cities like Beijing, Tianjin, Xi'an and Guangzhou score much lower on the urban habitable index, which takes traffic, environment, social welfare and security into account, due to its bad traffic, high housing prices and heavy pollution. Appendix XXIX provides some more statistics on livability of GSIs.

Table 5.11: Static star rating: Popular industry opinion

Stars - Popular industry opinion			
Shanghai	★★★★★	Guiyang	★
Hangzhou	★★★★	Shijiazhuang	★
Nanjing	★★★★	Zhengzhou	★
Beijing	★★★	Changsha	★
Guangzhou	★★★	Hohhot	★
Tianjin	★★★	Changchun	★
Chongqing	★★★	Urumqi	★
Wuhan	★★★	Kunming	★
Chengdu	★★★	Hefei	O
Fuzhou	★★	Lanzhou	O
Shenyang	★★	Haikou	O
Jilin	★★	Nanchang	O
Harbin	★★	Yinchuan	O
Xi'an	★★	Xining	O
Nanning	★	Taiyuan	O
		Lhasa	O

5.9. Conclusions

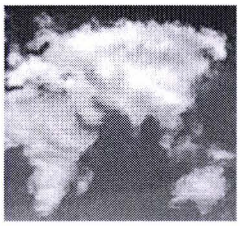
Now that all the data on location factors is presented the data can be aggregated and compared through star rankings (see table 5.12 on next page). Details for the calculation can be found in the customizable digital appendix: "Digital document 2: Static phase GSI scores.xlsx". Weights are assigned to each category of location factors after reviewing various studies that rank determinants of R&D locations such as Cornet (2001) and other presented here before.

From the table one can clearly see that coastal GSIs score by far best with Beijing and Shanghai score highest on almost all location factors. Guangdong and Jiangsu province are comparable provinces with lower scores on research institution presence and labor market but with very high upstream industry presence scores thanks to their high FDI stocks. In the north, near-west and far-west, Liaoning, Hubei and Shaanxi get the highest scores respectively.

The next chapter addresses the dynamic phase of the research approach to find out how each of these provinces scores on the location factors in five years time.

Table 5.12: GSI comparison – static phase

Region	GSI	IPR	RIP	Upstream	Labor Supply	Labor Wages	Market access	Gov. Policy	POI	Total
Anhui	Hefei	★	★★	★	○	★★★★	★	★	★	★★
Beijing	Beijing	★★★★★	★★★★★	★★★	★★★★★	★	★★★★	★★★★★	★★★★	★★★★★
Chongqing	Chongqing	★★	★	★	★★	★★★★★	★★	★	★	★★
Fujian	Fuzhou	★★	★★	★	★	★★★★★	★	★★	★★	★★
Gansu	Lanzhou	★	★	○	★★	★★★★★	★	★★	○	★
Guangdong	Guangzhou	★★★★	★★★	★★★★	★★	★★	★★★★	★★★	★★	★★★★
Guangxi	Nanning	★	○	○	○	★★★★★	○	★	★★	○
Guizhou	Guiyang	★	○	○	○	★★★★★	○	★★	★★	○
Hainan	Haikou	★	○	★	○	★★★★	★	★	★	★
Hebei	Shijiazhuang	★	★	★	★	★★★★★	★	★★	★	★
Heilongjiang	Harbin	★	★	○	★	★★★★★	★	★★★	★★	★
Henan	Zhengzhou	★	★	★	★	★★★★★	★★	★★	★★	★★
Hubei	Wuhan	★★	★★	★★	★	★★★★	★★	★★	★★	★★
Hunan	Changsha	★	★★	★	★	★★★★	★★	★★★	○	★★
Inner Mongolia	Hohhot	★	○	○	○	★★★★	★★	○	○	○
Jiangsu	Nanjing	★★	★★★	★★★	★	★★★	★★★	★★	★★★★	★★★★
Jiangxi	Nanchang	★	★	★	★	★★★★★	★	★★	★	★
Jilin	Changchun	★	★★	★★	★	★★★★★	★	★	★	★★
Liaoning	Shenyang	★★	★★	★★★	★★	★★★★	★★★	★★★	★	★★★
Ningxia	Yinchuan	★	○	○	★	★★★★	★	★	○	○
Qinghai	Xining	★	○	○	★★	★★★★★	○	★★	★	○
Shaanxi	Xi'an	★★	★★★	★	★	★★★★	★	★★	★	★★
Shandong	Jinan	★★	★★★	★	○	★★★★	★	★★	★	★★
Shanghai	Shanghai	★★★★	★★★★	★★★★	★★★★	○	★★★★★	★★★★	★★★★	★★★★★
Shanxi	Taiyuan	★	★	○	★	★★★★★	★	★★	★	★
Sichuan	Chengdu	★	★★	★	★	★★★★	★★	★★	★★	★★
Tianjin	Tianjin	★★	★★	★★★	★★★	★★★	★★★	★★★	★★	★★★
Tibet	Lhasa	★	○	○	○	○	○	○	○	○
Xinjiang	Urumqi	★	○	○	★	★★★★	★	★	○	○
Yunnan	Kunming	★	★	○	★	★★★★★	★	★	★	★
Zhejiang	Hangzhou	★★	★★	★★★	★★	★★★	★★★	★★★	★	★★★



6. Dynamic Phase

In this part of the report the third phase of the research design as implemented at PRAS is presented. The "dynamic" phase addresses the "future" and focus on research questions four and five. The chapter is based on book and literature reviews, expert interviews and statistics from a variety of sources. First the dynamic location factors are selected then data is compiled and gathered on them. After that, the mathematical model is presented.

6.1 Dynamic location factors

Not all the location factors in table 5.1 will show significant change in the next five years. The location factors that are expected to do show change and for which this change can reasonably be estimated, are called the dynamic location factors. Table 6.1 lists these dynamic location factors used in this research into R&D ecosystems.

Table 6.1: Dynamic location factors

Location factor category	**Dynamic location factors**
Research Institution Presence	Quality of universities
	Number of universities
Labour Market	Number of students
	Quality of graduates
	R&D wages
Market Access	Population
	GDP / capita
	GDP
Upstream Industry Location	FDI stocks
	FDI stocks in region
	Gross industrial output of foreign invested firms
Government Policy	Local government science and technology expenditure

The IPR category has completely been omitted in the list of dynamic location factors. This is for a couple of reasons. First of all, IP laws are implemented nationwide so there is no formal difference across the Chinese provinces. Secondly, the superiority of IPR courts in Beijing, Shanghai and Guangzhou at the moment is likely to remain unchanged in the next five years. Building up such IPR expertise in other courts requires two things, an inflow of qualified personnel and IPR cases. The prior is still not happening as Wang (2006) has shown and the latter is lagging because of the low concentration of high tech companies and the quality of the courts in those places. This situation will ensure that IPR courts in Beijing, Shanghai and Guangzhou do not give in any superiority over the next five years.

The number of SKLs in each GSI is also not likely to change over the next five years. New SKLs are occasionally found but their numbers are very limited. If new SKLs were to be found, their contributions to the state of the R&D ecosystem in the GSI will be very limited in the next five years due to operational ramp up. The number of MNE labs is here obviously the dependent variable and therefore not included as a dynamic location factor.

The number of universities however is likely to change in face of the drastic increase in the number of students that want to get a higher education. Since 2000, the number of students enrolled in higher education has quadrupled to about 20 million in 2008 but YOY growth rates have dropped significantly as well (see appendix XXX). But these newly found universities will not be a significant determinant of R&D ecosystem competitiveness because their operational ramp will limit them as sources of R&D and scientific publications in the next five years.

Wage increases in China have already had a significant effect the geographic distribution of certain businesses in China. Large parts of China's former low grade textile and toy manufacturing industries for example have already made a move to countries like Bangladesh and Vietnam in face of these rising costs. Labor costs are an important cost factor for R&D activities; at PRAS the labor costs account for over 50% of its annual budget. It is therefore an important dynamic location factor that needs to be included in this section.

Average level of education is an important location factor when searching for high concentrations of savvy consumers and definitely played a role in the current geographic distribution of R&D in China but this is unlikely to have significant changes in the next five years. Population, GDP and the resulting GDP per capita do change and these are generally also quite well studied location factors.

Besides FDI stocks in both the region and GSI and GIO of foreign invested companies, this phase of the research will also look at shares of secondary industry in the regions' GDPs. Lu (2004) has showed that many R&D in China is located near manufacturing bases so an increase in this activity can provide insights into future location of R&D activity. Exports and high tech exports are outcomes of ecosystems and therefore good during the static phase but less so in this phase. The future location of Philips' suppliers is also omitted as a location factor as it is beyond the scope of this research to accurately predict they are all located. To answer that, a whole set of separate ecosystem dynamics study should be undertaken for the each of the businesses of those suppliers.

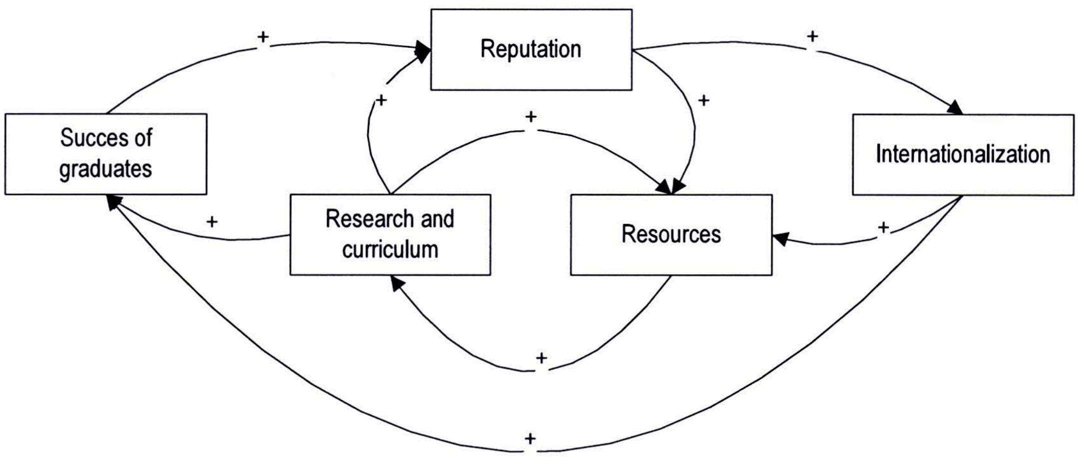
Government policy is included here as the Chinese communist government can have a relatively strong influence on the location of industries through preferential policies. CPC's plans should therefore be included to understand the future states of R&D ecosystems in China. Popular industry opinion is omitted here because we cannot predict how people think about GSIs in five years. The static results on that category of location factors will be taken into account in the evaluation phase though.

The next paragraphs shall discuss each dynamic location factor. Each shall address the reason of the factor's inclusion in the set of dynamic location factors; explain the methodology or approach used to determine the future states and provide the quantified states where applicable.

6.2 Research institution presence

The quality of universities is, as mention before, an important determinant of the location of corporate R&D activities. Because of this, and the fact that higher education has become more costly for families and individuals, the demand for comparative information on universities has increased (Usher and Savino, 2006). The number of individual ranking systems used worldwide runs well into the hundreds but Tang & Wu (2007) have identified a few broad categories of indicators used to explain university quality. Among other, these are resources, reputation, research and curriculum, success of graduates and internalization. Here we will use them as a guideline to explain university quality dynamics in China.

Figure 6.1: Path dependency in university quality



About 25 years ago already, Davies and Melchiori (1982) wrote a paper on the importance of image and public reputation for a university. Back then, the playing field was mostly national but these days universities compete for resources, students, international top talent and research funds on a global level, and reputation is a key determinant as Soutar (2002) among others have shown. Clearly there are strong positive feedback loops in place (see Figure 6.1) that lock the highest quality education systems geographically in place.

Every year Netbig.com[3], China's leading and oldest university ranking entity, publishes a ranking of Chinese top universities. The 2008 top 20 contains exactly the same names as the top 20 in 2003 and there are only 10 new names in the top 100 universities of 2008 compared to the 2003 list. This is strong support of the aforementioned and shows that university quality, in terms of its R&D efforts and contribution to S&T is likely to become relatively stronger in the current top GSIs like Beijing Shanghai and Nanjing.

The impact of potential new SKLs and universities on the competitiveness in any given GSI will be neglected here as they are unlikely to contribute significantly to R&D within five years time. Also, in case a significant public lab would be set up it is highly likely to be located in either Shanghai or Beijing because this is where the current R&D ecosystems are most competitive and most private R&D is located because the Chinese government is shifting its policy towards creating a firm centered innovation system (OECD, 2007), a trend graphically depicted in appendix XXXI.

[3] More details on their ranks can be found at: http://rank2008.netbig.com/cn/rnk_1_0_0.htm

With this in mind one can reasonable estimate that in terms of RIP ranking the GSIs that score highest in 2007 will still score highest in 2012 and those with many MNE labs will slightly climb the ranks. This yields the following star ranking for 2012:

Table 6.2: Dynamic star rating: IPR

Dynamic stars - IPR			
Beijing	★★★★★	Lanzhou	★
Shanghai	★★★★★	Shijiazhuang	★
Guangzhou	★★★★	Harbin	★
Nanjing	★★★★	Zhengzhou	★
Xi'an	★★★	Nanchang	★
Jinan	★★★	Changchun	★
Tianjin	★★★	Taiyuan	★
Hangzhou	★★★	Kunming	★
Wuhan	★★	Nanning	o
Changsha	★★	Guiyang	o
Shenyang	★★	Haikou	o
Chengdu	★★	Hohhot	o
Hefei	★	Yinchuan	o
Chongqing	★	Xining	o
Fuzhou	★	Lhasa	o
		Urumqi	o

6.3 Labor market

The quality of graduates is highly dependent on the quality of the universities they attend. Quality of university graduates therefore will show similar dynamics. Currently the number of students in China and The Netherlands are around 20 million and half a million[4] respectively, which is around 1.5% and 1.3% of total population respectively. The number of students has risen dramatically in recent years but YOY growth rates have declined from 35% in 2000 to just 7% in 2008. In GSIs like Beijing and Harbin YOY growth in student enrollment has completely stopped. Guangzhou, Xi'an, Chongqing and Nanjing still grow above average.

Coastal GSIs have the highest R&D labor pool YOY growth rates, with strong growth rates for provinces with high FDI stocks. Beijing has by far the biggest R&D labor pool followed by Shanghai. Nanjing, Tianjin and especially Hangzhou and Guangzhou are closing the gap. At current growth rates, these last two will overtake Xi'an and Wuhan in terms of R&D labor pool size. In Xi'an and Wuhan the SKLs have a relatively high share in the R&D activities which results in growth rates there are only around 2% YOY. Growth in R&D labor pools seem to correlate highly with GSI FDI stocks. This confirms the findings of Lu (2004) that corporate R&D in China colocates with manufacturing facilities in China.

Unfortunately, no time series for R&D wages could be found within the available budget. The China Statistical Yearbook each year does however contain a statistic on the average wage of staff and workers per GSI. This time series therefore shall be used as a proxy to R&D wage increases which are likely to follow at least similar trends as overall wage increases.

For every province in China forecasts were made using Brown's linear exponential smoothing in Statgraphics. The results can be found in "Digital document 3: wage forecasts.xlsx". Clearly from past data we can see that salaries in the most densely populated coastal GSIs are growing faster than other GSIs as one would expect from economic growth theory. This doesn't have significant results on 2012 star rankings though as the dynamics are widening rather than leveling out the geographical differences:

[4] CBS figures, added up university and higher education students

Table 6.3: Dynamic star rating: Labor supply

Dynamic Stars - Labor supply			
Beijing	★★★★★	Shijiazhuang	★
Shanghai	★★★★★	Taiyuan	★
Guangzhou	★★★	Urumqi	★
Hangzhou	★★★	Wuhan	★
Nanjing	★★★	Xi'an	★
Tianjin	★★★	Xining	★
Chongqing	★★	Yinchuan	★
Jinan	★★	Changsha	o
Shenyang	★★	Guiyang	o
Changchun	★	Haikou	o
Chengdu	★	Hefei	o
Fuzhou	★	Hohhot	o
Harbin	★	Lhasa	o
Kunming	★	Nanchang	o
Lanzhou	★	Nanning	o
		Zhengzhou	o

Table 6.4: Dynamic star rating: Labor wages

Dynamic Stars - Labor wages			
Lanzhou	★★★★★	Taiyuan	★★★★
Nanning	★★★★★	Urumqi	★★★★
Guiyang	★★★★★	Kunming	★★★★
Yinchuan	★★★★★	Hefei	★★★
Xining	★★★★★	Chongqing	★★★
Lhasa	★★★★★	Fuzhou	★★★
Shijiazhuang	★★★★	Haikou	★★★
Harbin	★★★★	Shenyang	★★★
Zhengzhou	★★★★	Jinan	★★★
Wuhan	★★★★	Chengdu	★★★
Changsha	★★★★	Nanjing	★★
Hohhot	★★★★	Hangzhou	★★
Nanchang	★★★★	Guangzhou	★
Changchun	★★★★	Tianjin	★
Xi'an	★★★★	Beijing	o
		Shanghai	o

6.4 Market access

The dynamics of China's population is a much debated topic. It is the country's greatest asset as well as its greatest challenge. The one child policy has definitely limited the growth rate and is likely to help achieve the government aim to limit its mainland population below 1.37 billion by 2010. According to data released, given China failed to implement the family planning policy, China's population would be nearly 400 million more than the present figure of 1.33 billion. But 119 boys are born for every 100 girls in the world's most populous nation. About 40 million men may live as frustrated bachelors by 2020.

But population will definitely grow! China's population increases each year by approximately 14 million people, a number that exceeds the total population of individual countries such as Belgium or Greece and US states like Illinois, or Pennsylvania. Toth et. al. (2003) combine national-level demographic scenarios for the period 2000 through 2030 with information about the provincial population distribution from the year 2000 census and projections of provincial birth-rate, death-rate, urbanization, and inter provincial migration based on historical data. After comparing their population distribution scenarios for 2015 made in 2000 with real figures population statistics from 2008 it became clear that China's population grows faster and inter province migration plays a bigger role than they've anticipated. More recent studies by Yue et al (2005) and Cao et al (2006) confirm this trend of population floating from the western and middle regions to the coastal provinces of China.

Until now, China had defied the traditional theories of how fast developing nations could grow. Its economic growth has compounded at an annual average rate of 10 percent over the past 30 years, a record that has surpassed the other miracle economies, such as Japan and South Korea. But now the law of large numbers seems to be catching up to China: in 1998, to grow its USD1 trillion economy by 10 percent, it had to expand its economic activities by USD100 billion and consume only 10 percent of the world's industrial commodities. Currently, to grow its USD3.5 trillion economy that fast, it needs to expand by USD350 billion a year and suck in nearly 30 percent of global commodity production. Most sources suggest GDP growth could slow down to 8 percent in 2009. But the highest concentrations of the richest Chinese citizens will not move because of this, they will remain where they are: in mega agglomerations like greater Guangzhou, Beijing and Shanghai.

Table 6.5: Dynamic star rating: Market access

Dynamic Stars - Market access			
Shanghai	★★★★★	Shijiazhuang	★
Beijing	★★★★	Harbin	★
Guangzhou	★★★★	Hohhot	★
Tianjin	★★★	Nanchang	★
Hangzhou	★★★	Changchun	★
Chongqing	★★★	Xi'an	★
Nanjing	★★★	Taiyuan	★
Chengdu	★★★	Urumqi	★
Zhengzhou	★★	Kunming	★
Wuhan	★★	Lanzhou	o
Changsha	★★	Nanning	o
Shenyang	★★	Guiyang	o
Hefei	★★	Haikou	o
Fuzhou	★★	Yinchuan	o
Jinan	★★	Xining	o
		Lhasa	o

6.5 Upstream industry presence

The static phase showed that China's economic reform and opening up has created prosperous and rapidly growing coastal regions where GSIs are an integral part of the global economy and a falling behind inland that is only marginally integrated. And there is no evidence that the gap is narrowing as Chen & Fleisher (1996), Yang (2002) and Wan (2007) have show successively. Regional FDI inflows are one of the main reasons for this imbalanced regional development as Barrel (1997) and Buckley (2002) show for Europe and China respectively.

Two theories of FDI location are agglomeration economies and regional comparative advantage. The former refers to the Marshallian forces of agglomeration of economic activities that are driven by knowledge and pecuniary spillovers; whereas the latter is based on cost comparison in terms of labor cost, transportation cost, and the availability and cost of energy and other intermediate inputs. If the Marshallian agglomeration economies dominate, location of FDI will be subject to a self-perpetuating process. On the other hand, the neoclassical theories of comparative advantage would predict that as a region's FDI concentration reaches a certain level, diseconomies of concentration, such as rising labor cost will become a serious drawback and as a result, FDI will flow into regions that have a more preferable configuration of comparative advantages.

FDI in China has been characterized by its high concentration in manufacturing industries. On average this is still around 65% which leaves FDI in tertiary industries lagging far behind the world average of around two-thirds. Given the fact that manufacturing activity is often relatively mobile and cost sensitive it is therefore no wonder that Hu and Owen (2007) find strong empirical support for the comparative advantage theory in China. That might also explain the recent spectacular YOY growth rates of FDI inflows per province and GSI (see appendix XXXI) in provinces like Henan, Anhui and Hunan in the near West. Places like Tianjin, Nanjing and Liaoning however also grow significantly faster than Beijing, Shanghai and Guangzhou.

Research by Amiti and Javorcik (2008) on the other hand indicates that supplier access is the most important factor affecting FDI location. Their findings show that access to markets and suppliers in the province of entry matters more than access to the rest of China.

Corporate R&D activity is more vertically integrated though, relying on linkages with other local foreign invested enterprises who account for 80% of China's high tech exports for example. Besides that, it also relies on cooperation with local universities and other labs to conduct the R&D. As such, the agglomeration theory is more likely to predict MNE R&D investment locations in the next five years. With economies of scale as the main determinant for FDI investments, GSIs like Shanghai, Guangzhou and Nanjing and Tianjin are still much more attractive locations.

Table 6.6: Dynamic star rating: Upstream industry presence

Dynamic Stars - Upstream industry presence			
Guangzhou	★★★★★	Changsha	★
Shanghai	★★★★★	Nanchang	★
Nanjing	★★★★	Chengdu	★
Tianjin	★★★★	Xi'an	★
Beijing	★★★	Lanzhou	o
Shenyang	★★★	Nanning	o
Hangzhou	★★★	Guiyang	o
Changchun	★★	Harbin	o
Jinan	★★	Zhengzhou	o
Chongqing	★★	Hohhot	o
Wuhan	★★	Yinchuan	o
Hefei	★	Xining	o
Fuzhou	★	Taiyuan	o
Haikou	★	Lhasa	o
Shijiazhuang	★	Urumqi	o
		Kunming	o

6.6 Government policy

Chinese national government policy in the past has had a big influence on the location of initial foreign Greenfield manufacturing investments. Guangdong and Fujian provinces were the first to open up special economic zones (SEZ). Today there are seven SEZ in Shanghai, Tianjin, Xiamen, Shantou, Shenzhen, Zhuhai and Hainan aimed to attract and utilize foreign capital. In SEZ the companies are mainly joint ventures between Chinese and foreign companies involved in production for exports.

Besides these SEZ there are many "technology parks", "free trade zones", "technological development zones" and "high tech development zones" established by lower level governments in almost all large and medium-sized cities. The result is a multilevel and untransparant collection of locations where preferential policies can be enjoyed. Fierce competition for FDI exists between these locations as one of the top priorities of every Chinese regional government is to attract FDI. An important instrument the local government use is the establishing of special zones within its jurisdiction where foreign investors can expect to receive generous benefits in the form of lower land prices and tax breaks.

Today these parks and their associated benefits have become such a commodity that, especially at the macro geographical scale used in this research. Unless the central government intervenes strongly by for example banning R&D in well developed places, there will be no distinct macro level government policy difference between GSIs in five years.

When looking at YOY growth each GSIs annual S&T expenditure budget and the relative share of it in its total annual budget it's safe to conclude that the coastal GSIs like Beijing, Shanghai will still be by far the most favorable in terms of government policy followed by Tianjin and Guangzhou. By 2012 these GSIs will also have much more experience in doing business with MNEs due to the current MNE lab distribution. The star rating in 2012 remains the same.

6.7. Computer model

An important part of this graduating project is to develop a structured research method that can be reapplied in ecosystem studies for different businesses. In order to provide Philips with a truly generic research method to the analysis of business ecosystem dynamics in China a fully customizable computer model has been developed. This model can help a business ecosystem dynamics research in two ways. First of all it is able to conduct simple neoclassical location model calculations (see chapter 2) which help explain dynamics in the GSI competitiveness. Secondly, the model does this visually which helps communication.

To define the business of interest the user can upload dynamic location factors (DLF) scores as variables on which to score the GSIs. Besides dynamic location factor scores, the user can also define the business of interest by specifying three other types of data layers: markets (M), factors of production (FOP) and transportation (T). Quantifying each of the specified layers allows the model to do market potential analysis or least production cost analysis (Hayter, 1997).

In order to compare the set of DLF and the result from the analysis phase, which can be of completely different nature, each individual score (s) has to be in an interval scale (Stevens, 1946) of zero to one, representing least and most competitive, respectively. To do this, the model divides each score (s) by that variable highest GSI score. This way, of course, the user can also feed the system with DLF scores in an order scale (e.g. five stars ranking system format) without loss of data integrity. Weights can be assigned to the importance of the analysis output and each DLF to compute GSI competitiveness score (CS):

$$CS_r = \sum_n s_{rn} \cdot w_n$$

Essentially the result is a region comparison grid (Daniels et. al. 2006) as shown in figure 6.1.

Figure 6.2: Region comparison grid

		GSIs (R)			
Variable (N)	**Weight (W)**	r_1	r_2	...	r
Analysis	w_0	s_{11}	s_{21}	...	s_{r1}
DLF_1	w_1	s_{12}	s_{22}	...	s_{r2}
...	...	...	...	...	...
DLF_n	w_n	s_{1n}	s_{2n}	...	s_{rn}
		CS_1	CS_2	...	CS_r

Because of this, the CS score itself is also on interval scale. The most competitive GSI is the one with the highest CS score. To display final competitiveness all CS scores first need to be divided by the highest GSI CS score to create the final competitiveness score FCS, on a zero to one interval. In the computer model these FCS scores are then translated into a color using the scheme in figure 6.2. The brighter white a region lights up on the screen the higher it's score.

Figure 6.3: FCS score – to – color scheme

By defining M, T, FOP, DLF for different years (Y) and watching the model compute FCS scores in quick succession one can clearly see GSI competitiveness dynamics in time across the various provinces.
In the next paragraphs all of the different components of the model are explained.

Regions

In the model, a predefined yet customizable set of regions (R) has been programmed. This set consists of all the GSIs and the regions they represent and major foreign markets. Because of the fact that the focus of the research is on business ecosystem dynamics within China, foreign markets are solemnly regarded by the module as markets to export to or points to import FOPs from.

Details on the set of regions preprogrammed into the model can be found in appendix XXXI. Given the nature of the business of interest in this study (i.e. R&D), which hardly employs exports or imports; the set of foreign markets kept rather limited in this study. In case a business is analyzed in which specific foreign markets are more important, the model can relatively easy be extended.

Factors of production

In this layer the user can define the business of interest by specifying a characterizing set of factors of production (F), the resources employed to produce the goods or service generated by business of interest. In classic economic theory, land, labor and capital are identified as the three types of FOPs. Here, all critical cost components of the production of a good or service can be included such as labor, rent, utilities and externally sources subassemblies. Because of their importance to the business of interest, FOPs are most likely already identified as dynamic location factors in the previous phase.

The availability and costs of the set of FOPs in a location has a direct influence on its competitiveness in the business of interest. In the model the user can quantify each FOP layer for each region R and timestamp (Y) as a monetary value (c_{ry}):

$$FOP_f = \begin{pmatrix} c_{f11} & \cdots & c_{fr1} \\ \vdots & \ddots & \vdots \\ c_{f1y} & \cdots & c_{fry} \end{pmatrix} \text{ with } r \in R\,,\, y \in Y$$

Markets

But factors of production are only one side of the story. A typical business ships out or delivers their products or services to certain markets. Proximity to- or the presence of such markets is, as shown in the Porter Diamond, an important determinant of a location's competitiveness, mainly because of the cost incurred with transportation to those markets. In the model the user is able to define the business of interest by quantifying a market layer M with market values (m_{ry}) for each of the regions R at different timestamps (Y). These market values can be in specific monetary terms such as expected turnover or annual demand or in non monetary terms such a population.

$$M = \begin{pmatrix} m_{11} & \cdots & m_{r1} \\ \vdots & \ddots & \vdots \\ m_{1y} & \cdots & m_{ry} \end{pmatrix} \text{ with } r \in R\,,\, y \in Y$$

Transportation

Transportation is what links markets and GSIs together. Sometimes a FOP is not available in a GSI or net cheaper to import from another region. Besides linking regions together in terms of FOPs, transportation also links markets together. Since the user can only specify one transportation layer per timestamp, the user has to define transportation functions or constants for each M and FOP layer to relate to the T layer.

$$T_y=\begin{pmatrix} t_{11} & \cdots & t_{1r} \\ \vdots & \ddots & \vdots \\ t_{r1} & \cdots & t_{rr} \end{pmatrix} \text{ with } r \in R \text{ , } y \in Y$$

Computer model – analyses

The model's user interface has tabs called general, market, FOP, transport and analysis. In the general tab the user can switch between a world view or zoom in on China. Also here is where the user can allow time to take place by selecting the timestamps watch the dynamics of the selected visible variable. This visible variable can be an individual layer of M, FOP or DLF, whose values are represented by bubbles of different sizes, or FCS scores, which are indicated by how bright a region lights up (see figure 6.2).

In the market tab, the user can see how the market M is defined and selected the market layer as visible variable. In the FOP tab the user can see the uploaded FOP layers and assign relative weights to them in case more than one is uploaded. In the transport tab one can look at the transportation grid loaded into the model and look the optimal path calculations between regions that the computer model uses.

In the analysis tab is basically a digital interactive version of figure 6.1 where the user can see and assign weights to the set of DLFs uploaded and selected analysis. The latter is a choice of two options: M or FOP. In the first option, the resulting analysis is basically a market potential analysis (Hayter, 1997):

$$MP_{ry}=\sum_i \left(\frac{m_{ry}}{t_{ir}}\right) \quad i \in R \text{ , } r \in R$$

This is Harris' (1954) influential market-potential function, which states that the demand for goods produced in a location is the sum of purchasing power in other locations, weighted by transport costs. Although criticized for its simplicity, a study by Mayer and Head (2004) shows that indeed the market potential function can explain location choice of Japanese investments in the EU at a macro level.

The second option is essentially a production cost analysis. This analysis calculates the production costs of the business of interest. First the model calculates the cheapest source of every FOP by comparing local FOP prices with the costs of importing them and selects the minimum. After this step the model calculates the total production cost by multiplying the cost of each FOP with its assigned weight, which is a representation of the share of the FOP in total production cost.

$$PC_{ry}=\sum_{f \in F} w_f \cdot \min\left(c_{fry} \cdot t_{ir}\right)$$

The working computer model can be found as digital document 3. A detailed user manual that explains how to use and customize the computer model can be found in digital document 4.

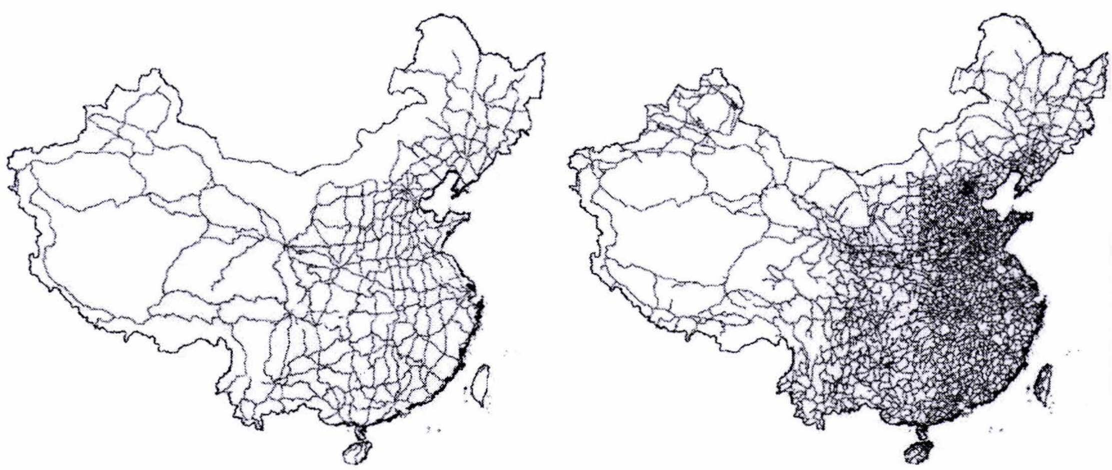
6.8. R&D ecosystem dynamics

To use this model in the analysis of R&D ecosystems dynamics, the market layer M has been defined as the total FDI stocks per province and quantified for 1996 to 2012. With the transportation constant set as 1 the market potential function outcome is a measure of each GSI's proximity to users of their output.

Average wages per GSI is the only FOP layer that has been selected because this cost category account covers around 75% of PRAS' has been defined as the FOP layer. Adding other layers wouldn't make a lot of sense for every other factor of production only contributes very little to total costs. The transportation constant is set at 100 to ensure that the model doesn't "import" labor from other GSIs. The layer is also quantified for each GSI from 1996 to 2012.

Because R&D activity doesn't rely on imports of FOP and physical exports to markets, the transportation layer is defined by overland distance by highways between GSIs in kilometers. Data for this layer was retrieved from Google Maps China[5]. Even though the Chinese government is investing a lot in infrastructure, especially in Western provinces, the assumption is made that kilometer distance will not decrease between GSI because the most major roads are already finished (see figure 6.3).

Figure 6.4: Spatial distribution of roads in 2000 (left) and 2010 (right), taken from Yue et. al (2005)



University quality, R&D labor pool, gross industrial output of foreign invested companies and accumulated future FDI flows are incorporated into the model as dynamic location factors on which to score the GSIs aside the neoclassical analysis. Unless the user completely tweaks the model to make accumulated future FDI flows the absolute determinant of corporate R&D competitiveness (which is obviously isn't) a clear conclusion can be drawn.

Now that all the estimates on dynamic location factors are presented the data can again be aggregated and compared through star rankings (see table 6.7 on next page). Details for the calculation can be found in the customizable digital appendix: "Digital document 5: Dynamic phase GSI scores.xlsx".

R&D ecosystems in Beijing and Shanghai remain the most competitive R&D ecosystems. The location factors here add up to the strongest Porter Diamond. This means that by far the most R&D investments by MNEs in China, aimed to conduct basic and applied research rather than experimental development will continue to be concentrated in those GSIs until 2012. One could say that Beijing and Shanghai remain 1st tier R&D locations.

[5] For more information: http://ditu.google.com

The analysis also revealed a group of 2nd tier R&D locations. These are Tianjin, Guangzhou, Hangzhou and Nanjing. All of these locations have accumulated high concentrations of FDI and have already seen their first MNE R&D labs opening up in recent years. None of the western- or northern GSIs are on the 2nd tier list. MNE's have opened up R&D labs in GSIs like Chengdu and Chongqing but these numbers are and will remain low compared to the activities in the 2nd tier coastal GSIs. The few labs that have been set up are also focused on development rather than research and this is unlikely to change in the next five year based on the outcome of this research.

Table 6.7: GSI comparison – Dynamic Phase

Region	GSI	IPR	RIP	Upstream	Labor Supply	Labor Wages	Market access	Gov. Policy	POI	Total
Anhui	Hefei	★	★	★	○	★★★	★★	○	★	★
Beijing	Beijing	★★★★★	★★★★★	★★★	★★★★★	○	★★★★	★★★★★	★★★★	★★★★★
Chongqing	Chongqing	★★	★	★★	★★	★★★	★★★	★	★	★★
Fujian	Fuzhou	★★	★★	★	★	★★★	★★	★	★	★★
Gansu	Lanzhou	★	★	○	★	★★★★★	○	★	○	○
Guangdong	Guangzhou	★★★★	★★★★	★★★★	★★★	★	★★★★	★★★	★★	★★★★
Guangxi	Nanning	★	○	○	★	★★★★★	○	○	★★	○
Guizhou	Guiyang	★	○	○	○	★★★★★	○	★	★	○
Hainan	Haikou	★	○	★	○	★★★	○	○	★	○
Hebei	Shijiazhuang	★	★	★	★	★★★★	★	★	★	★
Heilongjiang	Harbin	★	★	○	★	★★★★	★	★★	★	★
Henan	Zhengzhou	★	★	★	○	★★★★	★★	★	★★	★
Hubei	Wuhan	★★	★★	★★	★	★★★★	★★	★★	★★	★★
Hunan	Changsha	★	★★	★	○	★★★★	★★	★★	○	★
Inner Mongolia	Hohhot	★	○	○	○	★★★★	★	○	○	○
Jiangsu	Nanjing	★★	★★★★	★★★★	★★★	★★	★★★	★★	★★★	★★★★
Jiangxi	Nanchang	★	★	★	★	★★★★	★	★	★	★
Jilin	Changchun	★	★★	★★	★	★★★★	★	○	★	★★
Liaoning	Shenyang	★★	★★	★★★	★★	★★★	★★	★★	★	★★
Ningxia	Yinchuan	★	○	○	★	★★★★★	○	○	○	○
Qinghai	Xining	★	○	○	★	★★★★★	○	★	○	○
Shaanxi	Xi'an	★★	★★★	★	★	★★★★	★★	★	★	★★
Shandong	Jinan	★★	★★★	★★	○	★★★	★★	★	★	★★
Shanghai	Shanghai	★★★★	★★★★★	★★★★★	★★★★★	○	★★★★★	★★★★	★★★★★	★★★★★
Shanxi	Taiyuan	★	★	○	★	★★★★	★	★	★	★
Sichuan	Chengdu	★	★★	★	★	★★★	★★★	★	★★	★★
Tianjin	Tianjin	★★	★★★	★★★★	★★★	★	★★★★	★★★	★	★★★★
Tibet	Lhasa	★	○	○	○	★★★★★	○	○	○	○
Xinjiang	Urumqi	★	○	○	★	★★★★	★	○	○	○
Yunnan	Kunming	★	★	○	★	★★★★	★	○	○	○
Zhejiang	Hangzhou	★★	★★★	★★★★	★★★	★★	★★★★	★★	★	★★★★

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7. Evaluation Phase

In this part of the report the fourth phase of the research design as implemented at PRAS is presented. This final phase is the "evaluation" phase and focuses on research question six. The chapter is based on book and literature reviews and expert interviews.

7.1. Pull and push factors

The previous phases have revealed, at an aggregate level, there very little location factors that pull PRAS away from its current location in Shanghai, one of China's two R&D hotspots, which currently ranks just behind Beijing's R&D ecosystem in terms of the categories government policy, RIP and R&D labor supply. But Shanghai itself also scores well on those location factors and is better on the upstream industry and market access determinants so the pull is quite limited.

The biggest individual pull factor is definitely labor cost. And because it's reciprocal nature it is also the most important factor pushing PRAS out of Shanghai. Shanghai is China's most densely populated city and this together with the fierce competition for talent has resulted in average wages that are around 33% higher than compared to Hangzhou or Nanjing and around 100% higher when compared to western GSIs like Chengdu and Xi'an. This labor cost gap is not likely to become less in the next five years. For a business that is so labor intensive as corporate R&D it can therefore really be a consideration to move in light of this cost advantage. As a push factor the labor costs is relatively weak for Philips Research because R&D labor costs in Shanghai are still relatively low compared to R&D costs in their other labs in Europe or the US.

Another pull factor is the number of students in locations outside of Shanghai. Some other GSIs have considerably higher numbers of university students. But given Philips Research status as a source of IPR, Philips' good name as an employer and China's 6 million graduates per year that all compete for jobs, it is not very difficult for PRAS to attract highly qualified graduates.

Not all top universities in China are in Shanghai. PRAS has strategic partnerships with a number of Chinese universities outside of Shanghai but it is easier to cooperate with them in closer proximity. Being located close to universities also would make it easier to scout for and attract top talent on those universities.

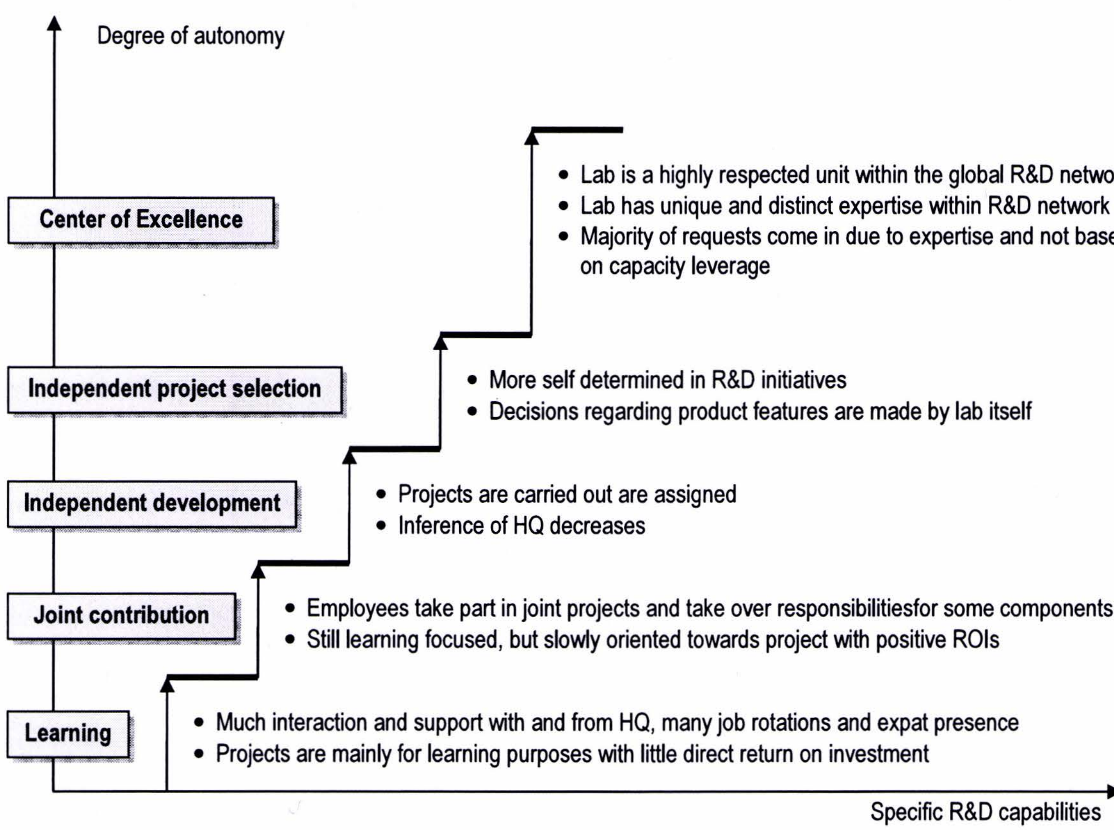
A final pull factor is any local government's eagerness to attract any R&D or MNE related FDI investment. Every MNE R&D manager in China has heard of the R&D labs of Intel and Honeywell located in Chengdu and Chongqing respectively. Foreign multinationals setting up R&D labs in the Western provinces is big news here in China. Government controlled media is keen to use it as examples of the success of it's the Communist Party's success in its "Go West" policy. Over and over again!

7.3. Keep factors

During this graduation project PRAS moved into its new location in Shanghai. Its new location is a beautiful campus environment on which Philips' China headquarter and Philips Lighting's Global Development Center are also located. From the beginning of this research it was clear that PRAS has no intention to move its location, i.e. there are no clear push factors that cause PRAS management to look for new potential sites.

Possibly the biggest keep factor is the fact it takes time to "build" a lab. The fact that it takes time for a newly found R&D lab to mature in a foreign country into a productive lab is recognized by many. Kuemmerle (1997) identified a simple ramp-up period of three to five years while Teece, Pisano, Shuen (1997) propose more complex theories describing the evolution of dynamic capabilities. Here five stages are proposed, based on results from an interview with the former PRAS general manager (figure 7.1).

Figure 7.1: R&D lab capability growth



Philips has put a lot of money in PRAS over the last nine years since it was founded in Shanghai. The lab in 2008 now had around 100 FTE and got 45 first filings, which is a legal concept that defines who has the right to the grant of a patent for an invention. In the same year Philips Research as a whole employed 1100 scientists who generated 1049 first filings patents down from 1111 in 2007.

When using first filings / scientist as a measure of productivity one can conclude that PRAS is still well behind Philip Research's global average. Moving the PRAS location for labor cost savings would mean undoing a large proportion (if not all) of the work Philips put in the lab to build it into what it is today. This is of course a paramount keep factor.

7.4. Scenarios

Based on these push, pull and keep factors four different types of scenarios are explored. The scenarios are organized in a 2x2 matrix. One axis is the distance from existing Shanghai base and the other one is size.

Figure 7.2 Four scenarios in response to R&D ecosystem dynamics in China

	Small move	Big move
Non coastal region	**Strategic possibilities** • Considerable operational cost savings • Partnering with good universities • Attract local university top talent • Government is eager to attract foreign MNE R&D • A lot of free publicity for a long time	**No advantages** • IPR protection is less mature • Government trend is for flattening of incentives • Physical connection to global R&D network is costly • Coastal China and export remain key markets • Coastal China will remain trend setting region • Suppliers are not located outside coastal provinces • Government is less experienced in supporting R&D • No distinct customer demand difference • Top research institute presence is in coastal China • Hard to attract top coastal and foreign talent
Coastal region	**Possibilities for some R&D activities** • Very case dependent • Depends on individual lab long term R&D strategy • Outside research scope	**No advantage** • Marginal operational cost savings • A lab matures, it needs time to become productive • Short distance offers no significant advantages for cooperation or opportunities to attract talent

The geographic axis is straightforward and involves a location in either a coastal- or non coastal GSI as specified in appendix VII. A big move would mean relocating a considerably large number of the R&D activities currently performed in PRAS, effectively making the new location Philips Research's main R&D lab. A small move refers to setting up a new R&D lab with a maximum of around 25 FTE like a specialized unit conducting a very specific type of R&D.

Next two sections will focus on the two scenarios that involve a small move. A large move for PRAS has no advantage no matter the destination GSI because the keep factor presented above is too important. Any scenario that could be classified as a big move would certainly have a negative cost/benefit ratio.

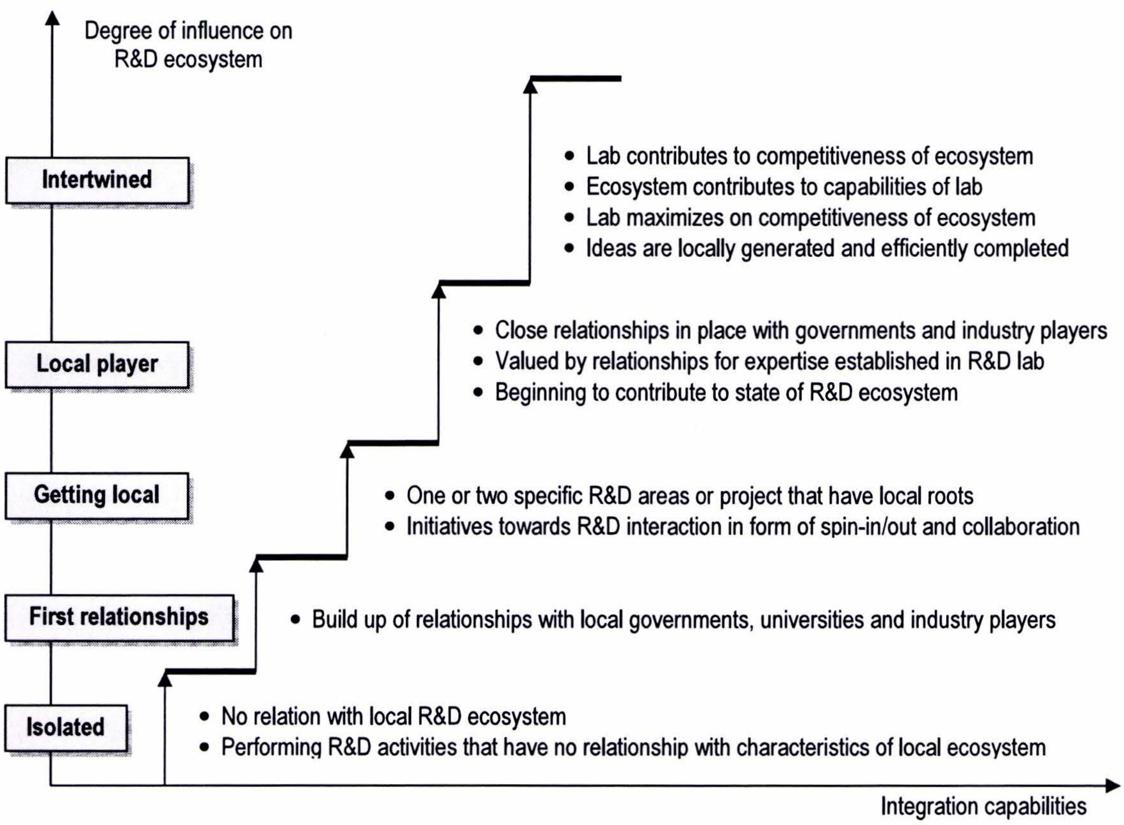
Small - Coastal

Philips has three sectors and each sector incorporates a multitude of technologies in its products. PRAS conducts R&D for each sector and as a result a lot of different kinds of research are conducted within the walls of PRAS. Relocating one type of research could be beneficial, mainly to be closer to development and manufacturing sites. Actual scenarios of this category are very specific and developing them was therefore outside the scope of this research. Furthermore, interviews with research group leaders about this revealed no obvious push factors or needs for developing them. Would there be a need one could conduct a new round of business ecosystem dynamics research in which the business of interest is be more specifically formulated to ensure exact factors of production and location factors are incorporated.

Small – Non coastal

Adding up all the pull factors identified does make some non coastal GSIs attractive, albeit more from a strategic than an operational point of view. Moving into less developed locations early, i.e. before the bulk of MNE can be advantageous because it is easier to have influence on an ecosystem when it's less mature. A move to such location could be classified strategic because there's no immediate positive cash flow.

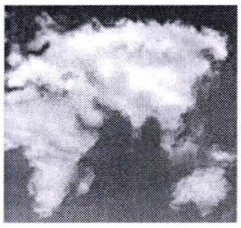
Figure 7.3: R&D lab integration with ecosystem



In general, every new lab goes through the stages depicted above in figure 7.3. Philips Research in Eindhoven can be regarded as an intertwined R&D lab inside the Eindhoven-Leuven-Aachen technology triangle (ELAt). It became to be such player due to its early involvement. Had Philips not been there, and would it only just now invest in that location it would never be able to shape the ecosystem to tailor its needs than the way it did.

The same applies now in China. Setting up a "lookout" labs could help Philips ensure future competitiveness at relatively low cost for a lookout lab doesn't necessarily have to grow beyond the second stage. Setting up such lab also gets a lot of free publicity, giving Philips' brand name a boost. It can be set up as a joint effort by Philips Research and Philips General Purchasing as both have an exploring task.

Concrete scenarios of this type haven't been developed because it was outside of the research scope but Xi'an and Shenyang seem the most attractive locations for in the West and North respectively. Xi'an doesn't have a lot of MNE R&D activity yet but its ecosystem is on par with Chengdu's and Chongqing's which both have attracted more, especially IT and telecommunication related R&D. Shenyang because it clearly stands out in the North in terms of its ecosystem's competitiveness.



8. Conclusions, limitations and discussion

8.1. Conclusions

Currently the R&D ecosystems with most comparative advantage in China are located in Beijing and Shanghai. This is mainly because of its high concentration of both corporate and public research institutes. And in five years from now these two locations will still be most competitive as economic activity based on new knowledge has a high propensity to cluster within a geographic region because it is generated and transmitted more efficiently via local proximity.

Nanjing, Tianjin, Guangzhou and Hangzhou will represent 2nd tier R&D locations in 2012. These GSIs are superior to all other GSIs included in the research because of their proximity to use large concentrations of FDI stock, the quality and number of research institutions present and their superior access to market access, both international and domestic.

FDI stocks in non coastal GSIs and provinces will on average grow faster than in their coastal sisters but this FDI will be mainly invested in manufacturing first. Chengdu, Xi'an, Chongqing and other non coastal GSIs might see new R&D investments locating within their borders but these will structurally lag behind R&D investments in the 2nd tier R&D locations identified above.

In light of these dynamics, four different kinds of scenarios have been proposed. A large scale move is never beneficial for PRAS. Small scale investments in non coastal GSIs are most plausible when a strategic justification of an investment is justified. No short term operational benefits can be gained by a move anywhere in China.

8.2. Limitations

The decisions made at the setup phase of the research strongly influence the research limitations. Because PRAS was mainly interested in high level R&D ecosystem dynamics in medium term in light of e.g. the "Go West" policy a decision was made to select capitals and their provincial backyards as GSI. After the dynamic phase it became apparent that most Western and Northern GSIs will not become more competitive in the business of R&D.The coastal regions will become more dominant.

In hindsight it would have been insightful to have included more coastal cities like Suzhou, Qingdao and Dalian to see how these are likely to perform compared to their big brother capitals Nanjing, Jinan and Shenyang, respectively. Now, the research can only conclude that it is likely that these places will benefit similarly but no answers can be provided beyond using mere logic.

Another limitation is the fact that the research described the business of interest at a relatively abstract, macro level. A decision was made to not investigate a specific type of R&D activity but to generalize and include all kinds of R&D activities performed at PRAS. Doing so made the results insightful for Philips Research and PRAS management and resulted in this thesis as a good internal reference when explaining your location to others, both inside and outside of Philips. But consequently the results are also rather crude and some dynamics that are important to PRAS could've been overlooked. Chengdu for example has been able to attract manufacturing and development focused FDI of both Intel and more recently AMD greatly promoting Chengdu's semiconductor R&D ecosystem

A final limitation is the reliance on forecasts in determining ecosystem dynamics. In the current economic climate it is hard enough to estimate next month's demand let alone make five year predictions on something with the size and complexity of China's economy. Although die-hard academics might disagree I think it is good that I've used a lot of proven high level economic theory and common sense rather than relying purely on statistics, especially in light of the reliability of Chinese statistics.

8.3. Discussion

Corporate research and development is possibly the most immobile of all activities a MNE engages in. There are strong positive feedback loops in play at both a macroeconomic and a micro / company level. This doesn't mean that R&D is completely immobile, as the recent surge foreign R&D investments in China clearly shows. It does move and because of the importance of innovation for future cash flow it is important to study how it moves. So is the research design presented here therefore adequate to investigate R&D ecosystem dynamics?

The timeline in which the graduation project has been completed has allowed the student to partly monitor whether the conclusions and recommendations are correct. One year has passed between presenting the conclusion of the research and the completion of this thesis. During that year many MNEs have invested in R&D activities in China and it looks like the conclusions and it looks like the conclusions were right; at least for the new locations of R&D labs similar to PRAS, which focuses on applied research rather than experimental design. Almost all of the major R&D investments were in Shanghai or Beijing and manufacturing FDI was highly concentrated in Tianjin and Jiangsu province.

This fit between predictions and reality can be used as a rough indication of how suitable the research design is. Unfortunately time and budget constraints didn't allow the student to also test the research design developed in this thesis in an ecosystem dynamics research for a business in which neoclassical theory of location competitiveness has the upper hand. I am confident that in those cases the design yields at least equally satisfying results and possibly more robust results due to the fact that neoclassical concepts are easier to quantify which makes geographical comparison easier.

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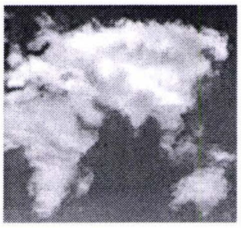


PHILIPS

Appendices

Appendix I: Philips General Structure

Healthcare
The Healthcare Sector employs approximately 33,000 people worldwide and operates in the business areas: Imaging Systems, Home Healthcare Systems, Customer Services, Healthcare Informatics and Ultrasound & Monitoring Solutions. It maintains sales and service organizations in more than 60 countries and runs manufacturing operations in the Netherlands, Germany, Finland, Israel and the USA.

Lighting
The Lighting sector employs approximately 55,000 people worldwide and operates in the business areas: Lamps; Professional Luminaires & Systems; Home Luminaires & Systems, Lighting Electronics; Automotive, Solid State Modules, Lumileds and Special Lighting Applications. It maintains sales and service organizations in over 60 countries and runs manufacturing operations in the Netherlands, Belgium, France, Germany, the United Kingdom, Poland, the USA, Mexico, Brazil, India, Indonesia, Thailand, China and South Korea.

Consumer Lifestyle
The Consumer Lifestyle sector employs approximately 25,000 people in 49 countries and operates in the business areas Connected Displays, Video & Multimedia, Audio & Multimedia, Home Networks, Peripherals & Accessories, Domestic Appliances, Shaving & Beauty and Health & Wellness. It runs manufacturing operations in the Netherlands, Belgium, France, Hungary, Austria, Poland, the USA, Brazil, Argentina, Mexico, China and Singapore.

Source: http://www.philips.com/about/company/businesses/index.page

Appendix II: Philips Research Mission Statement

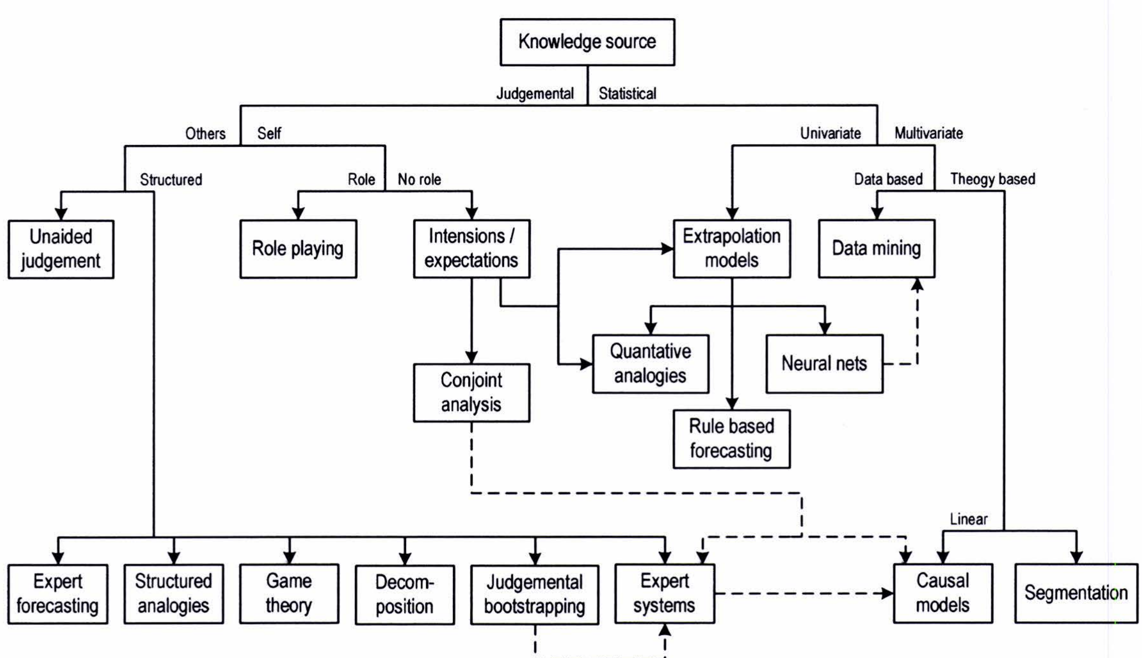
Philips Research, in close cooperation with its technology partners within Philips, drives breakaway innovation to create profitable growth for Philips, and supports the existing businesses mainly through feature innovation.

Philips Research continuously strives for its mission by:

- exploring the unknown to create new technologies
- promoting and demonstrating innovative concepts based on multi-disciplinary strength
- leveraging impact through open innovation
- building and sustaining a strong intellectual property position
- developing our key capabilities and technologies for future markets
- leveraging our capabilities and international presence to influence regional standards and markets
- generating new business initiatives
- translating global trends in innovation into directions to help shape the strategy of Philips
- creating and maintaining an exciting environment to attract international top-talent
- being a source of highly skilled people for Philips

Source: http://www.research.philips.com/profile/mission.html

Appendix III: Methodology tree for forecasting



Source: Armstrong (2001)

Appendix IV: List of interviewees

Name	Title	Organization
Jeroen Besuijen	Supply Chain Manager	Philips Lighting – SSL retrofit
Frans Greidanus	GM / CTO East Asia	Philips Research Asia Shanghai
Reinout Selbeck	CPO China	Philips General Purchasing
Joe Fu	GM	Philips SMIS
Sherry Yu	PR manager	Philips Research Asia Shanghai
Xiaoling Yan	Partnership & Strategy Manager	Philips Research Asia Shanghai
Guido van Tartwijk	Global Marketing Director	Philips Lighting – SSL retrofit
Emmy Fong	Senior Director	Philips Medical Systems
Michael Zhang	Purchasing Manager	Philips Consumer Lifestyle
William Dodson	CEO	Silk Road Advisors
Hans Oerlemans	VP Software Development	Philips Lighting

Appendix V: Divisions of the area administered by the People's Republic of

Level	Name	Types
1	Province level 省级行政区	• Provinces (省) (22) • Autonomous regions (自治区) (5) • Municipalities (直辖市) (4) • Special administrative regions (特别行政区) (2)
2	Prefecture level 地级行政区	• Prefectures (地区) (17) • Autonomous prefectures (自治州) (30) • Prefecture-level cities (地级市 dìjísì) (283) • Leagues (盟) (3)
3	County level 县级行政区	• Counties (县) (1,464) • Autonomous counties (自治县) (117) • County-level cities (县级市) (374) • Districts (市辖区) (852) • Banners (旗) (49) • Autonomous banners (自治旗) (3) • Forestry areas (林区) (1) • Special districts (特区) (2)
4	Township level 乡级行政区	41,636 townships
5	Village level 村级自治组织	> 700000

Source: http://en.wikipedia.org/wiki/Political_divisions_of_China

Appendix VI: Static phase GSIs

	Region name	Chinese name	GSI
Provinces	Heilongjiang	黑龙江	Harbin
	Jilin	吉林	Changchun
	Liaoning	辽宁	Shenyang
	Qinghai	青海	Xining
	Gansu	甘肃	Lanzhou
	Shaanxi	陕西	Xi'an
	Shanxi	山西	Taiyuan
	Hebei	河北	Shijiazhuang
	Sichuan	四川	Chengdu
	Hubei	湖北	Wuhan
	Henan	河南	Zhengzhou
	Shandong	山东	Jinan
	Anhui	安徽	Hefei
	Jiangsu	江苏	Nanjing
	Yunnan	云南	Kunming
	Guizhou	贵州	Guiyang
	Hunan	湖南	Changsha
	Jiangxi	江西	Nanchang
	Zhejiang	浙江	Hangzhou
	Hainan	海南	Haikou
	Guangdong	广东	Guangzhou
	Fujian	福建	Fuzhou
Municipalities	Beijing	北京	Beijing
	Tianjin	天津	Tianjin
	Chongqing	重庆	Chongqing
	Shanghai	上海	Shanghai
Autonomous regions	Xinjiang	新疆	Urumqi
	Tibet	西藏	Lhasa
	Inner Mongolia	内蒙古	Hohhot
	Ningxia	宁夏	Yinchuan
	Guangxi	广西	Nanning

Appendix VII: China provincial level map and regional categorization

Northern: Heilongjiang, Jilin, Liaoning, Inner Mongolia

Coastal: Beijing, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong

Near Western: Hebei, Shanxi, Henan, Anhui, Hubei, Hunan, Jiangxi, Guangxi, Hainan

Far Western: Xinjiang, Tibet, Qinghai, Gansu, Ningxia, Sichuan, Chongqing, Shaanxi, Guizhou, Yunnan

Appendix VIII: Major location factors

Location factor category	Example location factors
Costs	Fixed costs, transportation costs, wage rates and trends in wages, energy costs, other manufacturing costs, land cost, construction costs leasing costs and other factors (e.g. R&D costs, transaction and management costs etc.)
Labour characteristics	Quality of labour force, availability of labour force, unemployment rate, labour unions, attitudes towards work and labour turnover, motivation of workers and work force management
Infrastructure	Existence of modes of transportation (airports, railroads, roads and sea ports), quality and reliability of modes of transportation, quality and reliability of utilities (e.g. water supply, waste treatment, power supply, etc.) and telecommunication systems
Proximity to suppliers	Quality of suppliers, alternative suppliers, competition for suppliers, nature of supply process and speed and responsiveness of suppliers
Proximity to markets	Proximity to demand, size of market that can be served/potential customer expenditure, responsiveness and delivery time to markets, population trends and nature and variance of demand
Proximity to parent	Close to parent company
Proximity to competition	Location of competitors
Quality of life	Quality of environment, community attitudes towards business and industry, climate, schools, churches, hospitals, recreational opportunities (for staff and children), education system, crime rate and standard of living
Legal and regulatory framework	Compensation laws, insurance laws, environmental regulations, industrial relations laws, legal system, bureaucratic red tape, requirements for setting up local corporations, regulations concerning joint ventures and mergers and regulations on transfer of earnings out of country rate
Economic factors	Tax structure and tax incentives, financial incentives, custom duties, tariffs, inflation, strength of currency against US dollar, business climate, country's debt, interest rates/exchange controls, GDP/GNP growth and income per capita
Government and political factors	Record of government stability, government structure, consistency of government policy, and attitude of government to inward investment
Social and cultural factors	Different norms and customs, culture, language and customer characteristics
Characteristics of a specific location	Attitude of local community to a location, physical conditions (e.g. weather), etc.

Source: Atthirawong and MacCarthy (2000)

Appendix IX: IPR cases per province in 2004

	Patent infringements		Other disputes		Patent forgery		Counterfeit cases	
	filed	closed	filed	closed	filed	closed	filed	closed
Beijing	236	239	218	217	52	52	0	0
Tianjin	116	98	21	20	355	355	0	0
Hebei	256	231	56	55	887	885	45	45
Shanxi	58	43	39	30	35	31	15	14
Inner Mongolia	50	49	10	10	239	239	5	5
Liaoning	279	250	145	112	45	45	2	2
Jilin	103	102	53	45	155	155	4	4
Heilongjiang	347	243	104	94	84	84	4	5
Shanghai	386	347	57	57	148	143	8	8
Jiangsu	543	404	110	105	246	246	7	7
Zhejiang	1287	1080	99	81	44	42	17	13
Anhui	61	77	13	11	684	559	0	0
Fujian	227	173	24	21	52	46	1	1
Jiangxi	162	85	28	19	131	125	7	7
Shandong	1030	939	150	143	2862	2677	114	111
Henan	492	395	69	58	321	319	6	6
Hubei	446	387	175	125	302	290	17	16
Hunan	265	240	152	133	326	326	12	12
Guangdong	2409	2061	197	171	767	758	162	160
Guangxi	94	92	53	37	21	21	0	0
Hainan	60	59	7	6	39	39	7	7
Chongqing	10	9	1	1	73	71	0	0
Sichuan	540	446	144	116	204	202	25	23
Guizhou	82	63	28	23	274	215	1	0
Yunnan	124	115	27	22	6	6	11	11
Tibet	6	6	0	0	0	0	0	0
Shaanxi	120	103	28	23	669	667	0	0
Gansu	67	46	25	17	2	2	1	1
Qinghai	12	9	8	11	58	58	0	0
Ningxia	114	111	31	18	30	30	0	0
Xinjiang	221	138	8	5	106	106	2	2
Total	**10203**	**8640**	**2080**	**1786**	**9217**	**8794**	**473**	**460**

Source: China Statistical Yearbook 2005

Appendix X: GERD, R&D personnel per province (2007)

	GERD	Total R&D Personnel		GERD	Total R&D Personnel
	2007	2007		2007	2007
	(billion yuan)	(1000 people)		(billion yuan)	(1000 people)
Anhui	5.9	30	Jiangxi	3.8	26
Beijing	43.3	168	Jilin	4.1	28
Chongqing	3.7	27	Liaoning	13.6	69
Fujian	6.7	40	Ningxia	0.5	4
Gansu	2.4	17	Qinghai	0.3	3
Guangdong	31.3	147	Shaanxi	10.1	59
Guangxi	1.8	19	Shandong	23.4	97
Guizhou	1.5	11	Shanghai	25.9	80
Hainan	0.2	1	Shanxi	3.6	39
Hebei	7.7	44	Sichuan	10.8	69
Heilongjiang	5.7	45	Tianjin	9.5	37
Henan	8.0	60	Tibet	0.1	1
Hubei	9.4	62	Xinjiang	0.9	7
Hunan	5.4	40	Yunnan	2.1	16
Inner Mongolia	1.7	15	Zhejiang	22.4	103
Jiangsu	34.6	139	**Total**	**300.3**	**1502.5**

Source: China Science and Technology Statistics (http://www.sts.org.cn/sjkl/)

Appendix XI: Leading Universities in China

University Name	University Name
Anhui University	Nanjing Normal University
Beijing Film Academy	Nanjing University
Beijing Foreign Studies University	Nanjing University of Aeronautics and Astronautics
Beijing Forestry University	Nanjing University of Science & Technology
Beijing Institute of Technology	Nanjing University of Technology
Beijing Jiaotong University	Nankai University
Beijing Language and Culture University	Northeast Normal University
Beijing Normal University	Northeastern University
Beijing Sport University	Northwest Agriculture and Forestry University
Beijing University of Aeronautics and Astronautics	Northwest University
Beijing University of Chemical Technology	Northwestern Polytechnical University
Beijing University of Posts and Telecommunications	Ocean University of China
Beijing University of Technology	Peking University
Capital University of Medical Sciences	Qingdao University
Central South University	Renmin University of China
Chang'an University	Shaanxi Normal University
Chengdu University of Technology	Shandong Agricultural University
China Agricultural University	Shandong Normal University
China Medical University	Shandong University
China University of Geosciences	Shandong University of Science and Technology
China University of Mining and Technology	Shanghai Jiaotong University
China University of Political Science and Law	Shanghai Second Medical University
Chongqing University	Shanghai University
Communication University of China	Shanxi University
Dalian University of Technology	Sichuan University
Donghua University	Soochow University
East China Normal University	South China Agricultural University
East China University of Science and Technology	South China Normal University
Fudan University	South China University of Technology
Fujian Agriculture and Forestry University	Southeast University
Fujian Normal University	Southwest China Normal University
Fuzhou University	Southwest Jiaotong University
Guangdong University of Technology	Sun Yat-sen University
Guangxi University	Taiyuan University of Technology
Harbin Institute of Technology	The Central Academy of Drama
Hebei Normal University	The University of Science and Technology Beijing
Hebei University	Tianjin University
Hebei University of Technology	Tongji University
Hefei University of Technology	Tsinghua University
Heilongjiang University	University of Electronic Science and Technology of China
Henan University	University of Petroleum
Hohai University	University of Science and Technology of China
Huazhong Agricultural University	Wuhan University
Huazhong Normal University	Wuhan University of Technology
Huazhong University of Science and Technology	Xiamen University
Hunan Normal University	Xi'an Jiaotong University
Hunan University	Xiangtan University
Jiangsu University	Xidian University
Jilin University	Yangzhou University
Jinan University	Yanshan University
Kunming University of Science and Technology	Yunnan University
Lanzhou University	Zhejiang University
Nanchang University	Zhengzhou University
Nanjing Forestry University	Zhongnan University of Economics and Law

Source: http://english.hanban.edu.cn/english/features/highschool/66744.htm

Appendix XII: R&D entity distribution per GSI

Region	GSI	SKLs	Institutes of higher education		MNE R&D Labs	Area
			In GSI	Leading Universities		
		2007	2007	2007	2007	-
		(institutes)	(institutes)	(institutes)	(labs)	(km²)
Anhui	Hefei	1	41	2	1	7029
Beijing	Beijing	72	79	22	130	16400
Chongqing	Chongqing	2	38	2	0	82400
Fujian	Fuzhou	3	35	4	0	12188
Gansu	Lanzhou	5	18	1	0	13085
Guangdong	Guangzhou	6	63	5	56	7434
Guangxi	Nanning	0	28	1	0	22112
Guizhou	Guiyang	1	16	0	0	8034
Hainan	Haikou	1	10	0	0	2305
Hebei	Shijiazhuang	1	32	2	0	15848
Heilongjiang	Harbin	2	37	3	0	53068
Henan	Zhengzhou	0	39	2	0	7446
Hubei	Wuhan	13	55	7	4	8494
Hunan	Changsha	3	48	3	2	11819
Inner Mongolia	Hohhot	0	19	0	0	17224
Jiangsu	Nanjing	13	41	13	46	6582
Jiangxi	Nanchang	0	46	1	0	7402
Jilin	Changchun	7	26	2	1	20571
Liaoning	Shenyang	8	30	3	12	12980
Ningxia	Yinchuan	0	11	0	0	9555
Qinghai	Xining	0	8	0	0	7665
Shaanxi	Xi'an	12	48	6	9	10108
Shandong	Jinan	2	72	6	8	27120
Shanghai	Shanghai	27	60	8	203	6341
Shanxi	Taiyuan	1	34	2	0	6963
Sichuan	Chengdu	7	40	3	6	12390
Tianjin	Tianjin	3	46	3	10	11760
Tibet	Lhasa	0	4	0	0	54
Xinjiang	Urumqi	0	13	0	0	14216
Yunnan	Kunming	1	40	2	0	21011
Zhejiang	Hangzhou	8	36	1	11	16596

Source: GLORAD database, China Statistical Yearbook 2008 and own research

Appendix XIII: Top 10 Universities of China in 2008

Rank	Name	GSI
1	Tsinghua University	Beijing
2	Peking University	Beijing
3	Zhejiang University	Hangzhou
4	University of Science and Technology of China	Hefei
5	Nanjing University	Nanjing
6	Fudan University	Shanghai
7	Shanghai Jiaotong University	Shanghai
8	Beijing Normal University	Beijing
9	Harbin Institute of Technology	Harbin
10	Nankai University	Tianjin
	Renmin University of China	Beijing

Source: http://rank2008.netbig.com/cn/rnk_1_0_0.htm

Appendix XIV: Most prolific sources of scientific publications

Name	Number of papers	
	1995	2005
Tsinghua University	345	3650
Zhejiang University	188	3268
Peking University	488	2710
Shanghai Jiaotong University	161	2435
Nanjing University	617	2031
University of S&T of China	358	1992
Fudan University	353	1770
Shandong University	158	1344
Jilin University	259	1330

Source: OECD Review of China's Innovation Policy (2007)

Appendix XV: Foreign R&D labs in US

	No. Of Foreign R&D Facilities	
	(facilities)	(%)
California	188	26.82
New Jersey	67	9.56
Michigan	41	5.85
Ohio	40	5.71
North Carolina	34	4.85
Massachusetts	34	4.85
New York	33	4.71
Pennsylvania	30	4.28
Illinois	24	3.42
Connecticut	18	2.57
Texas	18	2.57
Total USA	**701**	**100**

Source: Sun (2007)

Appendix XVI: Science and engineer graduates

	Graduates of institutions of higher engineering	
	Science	Engineering
	(1000 people)	(1000 people)
2000	49	213
2001	64	220
2002	73	252
2003	103	352
2004	134	443
2005	163	517
2006	195	576

Source: China Statistical Yearbooks

Appendix XVII: Number of students in higher education in China (2007)

	Students 2007
	(1000 people)
Postgraduates	1195
Doctor's Degree	223
Master's Degree	973
Regular Undergraduates and College Students	18849
Enrolled in Full Undergraduate Courses	10243
Enrolled in Specialized Courses	8606

Source: China Statistical Yearbook 2008

Appendix XVIII: Breakdown of postgraduate students in China (2007)

	Total	PhD	MSc
	(persons)	(persons)	(persons)
Philosophy	14708	2982	11726
Economics	56738	11065	45673
Law	80311	9575	70736
Education	40980	3604	37376
Literature	93935	8816	85119
History	16389	3635	12754
Science	146146	38489	107657
Engineering	436352	92751	343601
Agriculture	45285	8493	36792
Medicine	128471	22952	105519
Military	704	132	572
Management	135028	20014	115014
Total	**1195047**	**222508**	**972539**

Source: China Statistical Yearbook 2008

Appendix XIX: Number and quality of students in higher education per GSI (2007)

Region	GSI	Expenditure for Science	Expenditure for Education	Full-time Teachers	Students	Education expenditure / student
		(100 million RMB)	(100 million RMB)	(1000)	(1000)	(RMB)
Anhui	Hefei	2.3	18.5	16.9	295.8	6251
Beijing	Beijing	90.7	263.0	54.6	567.9	46311
Chongqing	Chongqing	11.1	121.6	26.1	413.7	29381
Fujian	Fuzhou	2.4	31.3	13.9	233.1	13436
Gansu	Lanzhou	1.4	18.2	17.8	171.4	10613
Guangdong	Guangzhou	21.2	80.8	42.1	687.1	11755
Guangxi	Nanning	1.7	20.1	11.7	238.4	8440
Guizhou	Guiyang	2.2	19.5	10.3	209.5	9308
Hainan	Haikou	0.5	8.3	4.4	91.2	9123
Hebei	Shijiazhuang	3.2	40.3	18.4	316.8	12711
Heilongjiang	Harbin	6.2	45.1	24.9	384.9	11707
Henan	Zhengzhou	4.1	42.4	24.8	495.7	8558
Hubei	Wuhan	7.2	47.5	46.4	778.4	6105
Hunan	Changsha	7.5	31.4	27.3	454.3	6905
Inner Mongolia	Hohhot	0.7	14.9	10.5	165	9018
Jiangsu	Nanjing	6.6	45.5	40.8	679.9	6695
Jiangxi	Nanchang	2.0	16.9	27.6	481.1	3507
Jilin	Changchun	2.2	32.5	21.3	331	9810
Liaoning	Shenyang	9.9	48.5	21	317.5	15263
Ningxia	Yinchuan	0.5	9.5	3.6	52.7	17951
Qinghai	Xining	0.8	8.9	3.5	37.7	23501
Shaanxi	Xi'an	2.4	25.7	36.7	624.4	4121
Shandong	Jilin	0.8	22.2	4.5	69.4	31931
Shanghai	Shanghai	105.8	283.3	35.5	484.9	58431
Shanxi	Taiyuan	3.5	20.0	19.8	298.2	6690
Sichuan	Chengdu	6.2	49.5	34	540.6	9153
Tianjin	Tianjin	22.3	110.0	25.2	371.1	29647
Tibet	Lhasa					
Xinjiang	Urumqi	1.0	13.0	7.7	105.1	12341
Yunnan	Kunming	2.4	24.8	16.4	221.8	11195
Zhejiang	Hangzhou	12.2	62.8	23.2	366.2	17135

Source: China Statistical Yearbooks 2008

Appendix XX: Wage increase at MNEs

	2003	2004	2005	2006	2007	2008
	(%)	(%)	(%)	(%)	(%)	(%)
All industries office	7.4	7.3	8.2	8.1	8.3	8.4
High Tech	7.2	7.2	7.2	8.1	8.3	8.2
Consumer	6.7	6.7	7.5	7.3	8.0	8.1
All industries manufacturing	7.3	7.3	7.8	8.6	8.5	8.4

Source: Mercer Salary Enumeration 2008

Appendix XXI: Voluntary staff turnover at MNEs

	2003	2004	2005	2006
	(%)	(%)	(%)	(%)
All industries office	11.2	12.8	12.2	13.3
High Tech	10.7	13.2	14.3	13.9
Consumer	12.0	11.0	11.6	14.3
All industries manufacturing	10.5	8.8	10.2	11.2

Source: Mercer Salary Enumeration 2008

Appendix XXII: Annual salaries per province in various sectors (2006)

Region	GSI	Average	Agriculture	Manufacturing	ICT	Retail	Finance	Business Services	R&D	Education
		(yuan)	(yuan)	(yuan)	(yuan)	(yuan)	(yuan)	(yuan)	(yuan)	(yuan)
Anhui	Hefei	25874	8685	15736	23113	11318	22642	15453	20970	17375
Beijing	Beijing	46507	19147	29619	83394	38446	88408	42522	50853	40856
Chongqing	Chongqing	23098	12253	18367	34147	16263	33511	17519	27813	19003
Fujian	Fuzhou	23950	10717	16297	39147	18535	37393	19931	27159	21771
Gansu	Lanzhou	21019	10867	16929	15999	10729	19343	12366	20167	18545
Guangdong	Guangzhou	40561	11113	20349	52641	26655	53079	27023	46668	26359
Guangxi	Nanning	24791	9917	16805	27096	13133	28118	14170	22046	16495
Guizhou	Guiyang	22579	12361	15734	22464	13131	28612	15626	20308	16316
Hainan	Haikou	25723	7157	15438	42635	12405	33667	16560	16647	20560
Hebei	Shijiazhuang	19992	6622	14985	26628	9539	22699	12474	25895	16060
Heilongjiang	Harbin	22104	7093	14998	32034	14222	24362	13304	21992	19389
Henan	Zhengzhou	22156	9405	14853	22995	11536	24238	15261	22524	17151
Hubei	Wuhan	25136	6993	14526	29379	11978	22161	14032	24385	16754
Hunan	Changsha	27967	7923	16762	30502	16935	22846	15778	21407	18529
Inner Mongolia	Hohhot	26735	10148	15678	25962	13631	23521	17398	23721	21289
Jiangsu	Nanjing	35907	10181	19647	40801	19163	36760	21928	36220	25352
Jiangxi	Nanchang	23887	8208	13661	20428	12336	22921	13324	20372	16027
Jilin	Changchun	24189	7866	16643	25792	12877	21709	16750	19956	17875
Liaoning	Shenyang	27372	6619	18515	39360	16691	28549	12918	26377	20297
Ningxia	Yinchuan	28604	11757	15903	33686	15909	33365	13398	22540	20935
Qinghai	Xining	23333	15332	17184	29897	13850	25721	17468	35029	24173
Shaanxi	Xi'an	25014	11016	15825	36618	11137	24411	14665	23486	16897
Shandong	Jilin	23040	14519	15633	35191	13489	28207	17085	26764	21772
Shanghai	Shanghai	49310	22271	34206	74360	30174	66016	32351	47822	37819
Shanxi	Taiyuan	24688	11806	14764	21220	9513	22080	12087	19008	17478
Sichuan	Chengdu	26607	11224	16404	32229	15682	28282	19556	29754	16374
Tianjin	Tianjin	34938	17975	24354	40591	22677	49810	15810	41473	28752
Tibet	Lhasa	29119	14316	15252	66031	21157	56768	19075	34427	28375
Xinjiang	Urumqi	29110	11297	16751	28120	17122	26146	16099	21312	19612
Yunnan	Kunming	22432	12219	18837	26580	17514	27792	18642	20422	18344
Zhejiang	Hangzhou	36497	24760	18507	52141	27070	53667	23308	39682	38638

Source: China Statistical Yearbook 2007

Appendix XXIII: Exports per region

	2000	2001	2002	2003	2004	2005	2006
	(billion USD)	(billion USD)	(billion USD)	(billion USD)	(billion USD)	(billion USD)	(billion USD)
Anhui	2.17	2.28	2.45	3.06	3.94	5.19	5.41
Beijing	4.63	11.79	12.61	16.85	20.57	30.87	23.20
Chongqing	1.00	1.10	1.09	1.59	2.09	2.52	3.35
Fujian	12.91	13.92	17.37	21.13	28.95	34.85	41.27
Gansu	0.41	0.48	0.55	0.88	1.00	1.09	1.51
Guangdong	91.92	95.42	118.46	152.85	191.56	238.16	301.95
Guangxi	1.49	1.24	1.51	1.97	2.40	2.88	3.60
Guizhou	0.42	0.42	0.44	0.59	0.87	0.86	1.04
Hainan	0.80	0.80	0.82	0.87	1.09	1.02	1.38
Hebei	3.71	3.96	4.59	5.93	9.34	10.93	12.83
Heilongjiang	1.45	1.61	1.99	2.87	3.68	6.07	8.44
Henan	1.49	1.72	2.12	2.98	4.18	5.10	6.70
Hubei	1.93	1.80	2.10	2.66	3.38	4.45	6.26
Hunan	1.65	1.75	1.80	2.15	3.10	3.75	5.09
Inner Mongolia	1.02	1.14	1.37	1.44	1.68	2.07	2.14
Jiangsu	25.77	28.88	38.48	59.14	87.50	122.98	160.42
Jiangxi	1.20	1.04	1.05	1.51	2.00	2.44	3.75
Jilin	1.24	1.46	1.77	2.16	1.72	2.47	3.00
Liaoning	10.85	11.11	12.37	14.63	18.92	23.44	28.32
Ningxia	0.33	0.36	0.33	0.51	0.65	0.69	0.94
Qinghai	0.11	0.15	0.15	0.27	0.45	0.32	0.53
Shaanxi	1.31	1.11	1.38	1.74	2.40	3.08	3.63
Shandong	15.53	18.13	21.12	26.57	35.87	46.25	58.65
Shanghai	25.35	27.63	32.06	48.48	161.27	90.74	113.57
Shanxi	1.24	1.47	1.66	2.27	4.03	3.53	4.14
Sichuan	1.39	1.58	2.71	3.21	3.98	4.70	6.62
Tianjin	8.63	9.50	11.59	14.37	20.87	27.42	33.54
Tibet	0.11	0.08	0.08	0.12	0.13	0.17	0.22
Xinjiang	1.20	0.67	1.31	2.54	3.05	5.04	7.14
Yunnan	1.18	1.24	1.43	1.68	2.24	2.64	3.39
Zhejiang	19.44	22.98	29.42	41.60	58.15	76.80	100.90

Source: China Statistical Yearbook 2007

Appendix XXIV: High tech export per region

	2002	2003	2004	2005	2006
	(billion USD)	(billion USD)	(billion USD)	(billion USD)	(billion USD)
Anhui	0.09	0.13	0.18	0.30	0.35
Beijing	2.93	3.67	5.43	7.72	11.47
Chongqing	0.06	0.07	0.10	0.14	0.14
Fujian	3.22	4.65	6.82	7.80	8.89
Gansu	0.01	0.02	0.09	0.05	0.07
Guangdong	31.07	48.35	66.66	85.11	106.24
Guangxi	0.02	0.02	0.04	0.06	0.10
Guizhou	0.01	0.06	0.14	0.09	0.06
Hainan	0.01	0.01	0.02	0.04	0.07
Hebei	0.20	0.10	0.16	0.26	0.52
Heilongjiang	0.10	0.07	0.09	0.12	0.23
Henan	0.04	0.05	0.07	0.10	0.12
Hubei	0.09	0.30	0.33	0.44	0.96
Hunan	0.05	0.05	0.06	0.10	0.15
Inner Mongolia	0.00	0.00	0.00	0.15	0.07
Jiangsu	12.26	22.94	35.96	53.03	70.73
Jiangxi	0.02	0.05	0.05	0.07	0.16
Jilin	0.03	0.05	0.06	0.09	0.14
Liaoning	2.16	2.67	2.90	2.65	3.17
Ningxia	0.01	0.01	0.00	0.00	0.01
Qinghai	0.00	0.00	0.00	0.00	0.00
Shaanxi	0.12	0.18	0.19	0.27	0.36
Shandong	1.13	1.54	2.49	4.23	6.40
Shanghai	7.50	16.33	28.77	36.03	44.04
Shanxi	0.01	0.00	0.01	0.11	0.20
Sichuan	0.89	0.91	0.68	0.54	0.95
Tianjin	4.49	5.80	10.05	12.56	15.49
Tibet	0.01	0.00	0.00	0.00	0.01
Xinjiang	0.01	0.03	0.04	0.04	0.05
Yunnan	0.05	0.06	0.06	0.07	0.10
Zhejiang	1.27	2.20	3.94	6.10	10.22

Source: China Science and Technology Statistics (http://www.sts.org.cn/sjkl/)

Appendix XXV: High tech exports share in total exports per region (2006)

	High tech exporst share in total exports		High tech exporst share in total exports
	(%)		(%)
Anhui	0.06	Jiangsu	0.44
Beijing	0.49	Jiangxi	0.04
Chongqing	0.04	Jilin	0.05
Fujian	0.22	Liaoning	0.11
Gansu	0.05	Ningxia	0.01
Guangdong	0.35	Qinghai	0.00
Guangxi	0.03	Shaanxi	0.10
Guizhou	0.05	Shandong	0.11
Hainan	0.05	Shanghai	0.39
Hebei	0.04	Shanxi	0.05
Heilongjiang	0.03	Sichuan	0.14
Henan	0.02	Tianjin	0.46
Hubei	0.15	Tibet	0.02
Hunan	0.03	Xinjiang	0.01
Inner Mongolia	0.03	Yunnan	0.03
		Zhejiang	0.10

Source: China Statistical Yearbook 2007 and China Science and Technology Statistics (http://www.sts.org.cn/sjkl/)

Appendix XXVI: Accumulated FDI stocks and GOI per GSI (2008)

Region	GSI	Accumulated actually utilized FDI in region	Actually Utilized FDI in GSI in 2007	Gross Industrial Output Value of Foreign-funded Enterprises 2007 in GSI
		(million USD)	(million USD)	(billion RMB)
Anhui	Hefei	6705	1012	41.8
Beijing	Beijing	31121	5066	369.3
Chongqing	Chongqing	5101	1220	81.6
Fujian	Fuzhou	58319	700	65.7
Gansu	Lanzhou	721	128	1.6
Guangdong	Guangzhou	162847	3286	388.6
Guangxi	Nanning	8665	185	5.6
Guizhou	Guiyang	779	81	3.3
Hainan	Haikou	10540	504	5.7
Hebei	Shijiazhuang	15455	327	13.1
Heilongjiang	Harbin	9082	372	35.6
Henan	Zhengzhou	9783	1001	15.9
Hubei	Wuhan	17294	2250	81.9
Hunan	Changsha	14007	1504	16.4
Inner Mongolia	Hohhot	4231	603	13.6
Jiangsu	Nanjing	114045	1963	169.7
Jiangxi	Nanchang	13059	1231	26.4
Jilin	Changchun	5614	1688	151.4
Liaoning	Shenyang	38232	5045	121.7
Ningxia	Yinchuan	626	45	5.2
Qinghai	Xining	1030	51	1.0
Shaanxi	Xi'an	6010	1116	27.0
Shandong	Jilin	62942	289	2.2
Shanghai	Shanghai	64478	7920	1201.2
Shanxi	Taiyuan	5192	238	3.8
Sichuan	Chengdu	7111	1138	43.2
Tianjin	Tianjin	32370	5460	428.4
Tibet	Lhasa	54		
Xinjiang	Urumqi	618	67	1.2
Yunnan	Kunming	2220	300	10.5
Zhejiang	Hangzhou	44550	2802	161.8

Appendix XXVII: Market access statistics per GSI (2007)

Region	GSI	Total population	Percentage of population with college or higher education	Population density	GDP	GDP / capita
		(million people)	(%)	(people/km²)	(billion yuan)	(yuan)
Anhui	Hefei	4.79	4.7%	681	133	27,868
Beijing	Beijing	12.13	29.4%	1132	935	77,090
Chongqing	Chongqing	32.35	4.5%	1527	412	12,742
Fujian	Fuzhou	6.30	5.8%	517	197	31,328
Gansu	Lanzhou	3.19	3.3%	244	73	22,950
Guangdong	Guangzhou	7.73	5.7%	1040	711	91,912
Guangxi	Nanning	6.84	4.6%	309	107	15,640
Guizhou	Guiyang	3.60	2.7%	448	69	19,280
Hainan	Haikou	1.53	5.4%	664	39	25,741
Hebei	Shijiazhuang	9.55	3.9%	603	236	24,718
Heilongjiang	Harbin	9.87	6.1%	186	244	24,681
Henan	Zhengzhou	7.07	4.1%	950	249	35,173
Hubei	Wuhan	8.28	7.7%	975	314	37,936
Hunan	Changsha	6.37	5.1%	539	219	34,364
Inner Mongolia	Hohhot	2.21	6.5%	128	110	49,861
Jiangsu	Nanjing	6.17	7.2%	938	328	53,206
Jiangxi	Nanchang	4.91	4.7%	664	139	28,289
Jilin	Changchun	7.46	7.0%	363	209	28,006
Liaoning	Shenyang	7.10	9.6%	547	322	45,383
Ningxia	Yinchuan	1.49	7.3%	156	41	27,462
Qinghai	Xining	2.15	6.0%	281	34	15,902
Shaanxi	Xi'an	7.64	7.5%	756	176	23,078
Shandong	Jilin	4.33	5.7%	160	101	23,297
Shanghai	Shanghai	13.79	21.8%	2930	1219	88,398
Shanxi	Taiyuan	3.55	6.6%	510	125	35,320
Sichuan	Chengdu	11.12	4.5%	898	332	29,886
Tianjin	Tianjin	9.59	15.2%	2912	505	52,658
Tibet	Lhasa					
Xinjiang	Urumqi	2.31	8.7%	163	82	35,464
Yunnan	Kunming	5.18	3.1%	246	141	27,140
Zhejiang	Hangzhou	6.72	8.4%	405	410	60,983

Source: China statistical yearbook 2008

Appendix XXVIII: Local government S&T appropriation per GSI (2007)

Province	GSI	Budgetary Expenditure of Local Government	Expenditure for Science Administration	
		(100 million RMB)	(100 million RMB)	(% of total budget)
Anhui	Hefei	167.08	2.27	1.4%
Beijing	Beijing	1649.5	90.74	5.5%
Chongqing	Chongqing	768.39	11.05	1.4%
Fujian	Fuzhou	143.09	2.37	1.7%
Gansu	Lanzhou	83.3	1.36	1.6%
Guangdong	Guangzhou	623.69	21.16	3.4%
Guangxi	Nanning	118	1.71	1.4%
Guizhou	Guiyang	106.43	2.21	2.1%
Hainan	Haikou	43.21	0.51	1.2%
Hebei	Shijiazhuang	163.17	3.16	1.9%
Heilongjiang	Harbin	232.38	6.17	2.7%
Henan	Zhengzhou	240.68	4.12	1.7%
Hubei	Wuhan	307.23	7.21	2.3%
Hunan	Changsha	218.17	7.49	3.4%
Inner Mongolia	Hohhot	100.51	0.72	0.7%
Jiangsu	Nanjing	342.94	6.62	1.9%
Jiangxi	Nanchang	116.86	2.02	1.7%
Jilin	Changchun	181.56	2.2	1.2%
Liaoning	Shenyang	339.68	9.94	2.9%
Ningxia	Yinchuan	48.47	0.49	1.0%
Qinghai	Xining	45.05	0.82	1.8%
Shaanxi	Xi'an	161.25	2.36	1.5%
Shandong	Jinan	179.98	4.05	2.3%
Shanghai	Shanghai	2181.68	105.77	4.8%
Shanxi	Taiyuan	155.8	3.46	2.2%
Sichuan	Chengdu	356.05	6.19	1.7%
Tianjin	Tianjin	674.33	22.34	3.3%
Xinjiang	Urumqi	68.32	0.96	1.4%
Yunnan	Kunming	164.65	2.36	1.4%
Zhejiang	Hangzhou	335.72	12.16	3.6%

China Science and Technology Statistics (http://www.sts.org.cn/sjkl/

Appendix XXIX: Popular industry opinion statistics (2007)

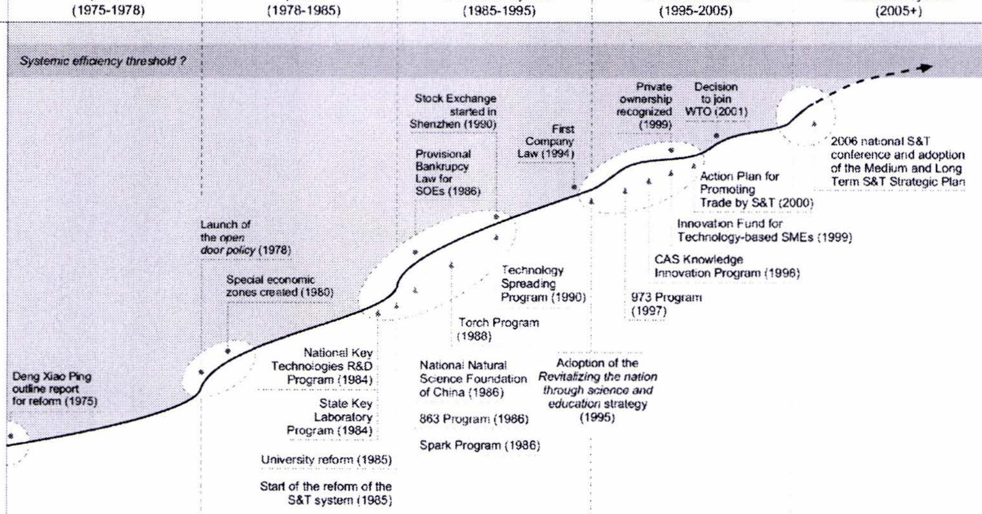
Region	GSI	Land Area of Completed Construction Area	Park,Garden and Green Area	Coverage Rate of Green Area in Completed Construction Area	Population Density	Theaters and Music Halls	Air Quality Level
		(km²)	(10000 hectare)	(%)	(person per sqkm)	(unit)	
Anhui	Hefei	224.74	0.69	33	668	25	III1
Beijing	Beijing	1254.23	5.32	44	963	201	III2
Chongqing	Chongqing	631.35	1.78	24	390	18	III1
Fujian	Fuzhou	266.6	0.59	32	520	129	III1
Gansu	Lanzhou	154	0.19	40	240	7	III1
Guangdong	Guangzhou	779.86	2.61	37	1023	11	III1
Guangxi	Nanning	170	3.35	38	304	10	III1
Guizhou	Guiyang	132	1.97	40	441	5	II
Hainan	Haikou	91.42	0.32	40	767	9	I
Hebei	Shijiazhuang	174.96	0.66	36	593	21	III1
Heilongjiang	Harbin	331.21	0.84	29	185	161	II
Henan	Zhengzhou	282	0.81	35	929	60	II
Hubei	Wuhan	222.3	0.72	38	964	61	III1
Hunan	Changsha	155	0.67	38	534	8	III1
Inner Mongolia	Hohhot	150	0.42	30	125	7	II
Jiangsu	Nanjing	574.94	7.43	46	923	12	III1
Jiangxi	Nanchang	168	0.64	39	654	7	II
Jilin	Changchun	267.38	0.91	42	359	19	II
Liaoning	Shenyang	395.5	1.2	36	542	12	II
Ningxia	Yinchuan	105.66	0.43	30	158	5	II
Qinghai	Xining	86.62	0.2	32	278	5	II
Shaanxi	Xi'an	261.4	0.81	40	745	39	II
Shandong	Jinan	305	0.99	37	738	11	III1
Shanghai	Shanghai	860.21	3.06	37	2158	148	III1
Shanxi	Taiyuan	197	0.68	37	499	16	II
Sichuan	Chengdu	396.94	1.43	38	891	17	II
Tianjin	Tianjin	539.98	1.57	37	805	28	III2
Xinjiang	Urumqi	235.88	0.44	21	185	13	III1
Yunnan	Kunming	232.76	0.66	27	245	8	II
Zhejiang	Hangzhou	327.45	1.13	38	401	35	III1

Appendix XXX: Overview of students enrolled in higher education in China

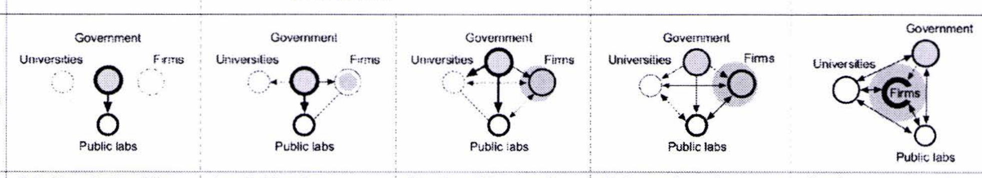
Year	Number of schools for higher education	Number of students enrolled in higher education		Science students	Engineering students
	(unit)	(million)	YOY growth (%)	(million)	(million)
1994	1,080	2.8		0.31	1.12
1995	1,054	2.9	4%	0.31	1.17
1996	1,032	3.0	4%	0.32	1.21
1997	1,020	3.2	5%	0.33	1.26
1998	1,022	3.4	7%	0.22	0.97
1999	1,071	4.1	21%	0.28	1.14
2000	1,041	5.6	35%	0.36	1.38
2001	1,225	7.2	29%	0.48	1.57
2002	1,396	9.0	26%	0.60	1.89
2003	1,552	11.1	23%	0.72	2.16
2004	1,731	13.3	20%	0.85	2.42
2005	1,792	15.6	17%	0.96	2.70
2006	1,867	17.4	11%	1.04	2.96
2007	1,908	18.8	8%	1.10	3.21
2008	2,263	20.2	7%		

Appendix XXXI: China innovation policy change

Innovation policy learning curve



Evolution of the innovation system



	The incubation phase (1975-1978)	The experimentation phase (1978-1985)	Structural reform of the S&T system (1985-1995)	Deepening of the S&T reform (1995-2005)	Toward a firm-centered innovation system (2005+)
Context	End of the cultural revolution. Urgent need for modernisation of the economy.	Launch of the reform of the economic system	The reform of the economic system expands into the S&T sphere	Fast economic growth, pressure from technology-based competition in domestic and international markets	Mounting concerns regarding the sustainability of the current growth trajectory
Type of learning	Learning from self reflection and criticism	Learning by doing bottom-up experimental reforms	Learning by designing and implementing top-down systemic institutional reforms	Accelerated learning from international good practices fostered by WTO membership and obververship in OECD CSTP	Toward endogenous institutional learning and evidence-based policy making, including international benchmarking
Policy focus	Remove conceptual / ideological barriers to S&T development	Address the shortcomings of the soviet model of a S&T system, especially the lack of science-industry links. Initial reform of the university system	Reform public research organisations (PROs),including the university system and the conversion of public labs specialised in applied research into business entities	Enhance firms' innovation capabilities & commercialisation of public research	Complete the shift from a PRO-centered inovation system to a firm-centered one. Better mobilise S&T for achieving sustainable development
Funding instruments	Direct public institutional support	Initial experimental changes of institutional funding, by relaxing the control of funding channels	Reduced public institutional support to applied research in public labs. Launch of the first large public competitive support programmes	Further differenciation of the public support system through the launch of new programmes. Emergence of new publicly sponsored funding channels, e.g. venture capital	Improved mix of instruments to support more efficiently both market-led and mission-oriented S&T development and innovation

Source: OECD, 2008

Appendix XXXII: Regions programmed in the computer model

Region	GSI	2007 region FDI flow	3 year average growth	2007 region FDI stock	3 year average growth	2007 GSI FX utilized	3 year average growth
		(million USD)	(%)	(million USD)	(%)	(million USD)	(%)
Anhui	Hefei	2999	81%	9717	29%	1012	49%
Beijing	Beijing	5066	18%	36187	16%	5066	18%
Chongqing	Chongqing	1085	39%	6199	17%	1220	22%
Fujian	Fuzhou	4061	1%	58665	6%	700	-15%
Gansu	Lanzhou	118	101%	844	8%	128	
Guangdong	Guangzhou	17126	20%	182418	10%	3286	11%
Guangxi	Nanning	684	33%	9450	6%	185	36%
Guizhou	Guiyang	127	29%	909	16%	81	2%
Hainan	Haikou	1120	22%	11726	9%	504	16%
Hebei	Shijiazhuang	2416	14%	17887	16%	327	1%
Heilongjiang	Harbin	2085	19%	11201	23%	372	-2%
Henan	Zhengzhou	3062	52%	12859	24%	1001	62%
Hubei	Wuhan	2766	10%	20073	17%	2250	14%
Hunan	Changsha	3271	32%	17309	23%	1504	46%
Inner Mongolia	Hohhot	2149	53%	6781	59%	603	38%
Jiangsu	Nanjing	21892	22%	135979	18%	1963	-3%
Jiangxi	Nanchang	3104	15%	16170	27%	1231	19%
Jilin	Changchun	885	26%	6504	16%	1688	23%
Liaoning	Shenyang	9097	28%	47380	18%	5045	32%
Ningxia	Yinchuan	50	24%	576	19%	45	-5%
Qinghai	Xining	310	11%	1343	40%	51	433%
Shaanxi	Xi'an	1195	32%	7374	17%	1116	63%
Shandong	Ji'nan	11012	8%	73980	19%	561	7%
Shanghai	Shanghai	7920	7%	72603	13%	7920	7%
Shanxi	Taiyuan	1343	67%	4879	21%	238	96%
Sichuan	Chengdu	1493	29%	8820	19%	1138	109%
Tianjin	Tianjin	5278	29%	33774	17%	5460	27%
Xinjiang	Urumqi	125	48%	762	16%	67	67%
Yunnan	Kunming	395	42%	2620	14%	300	77%
Zhejiang	Hangzhou	10366	16%	55125	25%	2802	26%