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Group Countries by National Competitiveness —Focusing on High-Tech Industry

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以國家競爭力作國家分群之策略分析—專注在高科技產業
Group Countries by National Competitiveness —Focusing on High-Tech Industry

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Group Countries by National Competitiveness —Focusing on High-Tech Industry

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Abstract

It's common knowledge that high-tech industry plays a critical role to the development of global economy. In the national level, the patents statistics are key indicators to demonstrate the nation's capability of development. To identify a nation's global competitiveness, one approach is to find the relationship between patents statistics and multi-infrastructures such as basic infrastructure, technological infrastructure, science infrastructure, health and environment, and education.

This paper presents the insight gained from the use of factor analysis to identify the key components associated with national competitiveness. The six factors were common explanatory variables for both the general regression equation and the principal component analysis. In other hand, for our purposes, the most accurate position of a country can only be determined after the grouping of countries showing similarities to the evaluated country in terms of competitiveness. Based on similarity of characteristics, we now appropriately group/cluster the countries under study.

Since patents are so important to the development of high-tech industry, for Taiwan, how to improve our multi-infrastructures to increase our patents competitiveness is very important. In that way, we can make our country go into the highest competitive countries group. This thesis concludes with some important guidelines for policy formulation at the national level in both developed and developing countries as well as in multinational organizations.

***keywords*：**Competitiveness；High-tech；Index；Patent statistic；Innovation；Principal components analysis；Regression；Cluster analysis

中文摘要

高科技產業在全球經濟發展上所扮演的重要角色是眾所皆知的。在國家的層級上，專利統計數目(Patents statistics)是代表國家發展潛力的重要指標。為了識別國家的競爭力，我們可以研究國家專利數目與其各種內部建設之間的關係，諸如，基礎建設、技術建設、科學建設、健康、環境及教育等，並以此方法達到我們的目標。

本篇論文利用因素分析(Factor analysis)的方法來探討與國家競爭力相關的重要因子。本篇所提到的六項因子無論對於回歸分析方程式(General regression equation)或是主成分分析(Principal components analysis)來說都是尋常的解釋變數。另一方面，為了更準確地定位出各個國家的競爭力，我們必須將所探討之國家先就其競爭力的相似度預做分類。根據這些相似的特色，我們即可將欲研究的國家恰當地群組起來做集群分析(Cluster analysis)。

對於台灣來說，專利對於高科技產業的發展非常重要，因此如何加強我國內部的公共建設及大環境以增進國家競爭力是刻不容緩的。如此，我們才可以帶領台灣進入高競爭力國家的群組當中。對於已開發及未開發國家亦或是國際性聯合組織來說，本篇論文提供了許多關係國家層級政策制定重要的指導方針。

關鍵字：競爭力、高科技、指標、專利統計、創新、主成分分析、回歸、集群分析

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Chapter One
Introduction

1.1. Background

It is common knowledge that the marketplace is no longer restricted to a particular geographic location. A business can no longer expect competition only from neighboring businesses or from businesses within its own region. The marketplace is now global and even the smallest of organizations compete on an international level. Many countries are aware of the implications of the globalization process, and the nature of competition has become a key issue for them. The international competitiveness of a country thus needs to be defined so as to give businesses the opportunities for realizing the global competitive advantages they require in order to survive.

Patents and patent statistics have fascinated economists for a long time. Questions about sources of economic growth, the rate of technological change, the competitive position of different firms and countries, the dynamism of alternative industrial structures and arrangements all tend to revolve around notions of differential inventiveness: What has happened to the “underlying” rate of technical and scientific progress? How has it changed over time and across industries and national boundaries? We have, in fact, almost no-good measures on any of this and are thus reduced to pure speculation or to the use of various, only distantly related, “residual” measures and other proxies. In this desert of data, patent statistics loom up as a mirage of wonderful plentitude and objectivity. They are available; they are by definition related to inventiveness, and they are based on what appears to be standard.

1.2. Purpose of Study

There are many countries in the world. Every country has its own strengths and power, and How to improve it is very popular issue. So at first, I will use principal component analysis to find out the factors. Based on the results, it's possible to group countries by the term of "national competitiveness". Furthermore, that can help to develop so-called "strategic groups".

On the other hand, as we know, High-Tech industry plays an important role in the world economic development. There is an initial relationship between patents and high-tech development. So I want to make an exploration of patents statistics based on multi-infrastructures. After that, it's a way to conjecture national competitiveness by the final model. The final purpose in this paper is that I want to suggest some important guidelines for policy formulation at the national level in both developed and developing countries as well as in multinational organizations. Some countries will be chosen as the subjects for this analysis. Of course, Taiwan must be selected to evaluate the impact of policy suggestions in my home country.

1.3. Statement of problem

Our hypothesis is that the long-term competitiveness of a country can be predicted based on objective attributes, which measure its patent statistics of high-tech industry, defined as followed. The first step is to test whether there is a direct relationship between patent statistics of high-tech industry and macroeconomic competitiveness. If the hypothesis is true, then it will be possible to objectively explain the relative competitive level of a country by using explanatory variables that reveal its relative power. The subjectivity and bias resulting from experts' opinion surveys may then be avoided, or at least lessened. In turn, this would allow for an evaluation of the overall macro competitiveness of countries in the most comprehensive way possible. Such an evaluation would also help provide guidelines and policy recommendations, particularly for developing countries.

1.4. Organization of the Study

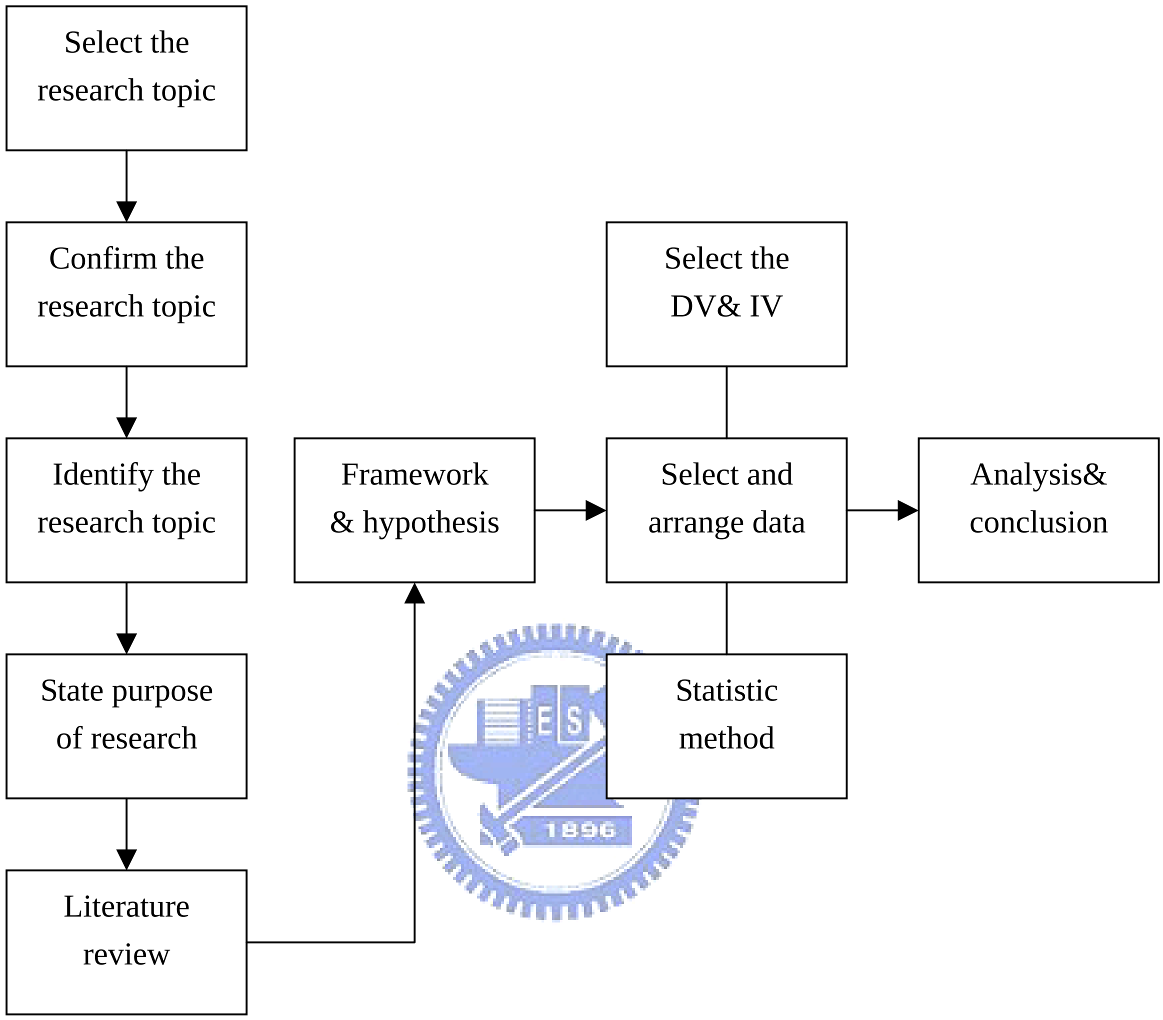

Figure1-1：the flowchart of the research

Chapter Two
Literature Review

2.1. Defining national competitiveness

A generally accepted definition of the term *national competitiveness* has not yet been achieved, thus various defensible definitions exist (Spence and Hazard, 1988). It may be that this lack of consensus is because national competitiveness can mean many different things. For example, a researcher may define national economic superiority by world market share held by the companies of a certain country, by the profitability of those firms, or by more subjective measures (potential for growth or significance of current R&D projects, for example), which may yield different results as to which country holds economic advantage (see, for example, Johnson and Yip, 1994). Similarly, authors of newspaper and magazine articles are able to use the term at will to inspire either hopeful or fatalistic perceptions of a country's economic outlook, depending solely upon the article's orientation.

Although there is variation in the definitions of national competitiveness, most have certain core aspects. These include such concepts as a nation's ability to increase the wealth and welfare of its inhabitants and the ability of its companies to discover and then profit from technologies and products in world markets. Many definitions of national competitiveness are centered on these key ideas. For example, Porter defines a nation's competitiveness as depending upon the "capacity of its industry to innovate and upgrade" (Porter, 1990). Scott and Lodge define it as "a country's ability to create, produce, distribute, and/or service products in international trade while earning rising returns on its resources" (Scott and Lodge, 1985). According to Blaine, "a nation's competitiveness refers to its ability to produce and distribute goods and services that can compete in international markets, and which simultaneously increase the real incomes and living standards of its citizens" (Blaine, 1993). The Institute of Management Development's 1996 World Competitiveness Yearbook states that competitiveness is the ability of a country to create added value, and, thus, increase national wealth by managing assets and processes, attractiveness and aggressiveness, global breadth and proximity, and integrating these relationships into an economic and social model.

Two important points should be taken from these definitions of national competitiveness. First, there are two different units of analysis that are proposed: the nation-state, as in the definitions of Scott and Lodge (1985), Blaine (1993), and the Institute of Management Development; and industry, as in Porter's (1990) definition. The importance of this difference lies in its implications for addressing issues of national competitiveness. In particular, in developing competitiveness, should countries place emphasis on particular industries and the firms within them, or concentrate on improving the general industrial climate of the nation? Second, the key concept in the national competitiveness definitions presented here seems to be the ability of the firms within a nation to increase their productivity, which leads to the accrual of economic benefits by the residents of the nation.

2.2. Competitive measures

A nation's competitiveness, quoted widely by many authors, has been defined by the US President's Commission on Industrial Competitiveness (1985) as "the degree to which a nation can, under free and fair market conditions, produce goods and services that meet the test of International markets while simultaneously expanding the real incomes of its citizens", thus improving their quality of life. Although many view competitiveness as a synonym for productivity (Porter, 1990), these two related terms are in fact quite different, in that, "productivity refers to the internal capability of an organization, while competitiveness refers to the relative position of an organization against its competitors" (Cho and Moon, 1998). Country risk, namely the evaluation of the creditworthiness and the economic performance of a country, is regularly assessed in two magazines, Euromoney and Institutional Investor. Country risk may be viewed as a component rather than substitute of competitiveness (as is innovation); both country risk and innovation are input variables in our study. In particular because of recent pressures introduced by globalization, it is important to have a model for analysis of a country' s competitive position in the international market, and not simply its internal measure of productivity. A nation's competitiveness can be viewed as a nation's relative competitive position in the international market among other nations of similar economic development (Cho and Moon, 1998).

Although many researchers have studied the subject of competitiveness and suggested relevant measures, most of the studies focus on the. Firm level (Karnani, 1982; Oral, 1985, 1993; Oral and Chabchoub, 1996; Oral et al., 1999; Li and Deng, 1999). Table 1 summarizes the measures proposed in these studies, which are primarily within a firm or an industry, and mostly within a single country. Fewer studies have attempted to compare the relative competitiveness of countries for a specific industry, as shown in Table 1.

In fact, the motivation for my study is best summarized by Menzler-Hokkanen (1989) in his concluding remarks: “The level of international competitiveness of an industrial sector or a given firm depends on several forces on the micro and macro level. Only the collective consideration of these variables will lead to an understanding of the dynamics underlying international competitiveness.

Table2-1 Literature review of competitiveness

Author	Measure	Scope of Measure	Goal
Enoch（1978）	Unit labor cost	Typical concept	Define a country's manufacturing competitiveness
Karnani (1982)	Developed the concept of equilibrium market share	Conceptual, within a firm	To determine the firm's growth potential and competitive strength
Oral（1985,1993） Oral, Chabchoub（1996） Oral, Ozkan（1996）	Describe a measure of foreign-market competitiveness of local manufacturing firms.	Within an industry and a country. Based on the study of Turkish manufacturing firms	Industrial competitiveness model, analyzes the degree of competitive advantage on the basis of industrial mastery and cost superiority
Peterson and Barras（1987）	Relative competitive advantage index measuring the importance of service exports to total exports of a country	Across industries and a country	Competitiveness index for tradable products and services
Artto（1987）	Total competitiveness indicators, based on relative total cost (RTC), drawn from the financial statements of the firms and including all the traditional competitiveness dimensions (cost, price, and non-price factors) relating total cost to net sales	Total competitiveness indicators for the Finnish paper industry in relation to that of four other countries	Compare the Finnish paper industry competitiveness to the Swedish, West German, Canadian, and US paper industries
Menzler-Hokkanen（1989）	Redefines ULC as the sum of all labor costs (including wages, salaries, social costs and other employment taxes) divided by the volume of output produced by that labor	Extended ULC concept	Extend definition of country's manufacturing competitiveness, and point out the shortcomings of both ULC and RTC

Table2-1（continued）

Yamin et al.（1997）	Hypotheses and factors affecting competitive strategy, organizational innovation and performance	Within an industry and a country. Based on Australian manufacturing companies	Based on surveys of industry managers, but stops short of aggregating this information into a single index
Velocci（1998）	Index calculated via discriminant analysis of key operating and financial ratios, including asset utilization, productivity, financial stability, earnings protection, liquidity, and market valuation, weighted based on surveys of executives from those industries	Within an industry and a country. Based on publicly traded airlines and aerospace enterprises	Calculate an index of competitiveness rankings for an industry
Li and Deng（1999）	Developed a model to identify and relate the determinant factors of competitive advantage (DFCA) and competitive strategic goals (CSGs)	Within a firm and a country. Based on a study of an electronic plant in China	Develop a comprehensive analysis model of competitive advantage (AMCA) to help managers understand the firm's competitive position that of their competitors', the firm's strategic goals, and the relationship between the firm's DFCA and CSGs
Kao and Liu（1999）	Two primary indicators: automation technology and manufacturing management. Index is based on a linear programming fuzzy weighted average approach, containing four secondary indicators that describe technology, and eighteen that describe management	Within an industry and a country. Rank the competitiveness of 15 machinery firms in Taiwan	Calculate the relative competitiveness of industries within a country

2.3. Patents as information

The consideration of patent statistics as the indicators of technological innovation has evolved dramatically since Schmookler's work in 1966. Among them, Pavitt, Baseberg, Griliches, Archibugi, OECD, and Archibugi and Pianta have developed the comprehensive views on patent indicators. One of the most useful measures of the pace of inventive activity is the number of patents granted to a specific firm over a given time period, say one year. The widespread use of patent statistics stems from the fact that long-available patent data are derived from an objective and slow-changing standard. Under present law, the term of a US patent is 20 years from the filing date of the patent application, or if reference is made to an earlier application, from the filing date of that earlier application. A wide body of economic research documents the strong relationship between patent numbers and R&D expenditures, and implies that patents are a good indicator of differences in inventive activity across firms (Griliches, 1990).

In the early-1990s, Kortum (1993) noted that the patent-R&D ratio in the United States had declined steadily for over thirty years. At that time, some suggested that an exhaustion of technological opportunities had reduced the productivity of corporate R&D. Others argued that expanding world markets had raised the value of patents, and that growing competition in the research sector had resulted in greater R&D expenditures per patent. Like Griliches (1990), Kortum (1993) simply found that rising costs of dealing with the patent system had led researchers to patent fewer of their inventions. While industry data once supported the inference of a decline in the corporate propensity to patent, more recent data suggest the opposite. During the 1990s, there was an unprecedented surge in corporate patenting in the United States. Using both international and domestic data on patent applications and awards, Kortum and Lerner (1999) show that the recent jump in corporate patenting reflects an increase in innovation spurred by improvements in the strategic management of corporate R&D expenditures.

The use of patent statistics in economic research has been impeded by the fact that patents vary in their economic importance or value. Hence, simple patent counts are less than fully informative about the economic value of innovative output. Trajtenberg (1990) addressed this problem by examining the usefulness of patent indicators in the context of a particular innovation, Computed Tomography scanners, one of the most important advances in medical technology of recent times. As in prior studies, Trajtenberg (1990) found that simple patent counts are highly correlated with contemporaneous research and development expenditures. Interestingly, Trajtenberg (1990) also found a close association.

2.4. High-tech industry in Taiwan

If innovation stands for the process that could realize ideas into profits, Taiwan performs better as realizing ideas of technology development into industry development than pervading innovations derived from the science research into ideas of the technology development. This phenomenon could be observed from two indexes, namely, the science linkage index analyzed from Taiwan’s overall patents granted in the U.S. and the innovation index surveyed by the World Economic Forum (WEF) in 2003. The science linkage index of Taiwan is relatively low to those of other industrialized countries, but the innovation index of Taiwan ranks No.2 in the world. Chief factors of such consequences could be concluded in some mechanism problems for interactions of science research and technology development.

In Taiwan, science research is mainly conducted by universities, which perform well in paper publishing and talent cultivation, but induce little impact on the technology development. On the contrary, non-profit research institutes of industrial technology as well as enterprises do technology research mainly focused on manufacturing process improvement. However, the science research results are hardly applied to the technology development. Therefore, it results in the weak linkage of science research and technology development. To tighten the linkage, there are many measures taken by Taiwan’s government to facilitate the development from technology to industry so as to better innovation performance of industry.

Around 1970, Taiwan’s economic development was based on labor-intensive light industries. Textiles, Plastics and Appliances soared and played key roles in the world’s markets. Taiwan’s balance of trade turned from a deficit to a surplus.

During that time, Taiwan’s economic development was fiercely affected by the oil crisis because local industrial development had the strong dependency with oil supply. In order to transform structure of local industry from labor-intense to technology-intense, which was highly decisive to human brains and less correlated to natural resources, Taiwan's government decided to set up the first industrial technology research institute, ITRI, in 1973. Missions of ITRI are assigned to develop industrial technologies and transfer them to industry, which is composed mainly of small and medium sized enterprises.

ITRI transferred high technologies from abroad to Taiwan, which were suitable to develop locally, and continued to add value. Combining talent and capital investment, new company spin-offs from ITRI blossomed into new industries. For instance, United Manufacturing Company was spun off from ITRI in 1980. UMC became the 2nd largest IC foundry in the world in terms of production. Taiwan Semiconductor Manufacturing Company was spun off from ITRI in 1986. TSMC also became the largest IC foundry company in the world in terms of production as well. Following the spin-offs, IC foundry, IC packaging, IC design etc., completely new industries, developed one after another. The number of companies for each industry is illustrated in Table2 in 2002. Meanwhile, Personal Computers, Optoelectronics, Telecom and so on all followed the same development path. Many of Taiwan's products were Number 1 in world market share in 2003 as demonstrated in Table 3.

Table2-2 Number of companies for IC industry in Taiwan in 2002

	Design	Mask	Foundry	Package	Test	Chemicals	Lead frame
Number of companies	180 （+40）	4	15 （-1）	45 （-3）	36 （-1）	19 （-1）	4

Source: Project of Industrial Technology Intelligence Services (ITIS), DOIT, MOEA, 2003, (+/-): increasing/decreasing number of companies in comparison with those of 2001.

Table 2-3 World No. 1 products in terms of market shares of Taiwan in 2003

IC		
	Market shares/Production	World Penetration
Foundry	US$8,349M	65.80%
Mask ROM	US$271M	89.70%
IC Packaging	US$2,650M	27.90%
Computer & Peripheral Devices		
CD-R Disk	5923.8M Pcs	64%
CD-RW Disk	228.23M Pcs	84%
DVD-R Disk	517.9M Pcs	75%
DVD-RW Disk	73.02M Pcs	62%
Networking Products		
ADSL Modem	14M Sets	59%
Wireless LAN	39.4M Sets	78%
Analog Modem	9,018K Sets	25%
SOHO Router	6,491K Sets	35%
Other		
ABS Resin	1530K M.T.	24.30%

Source: ITIS, DOIT, MOEA, 2004

In step with ITRI's growth, Taiwan has become a premier world-manufacturing center over the last 30 years. Taiwan was the 4th largest information technology (IT) hardware production country in the world in 2003, which was after the U.S., China and Japan. Furthermore, Taiwan's companies made up 72.9% of China's IT production. Taiwan was also the 4th largest semi-conductor production country in the world in 2003, which was after the U.S., Japan and South Korea. In addition, Taiwan was the 2nd largest thin film transistor - liquid crystal display (TFT-LCD) production country in the world in 2003, which was after South Korea and outpaced Japan. The market penetration of the above three industries is shown in Table 4.

Table 2-4 Market penetration of Taiwan's high-tech in 2003

	IT hardware production	Semi-conductor production	TFT-LCD production
Rank1st	US (28.2%)	US (51%)	S.Korea (46.3%)
Rank2nd	China (22.2%)	Japan (25.6%)	Taiwan (34.5%)
Rank3rd	Japan (10.1%)	S.Korea (8%)	Japan (19.2%)
Rank4th	Taiwan (5.4%)	Taiwan (7.8%)	

Source: ITIS, DOIT, MOEA, 2004

Chapter Three
Research Design & Method

This chapter presents the research design and methodology. The first section presents the definitions and measurement indices of variables, and the research structure. The discussion the research design includes brief descriptions of the sources of data, and the items used for measuring the variables in the hypothesis. Next, it's my hypothesis of this thesis. Finally, I introduce what statistic measure I take.

3.1. Data of Research

By adapting International Institute for Management Development（IMD）–World Competitiveness：Infrastructure Criteria 2002/2003, there are 49 countries of the world chosen. According to 20 items of basic infrastructure, 20 items of technological infrastructure, 19 items of science infrastructure；16 items of health and environment, 14 items of education, totally 89 items are selected as independent variables. In other hand, because of knowledge economics, we defined patent statistics of high-tech industry（material patents+ semi-conductor patents）as dependent variable. The figure 3-1 is a flowchart of research structure. The list of these attributes, as well as there measurement units are given in Table 3-1.

The reason we chose IMD as the database of the research is that IMD was established in January 1990, as the successor to two previously independent business schools; IMI, founded in Geneva by Alcan in 1946, and IMEDE, founded in Lausanne in 1957 by Nestlé's Incorporated under the name "International Institute for Management Development," IMD, as the institution is known around the world, is a leading provider of Executive Education for large and medium size international businesses, and for individuals. IMD today delivers the best in "real world" learning to build global organizations and individual careers. In the other hand, IMD is one of the world leading business schools with over 50 years' experience in developing the leadership capabilities of international business executives at every stage of their careers. The majority of their program participants come from medium to large corporations and all have an international orientation to the businesses. Many companies, who begin by sending their managers to IMD programs, go on to develop their relationship with the institute to a closer level and become part of the IMD Learning Network, which provides still further learning advantages

3.2. Research Framework

In this research, I design my research framework for two parts. One is factor analysis and cluster, and the other is regression.

1. The first step is to use principal components analysis to find out the important factors. Then, based on the results, we can group the countries by so-called national competitiveness. In that way, we can identify the tactical groups and understand the position of the world
2. The second step is to use regression technique. Because we know that there is a direct relationship between patent statistics of high-tech industry and macroeconomic competitiveness. If the model has explanatory power, the long-term competitiveness of a country can be conjectured based on objective attributes, which measure its patent statistics of high-tech industry, defined as followed.
3. Then it will be possible to objectively explain the relative competitive level of a country by using explanatory variables that reveal its relative power. The subjectivity and bias resulting from experts' opinion surveys may then be avoided, or at least lessened. In turn, this would allow for an evaluation of the overall

macro competitiveness of countries in the most comprehensive way possible. Such an evaluation would also help provide guidelines and policy recommendations, particularly for developing countries.

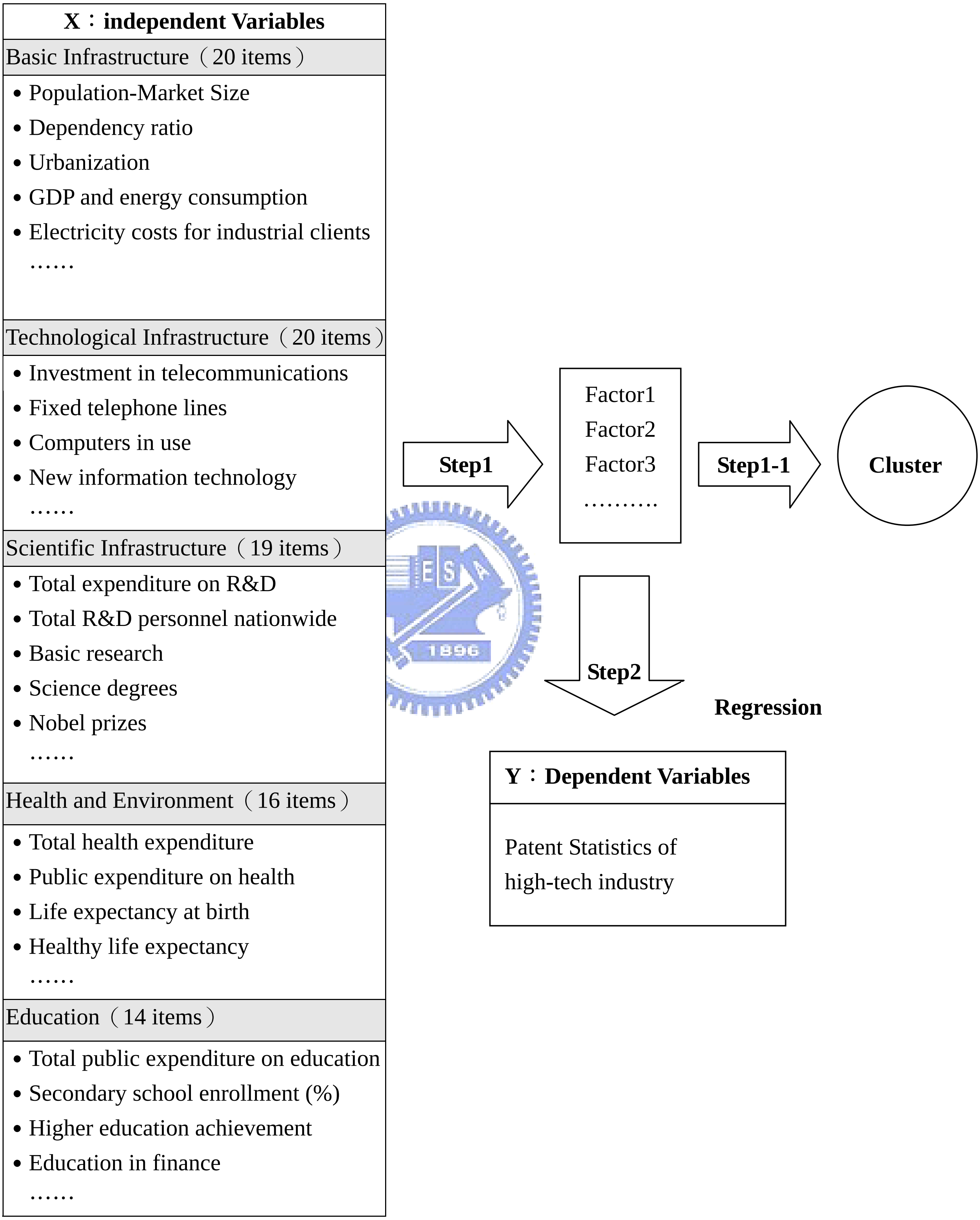

Figure3-1 Research Framework

Table3-1 Attributes to evaluate the patent statistics of high-tech industry

	Unit of measurement		Unit of measurement
I. Demographic Structure		V. Economic	
Land area	1000km2	GDP	Million dollars
Urbanization	%	GDP per capita	Dollar
Population - market size	Millions		
Population under 15 years	%	VI. Technology	
Population over 65 years	%	Investment in telecommunications	%
Dependency ratio		New information technology	
		Computers in use	%
II. Education		Computers per capita	Number
Total public expenditure on education	%	Internet costs	US
Secondary school enrollment (%)	%	Suitable internet access	
Higher education achievement	%	Information technology skills	
Illiteracy	%	Total expenditure on R&D	US$ millions
Economic literacy	%	Business expenditure on R&D	US$ millions
Education in finance	%	Total R&D personnel in business enterprise	FTE 1,000s
Qualified engineers	%	Science degrees	%
Knowledge transfer	%	Scientific articles	Number
		Interest in science and technology	
III. Health		Patent and copyright protection	
Life expectancy at birth	Year	Number of patents in force	Number
Total health expenditure	%	Patent productivity	Ration
Medical assistance	Per physician	Numbers of TFT LCD Patent	
IV. Environment		VII. Policy	
Distribution infrastructure		Technological cooperation	
Roads	Km per square km	Development and application for technology	
Railroads	Km per square km	Funding for technological development	
Water transportation			
Energy consumption per inhabitant			

Table3-1 (continued)

	Unit of measurement		Unit of measurement
Energy infrastructure			
Total indigenous energy production	%		
Total final energy consumption per capita	Millions		
Electricity costs for industrial clients	US$ per kwh		
Carbon dioxide emissions	Tons		
Quality of life			

3.3. Principle Components Analysis

Principle Components Analysis is commonly used in micro array research as a cluster analysis tool. It is designed to capture the variance in a dataset in terms of *principle components*. In effect, one is trying to reduce the dimensionality of the data to summarize the most important (i.e. defining) parts whilst simultaneously filtering out noise. Normalization, however, can sometimes remove this noise and make the data less variate, which could affect the ability of PCA to capture data structure. What are Principle Components？That is a set of variables that define a projection that encapsulates the maximum amount of variation in a dataset and is orthogonal (and therefore uncorrelated) to the previous principle component of the same dataset.

The multivariate statistical method of Principle Component Analysis is a very useful tool for reducing the number of variables in a data set and for obtaining useful two-dimensional views of a multi-dimensional data set. As explained above, the data matrix consisting of fifteen elements can be considered to exist in fifteen-dimensional space (since this would be the number of dimensions required to simultaneously plot all of the variables against one another). For a data set with multivariate normal distribution, when the data points are all plotted they will form a "cloud" of points which may have an oval to circular cross-section in any particular direction. A three-dimensional version can be pictured as a (flattened-) football-shaped cloud of data points.

A Principal Component Analysis of the data set will determine the perpendicular axes (called *eigenvectors*), which are defined by the dimensions of the data set. There will be the same number of axes as variables/dimensions; the longest axis is the First Principle Component (PC1), the next major axis is the Second Principle Component (PC2), etc. In the example of a three-dimensional football shape, PC1 is the axis running through the football tip to tip, and PC2 and PC3 are two equal perpendicular axes through the equator of the football. If the football is deflated and flattened a bit, then PC2 and PC3 are no longer equal; PC2 is by definition the longer of the two.

The nature of the Principle Components does not change if the data set is not multivariate normal, or consists of several subgroups of data. PC1 will still be the longest possible axis running through the data points, PC2 will be the longest possible axis perpendicular to PC1, and so forth.

The advantage of defining these Principle Component axes is that the axes can now be used to define planar sections through the data set. If one makes a slice through the cloud of data points using the plane defined by PC1 and PC2 and projects all of the data points onto this plane, then it becomes a two-dimensional representation of the data retaining the maximum variation (and hopefully information) contained in the multivariate data set. In many cases, this is the best two-dimensional representation of the multi-dimensional system. Similarly, if the multi-dimensional data contain multiple separate clusters of points, the plane of PC1 and PC2 will often provide a view of the maximum two-dimensional separation between them. Depending upon the distribution of the data set and the intended goal of the analysis, this will often be the best two-dimensional representation of a set of multi-dimensional data clusters.

Furthermore, each variable in the analyzed data set can be assessed concerning its contribution to the overall distribution of the data set. This is done by correlating the direction of maximum spread of each variable with the direction of each Principle Component axis (eigenvector). If one particular variable has a much larger range of values than others (for example, if it is responsible for stretching out a 3-D sphere of data points into an elongate football-shape), then the direction of maximum spread for this variable will strongly correspond to PC1. A high correlation between PC1 and a variable indicates that the variable is associated with the direction of the maximum amount of variation in the data set. More than one variable may correspond highly with PC1; more than one variable may be having a strong influence on the distribution of the data. Similarly, if the whole data set contains two data clusters and a single variable corresponds highly with PC1, then that variable may be responsible for the separation and unique definition of the two data groups. A strong correlation between a variable and PC2 indicates that the variable is responsible for the next largest variation in the data perpendicular to PC1, and so on.

Conversely, if a variable does not correspond to any PC axis, or corresponds only with high-number PC axes, this usually suggests that the variable has little or no control on the distribution of the data set. Therefore, Principle Component Analysis may often indicate which variables in a data set are important and which ones may be of little consequence. Some of these low-performance variables might therefore be "weeded out" and removed from consideration in order to simplify the overall analyses. For PCA, the calculations of eigenvectors can be made using either the covariance matrix or the correlation matrix of the data set. The latter is commonly used when different variables in the data set are measured in different units, or if different variables have strongly different variances. Using the correlation matrix recalculates all of the variables so that their variances are equal. This can be a significant concern with agrochemical data, since some elements typically have a much broader range of concentrations than others in the samples.

3.4. Cluster analysis

The cluster definition problem is NP-complete. As a result, an optimum does not exist. A number of heuristic methods are built for this purpose including agglomerative techniques, which are the mostly widely known and used for such procedures. All hierarchical agglomerative heuristics begin with n clusters where n is the number of observations. Then, the two most similar clusters are combined to form n-1 clusters. In the next iteration, n-2 clusters are formed with the same logic; this process continues until one cluster remains. Only the rules used to merge clusters differ across hierarchical agglomerative heuristics. The "simple linkage" approach merges the clusters by finding the minimum distance between one observation in one cluster and another observation in the second cluster. "Furthest neighborhood", in contrast, takes the farthest distance between two observations, while ''average linkage'' takes the average distance of the observations belonging to each cluster and merges them with a minimum average distance between all pairs of observations in the respective clusters. In Ward's method, on the other hand, the distance is the ANOVA sum of squares between the two clusters summed over all variables. Although all hierarchical methods successfully define clusters for compact and isolated data, they generally fail to accurately provide defined clusters for "messy" data. The major issue with all clustering techniques is how to select the number of clusters. Different clustering methods may lead to different clusters, where the differences are generally due to the inherent characteristics of the methodology employed. In fact, there is no single methodology that can be recommended in selecting the most appropriate number of clusters. Cluster analysis is thus generally accepted to be more of an art than a science.

3.5. Regression

Regression models are used to predict one variable from one or more other variables. Regression models provide the scientist with a powerful tool, allowing predictions about past, present, or future events to be made with information about past or present events. The scientist employs these models either because it is less expensive in terms of time and/or money to collect the information to make the predictions than to collect the information about the event itself, or, more likely, because the event to be predicted will occur in some future time. Before describing the details of the modeling process, however, some examples of the use of regression models will be presented.

In order to construct a regression model, both the information, which is going to be used to make the prediction and the information, which is to be predicted, must be obtained from a sample of objects or individuals. The relationship between the two pieces of information is then modeled with a linear transformation. Then in the future, only the first information is necessary, and the regression model is used to transform this information into the predicted. In other words, it is necessary to have information on both variables before the model can be constructed. X_i is the variable used to predict, and is sometimes called the independent variable. Y_i is the observed value of the predicted variable, and is sometimes called the dependent variable.

The goal in the regression procedure is to create a model where the predicted and observed values of the variable to be predicted are as similar as possible. The more similar these two values, the better the model. The next section presents a method of measuring the similarity of the predicted and observed values of the predicted variable. A classic statistical problem is to try to determine the relationship between two random variables X and Y. For example, we might consider height and weight of a sample of adults. Linear regression attempts to explain this relationship with a straight line fit to the data. The linear regression model postulates that $Y= a+bX+e$, where the "residual" e is a random variable with mean zero.

Regression models are powerful tools for predicting a score based on some other score. They involve a linear transformation of the predictor variable into the predicted variable. The parameters of the linear transformation are selected such that the least squares criterion is met, resulting in an "optimal" model. The model can then be used in the future to predict either exact scores, called point estimates, or intervals of scores, called interval estimates.

Chapter Four
Results and Data Analysis

The chapter is organized as following. First, the descriptive results of data are presented. Next, the discussion of the principal components analysis results is accessed. Finally, there is the result of grouping of countries based on PCA values, and the extensive analysis is performed to assess the hypothesized relationship.

4.1. Descriptive analysis

Table 4-1 Descriptive analyses of 89 items

Independent variables 89 items			
Basic infrastructure (20 items)			
Item		Average	Standard Deviation
01	Population-market size	89	230.414248
02	Population under 15 years	22.036735	6.174647
03	Population over 65 years	11.410204	4.52431
04	Dependency ratio	50.54	6.67384
05	Maintenance and development	5.306122	1.830526
06	Roads	1.069949	1.125654
07	Railroads	4.09E	3.92E
08	Air transportation	31834.66327	91029.89225
09	Quality of air transportation	6.71	1.35
10	Distribution infrastructure	6.371367	1.685214
11	Water transportation	6.434796	1.773853
12	Arable area	3490.53	4329.48
13	Urbanization	5.76051	1.454978
14	Energy intensity	15463.23469	14105.52441
15	Energy infrastructure	6.68	1.8
16	GDP and energy consumption	1.77402	3.770919
17	Total indigenous energy production	92.590612	130.166394
18	Energy imports vs. merchandise exports	9.00597	7.827716

19	Self-sufficiency in non-energy raw material	22.94	253.01
20	Electricity costs for industrial clients	5.63E	2.35E
Technological Infrastructure (20 items)			
21	Invest in telecommunications (in GDP)	0.69	0.38
22	Fixed telephone lines	430.387755	220.492777
23	International fixed telephone costs	1.021245	0.731324
24	Mobile telephone subscribers	538.522449	289.046284
25	Mobile telephone costs	0.63	0.44
26	Adequacy of communication	7.265612	1.29763
27	New information technology	7.334633	1.133692
28	Computer in use	1.87	4.47
29	Computers per capita	319.020408	226.404072
30	Internet users	293.607449	189.154709
31	Secure servers	56.3	62.67
32	Internet costs	34.28	12.51
33	Suitable internet access	7.673408	1.277398
34	Information technology skills	7.233449	1.084463
35	Technological cooperation	5.621643	1.198767
36	Development and application of technology	6.527531	1.050331
37	Funding for technological development	5.087653	1.566084
38	High-tech exports	27919.52	68375.66
39	High-tech exports ratio	20.75	14.65
40	Data security	6.053816	1.413467
Scientific Infrastructure (19 items)			
41	Total expenditure on R&D	13627.81	43752.07
42	Total expenditure on R&D (in GDP)	1.41	0.95
43	Business expenditure on R&D	9798.83	32860.54
44	Business expenditure on R&D per capita	187.86	227.74
45	Total R&D personnel nationwide	126.7	236.04
46	Total R&D personnel nationwide per capita	3.41	2.6
47	Total R&D personnel in business enterprise	71.65	144.65
48	Total R&D personnel in business per capita	1.83	1.69
49	Science degrees	39.49	15.99
50	Science articles	11400.06	25846.34
51	Science in schools	5.148276	1.282037
52	Interest in science and technology	5.3	1.08

53	Nobel prizes	7.561224	29.855689
54	Nobel prizes per capita	0.156092	0.304209
55	Patents granted to residents	7126.79591	22170.8288
56	Change in patents granted to residents	10235.08	22839.81
57	Securing patents abroad	6.396735	1.682929
58	Patent and copyright protection	451.81	1040.63
59	Patent productivity	53.15	79.1
Health and Environment			
60	Total health expenditure	6.903673	2.51114
61	Public expenditure on health	65.305102	17.503688
62	Life expectancy at birth	74.65	5.726197
63	Healthy life expectancy	64.22	11.32
64	Medical assistance	677.255102	1045.48403
65	Health infrastructure	5.537	2.145214
66	Urban population	72.204082	17.975332
67	Human population	0.86	8.56E
68	Alcohol and drug abuse	6.564898	1.275329
69	Paper and cardboard recycling rate	39.02	23.34
70	Waste water treatment plants	53.42	30.18
71	Carbon dioxide emissions	987.455102	930.164355
72	Ecological footprint	5.04	2.58
73	Sustain development	6.429367	1.160947
74	Pollution problems	5.949898	1.647751
75	Environmental laws	6.045204	0.859575
Education			
76	Total public expenditure on education (%)	5.19	1.71
77	Pupil-teacher ratio (primary education)	19.67	7.2
78	Pupil-teacher ratio (secondary education)	15.93	5.96
79	Secondary school enrollment (%)	81.84	15.15
80	Higher education achievement (%)	25.04	12.39
81	Educational assessment (mathematics)	493.48	17.97
82	Educational assessment (sciences)	494.31	38.33
83	Educational system	5.26	1.52
84	University education	5.8	1.33
85	Illiteracy (%)	4.79	7.09
86	Economic literacy	5.31	1.51

87	Education in finance	6.18	1.24
88	Qualified engineers	7.03	1.24
89	Knowledge transfer	4.84	1.26

4.2. Discussion of the principal components analysis results

Principal components analysis was conducted to investigate which of the Table 1 attributes were significant in explaining membership of a country within the groups specified by our cluster analysis. Based on this analysis, it was also possible to find those countries that did not fit perfectly into their groups, and to specify the most appropriate group for such countries. All the attributes given in Table 1 were taken as potential explanatory variables, and the principal components analysis was conducted to identify the most efficient explanatory variable set. Analysis revealed that 69% of the countries had been classified appropriately. The principal components analysis was also used in a Discriminant analysis wherein the potential explanatory variables were found to be the same as those given in Table 4-1. As a result, eleven principal components were found statistically significant.

How many factors should be retained for analysis? There is no clear answer but a couple of rules of thumb：

1) One rule is to consider only those with Eigenvalues over 1.

2) Another rule of thumb is to plot all the Eigenvalues in their decreasing order. The plot looks like the side of a mountain, and "Scree" refers to the debris fallen from a mountain and lying at its base.

We take the “Scree Plot” as reference, given in Figure4-1. A Scree Plot is a simple line segment plot that shows the fraction of total variance in the data as explained or represented by each PC. The PCs are ordered, and by definition are therefore assigned a number label, by decreasing order of contribution to total variance. The PC with the largest fraction contribution is labeled with the label name from the preferences file. Such a plot when read left-to-right across the abscissa can often show a clear separation in fraction of total variance where the 'most important' components cease and the “least important” components begin. The point of separation is often called the “elbow”. In the PCA literature, the plot is called a “Scree” Plot because it often looks like a “Scree”slope, where rocks have fallen down and accumulated on the side of a mountain.

1. The first component included Adequacy of communication、New information technology、Development and application of technology、Water transportation、Urbanization、Maintenance and development、Distribution infrastructure、Data security、Quality of air transportation、Suitable internet access、Funding for technological development、Sustainable development、Technological cooperation、Patent and copyright protection、Health infrastructure、Energy infrastructure、Pollution problems、Economic literacy、Computers per capita、Internet users、Knowledge transfer、Education in finance、Fixed telephone lines、Alcohol and drug abuse、Environmental laws、Information technology skills、Business expenditure on R&D per capita (US$)、Ecological footprint (hectares)、Total expenditure on R&D (%)、Total R&D personnel nationwide per capita (FTE)、Total public expenditure on education (%)、Total R&D personnel in business per capita (FTE)、International fixed telephone costs. The item「Technology application」is used to stand for them.

2. The second component included ：Population under 15 years (percentage of total population %)、Population over 65 years (percentage of total population %)、Pupil-teacher ratio (primary education)(ratio)、Pupil-teacher ratio (secondary education)(ratio)、Secondary school enrollment (%)、Public expenditure on health (%)、Illiteracy (%)、Mobile telephone subscribers、Dependency ratio、Life expectancy at birth (age)、Waste water treatment plants (%). The item 「Basic power」is used to stand for them.

3. The third components included：Air transportation、Computers in use、Scientific articles (number)、Nobel prizes (number)、Total expenditure on R&D (US$ millions)、Patent productivity (number)、Total indigenous energy production (%)、High-tech exports (US$ millions). The item 「Academic achievement」 is used to stand for them.

4. The fourth components included：Qualified engineers、University education、Interest in science and technology、Educational system、Science in schools. The item 「Higher education investment」 is used to stand for them.

5. The fifth component included：Total R&D personnel nationwide (FTE (1,000s))、Total R&D personnel in business enterprise (FTE (1,000s))、Science degrees (%)、Population-Market Size (estimate in millions). The item 「Human Resource Potential」 is used to stand for them.

6. The sixth component included：Electricity costs for industrial clients、Energy intensity、Carbon dioxide emissions (tons)、GDP and energy consumption. The item 「Energy supply」 is used to stand for them.

Table 4-2 Rotated Component Matrix

	1	2	3	4	5	6
Adequacy of communication	.923	.097	.106	.078	-.129	.100
New information technology	.906	.026	.100	.170	-.129	.059
Development and application of technology	.894	.082	.119	.243	-.102	.072
Water transportation	.893	.251	.019	-.062	.045	.013
Urbanization	.883	.278	.048	.083	.131	.001
Maintenance and development	.879	.180	.057	.048	.154	.077
Distribution infrastructure	.879	.194	.099	.031	.090	.041
Data security	.879	.206	.033	.059	-.170	.003
Quality of air transportation	.875	-.064	.040	-.075	-.005	.094
Suitable internet access	.864	-.015	.073	.018	-.118	.121
Funding for technological development	.863	.200	.209	.178	-.016	.066
Sustainable development	.849	.072	-.109	.075	.088	-.020
Technological cooperation	.835	.174	.173	.299	-.024	.011
Patent and copyright protection	.834	.363	.156	.098	-.082	-.047
Health infrastructure	.802	.282	.025	.162	.081	.194
Energy infrastructure	.792	.307	-.013	.050	-.071	-.028
Pollution problems	.788	.295	-.076	.085	-.055	-.026
Economic literacy	.763	.215	-.054	.361	-.006	.220
Computers per capita	.747	.410	.196	.053	-.035	.115
Internet users	.733	.450	.141	-.040	-.051	.146
Knowledge transfer	.720	-.044	.168	.502	-.079	.087
Education in finance	.645	-.027	-.079	.566	-.269	.082
Fixed telephone lines	.641	.608	.162	-.022	-.052	.190
Alcohol and drug abuse	.600	.115	-.160	.154	.116	.557
Environmental laws	.599	.066	-.066	.357	.276	.155
Information technology skills	.593	-.089	.108	.476	-.133	.007
Business expenditure on R&D per capita (US$)	.567	.283	.362	.072	.172	.166
Ecological footprint (hectares)	.559	.383	.269	.051	-.026	-.064
Total expenditure on R&D (%)	.555	.321	.221	.150	.236	.076
Total R&D personnel nationwide	.532	.524	.107	.194	.237	-.053

per capita (FTE)						
Total public expenditure on education (%)	.525	.239	.102	.215	-.399	-.152
Total R&D personnel in business per capita (FTE)	.501	.418	.170	.239	.249	.020
International fixed telephone costs	-.454	-.385	-.077	-.122	.300	-.019
Population under 15 years (percentage of total population %)	-.242	-.907	-.055	.108	-.183	-.020
Population over 65 years (percentage of total population %)	.224	.862	.071	-.034	.029	.027
Pupil-teacher ratio (primary education)(ratio)	-.165	-.816	-.033	-.070	.127	.013
Pupil-teacher ratio (secondary education)(ratio)	-.080	-.773	.005	-.282	-.051	-.054
Secondary school enrollment (%)	.396	.733	.077	.070	.107	-.015
Public expenditure on health (%)	.188	.687	-.168	.045	-.187	-.129
Illiteracy (%)	-.206	-.654	-.085	.109	.127	-.049
Mobile telephone subscribers	.513	.634	-.070	-.007	-.176	.284
Dependency ratio	-.169	-.606	-.010	.181	-.341	.003
Life expectancy at birth (age)	.405	.587	.061	.050	.008	.470
Waste water treatment plants (%)	.323	.441	.107	-.128	-.111	-.204
Air transportation	.097	.002	.980	.031	.033	.014
Computers in use	.093	.023	.977	-.023	.143	.026
Scientific articles (number)	.113	.084	.958	.007	.119	-.010
Nobel prizes (number)	.123	.022	.958	.022	-.060	-.070
Total expenditure on R&D (US$ millions)	.103	.060	.934	-.011	.179	.118
Patent productivity (number)	.111	.072	.808	-.103	-.008	.062
Total indigenous energy production (%)	-.114	-.137	.511	.057	.241	-.244
High-tech exports (US$ millions)	.251	.011	.452	-.241	.332	-.051
Qualified engineers	.170	-.113	-.043	.768	-.055	.262
University education	.524	-.033	.038	.720	-.193	-.164
Interest in science and technology	.350	.109	-.096	.691	.160	-.077
Educational system	.595	.191	-.055	.649	-.055	-.147
Science in schools	.527	.219	-.052	.594	.165	-.222
Total R&D personnel nationwide	-.177	.081	.389	-.030	.836	-.153

(FTE (1,000s))						
Total R&D personnel in business enterprise (FTE (1,000s))	-.139	.126	.411	-.048	.812	-.150
Science degrees (%)	.251	-.037	-.018	-.045	.722	.120
Population-Market Size (estimate in millions)	-.206	-.317	.184	.067	.490	-.157
Electricity costs for industrial clients	-.045	.002	.008	.046	.129	.706
Energy intensity	-.425	-.114	-.070	.123	.343	-.684
Carbon dioxide emissions (tons)	-.404	-.149	-.062	.092	.307	-.670
GDP and energy consumption	-.029	.097	-.015	-.018	.158	-.546
Healthy life expectancy (age)	.034	.231	.035	.044	.036	-.011
Human development index (index)	.289	.353	.069	-.044	-.028	.158
Nobel prizes per capita (per million)	.369	.186	.262	-.100	-.103	-.070
Energy imports vs. merchandise exports	-.154	-.108	.111	.020	-.052	.102
Medical assistance (per physician)	-.149	-.421	-.053	-.224	.039	-.034
Urban population (%)	.391	.120	.022	.007	.019	.291
High-tech exports (%)	.346	-.148	.108	.059	.080	.074
Paper and cardboard recycling rate (%)	.356	.308	.104	-.070	-.028	.065
Total health expenditure (%)	.240	.409	.375	.040	-.183	.046
Investment in telecommunications	-.027	-.051	-.045	-.148	-.036	-.231
Arable area	.036	.075	.088	.167	-.063	-.238
Self-sufficiency in non-energy raw material	.125	.011	-.080	-.050	-.045	-.027
Change in patents granted to residents (%)	-.183	.082	-.004	-.105	-.060	.026

The name of the variances：

- Factor1：Technology application
- Factor2：Basic power
- Factor3：Academic achievement
- Factor4：Higher education investment
- Factor5：Human Resource Potential
- Factor6：Energy supply

Table 4-3 Variance Explained

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	29.175	37.404	37.404	22.098	28.331	28.331
2	7.641	9.796	47.200	9.144	11.723	40.054
3	6.297	8.074	55.273	7.112	9.119	49.172
4	4.133	5.299	60.573	4.337	5.561	54.733
5	3.657	4.689	65.262	3.868	4.959	59.692
6	2.704	3.466	68.728	3.301	4.232	63.924
7	2.180	2.795	71.523	2.739	3.512	67.436
8	1.975	2.532	74.054	2.569	3.294	70.730
9	1.795	2.301	76.356	2.105	2.698	73.428
10	1.653	2.119	78.475	1.972	2.528	75.956
11	1.400	1.794	80.269	1.886	2.418	78.373
12	1.272	1.631	81.900	1.667	2.137	80.510
13	1.164	1.492	83.392	1.521	1.951	82.461
14	1.096	1.405	84.797	1.497	1.920	84.380
15	1.005	1.289	86.086	1.331	1.706	86.086

A Scree plot shows the sorted Eigenvalues, from large to small, as a function of the Eigenvalues index.

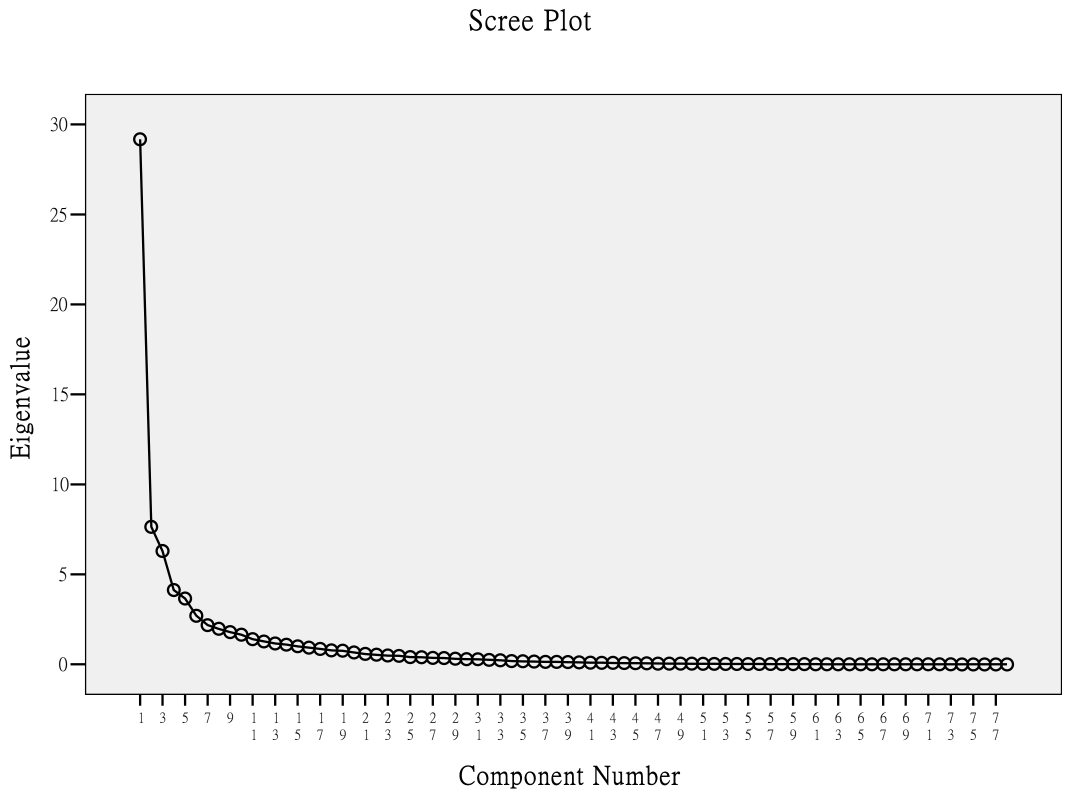

Figure4-1 Scree plot

4.3. Grouping of countries based on PCA values

Although the analysis given in 4.2 sections shows satisfactory results, a key drawback of a study based solely on ranking is that the ordinal scale does not reflect the appropriate competitiveness level of a country (entity) relative to other countries (entities). For our purposes, the most accurate position of a country can only be determined after the grouping of countries showing similarities to the evaluated country in terms of competitiveness. Thus, based on similarity of characteristics, we now appropriately group/cluster the countries under study. Cluster analysis, which is, in fact, a multivariate statistical technique, is used for this purpose. It involves grouping similar objects into mutually exclusive subsets or clusters.

The Cubic Clustering Criterion (CCC) is used to estimate the number of clusters based on minimizing the within cluster sum of R squares. It is obtained by comparing the observed R-squared to the approximate expected R-squared using an approximate variance stabilizing transformation. Positive values of the CCC mean that the obtained R-squared is greater than would be expected if sampling from a uniform distribution and therefore indicate the possible presence of clusters. Treating the CCC in this way provides a crude test of hypothesis in estimating the number of population clusters. Given the CCC value in the table4-4.

Table4-4 Cubic Clustering Criterion

	Cluster2	Cluster3	Cluster4	Cluster5
F Statistic	1.001	2.512	7.808	6.2055
C.C.C. value	17.68	19.23	25.26	23.52

Table4-5 Cluster Analysis

	F1：Technology Application	F2：Basic Power	F3：Academic Achievement
Cluster1	0.529702971	0.492110339	0.317437537
Cluster2	0.497815866	0.335712171	0.152288352
Cluster3	0.644876369	0.566154381	0.146564576
Cluster4	1.222976527	0.650920194	0.479439557
	F4：Higher Education Investment	F5：Human Resource Potential	F6：Energy Supply
Cluster1	1.062812601	0.565804385	0.824779078
Cluster2	0.809233924	0.272264055	0.686886772
Cluster3	0.994548076	0.530131084	1.031185096
Cluster4	1.227304929	0.707363437	2.108517555

Nevertheless, they were among the Explanatory variables of the general regression model and had an important impact on the ranking of countries within their groups. Evaluation of the four groups noted earlier based on the six significant variables can be seen in Table 5. As noted earlier, Groups 4 and 1 consist of competitive countries.

Table4-6 Countries in the cluster

Cluster4	Cluster1	Cluster3	Cluster2
China	Australia	Argentina	Belgium
Germany	Austria	Brazil	Czech Republic
Japan	Canada	Chile	Greece
Russia	Denmark	Colombia	Hungary
United Kingdom	Estonia	India	Ireland
USA	Finland	Indonesia	Italy
	France	Mexico	Poland
	Hong Kong	Philippines	Portugal
	Iceland	South Africa	Slovak Republic
	Israel	Thailand	Slovenia
	Korea	Turkey	
	Luxembourg	Venezuela	
	Malaysia		
	Netherlands		
	New Zealand		
	Norway		
	Norway		
	Sweden		
	Switzerland		
	Taiwan		

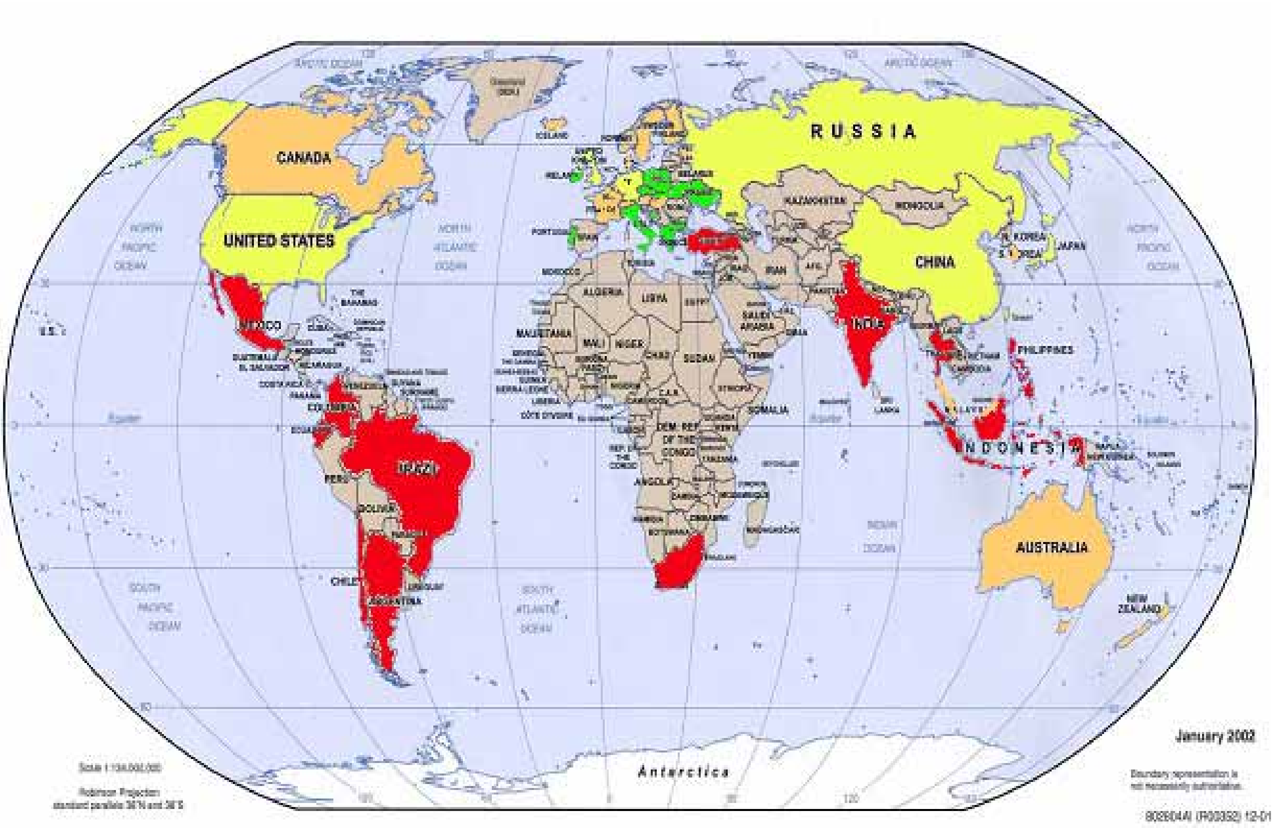

Figure4-2 graphical remark

4.4. Regression results

As previously noted, the general regression equation has an explanatory power. But, it's not strong because there are too many factors that will affect the result. As it can be seen in Fig. 1, its predictive abilities for high values of patents statistics are less than that for lower values. The adjusted R2 of the final model is 0.125, and the value of F is 3.766. The Patents statistics are estimated by the following equation：

- $Y= A+b_1X_1+b_2X_2+b_3X_3\ldots+b_6X_6+E$
  Y=Patents statistics ， X1= Technology application, X2=Basic power, X3=Academic achievement, X4=Higher education investment, X5=Human Resource Potential, X6=Energy supply

Table 4-7：Regression result

Model	R	R Square	Adjusted R Square	F	Sig.
1	.412(a)	.170	.125	3.766	.004(a)

Chapter Five
Implications for national policy setting

To the extent that PCA indicates a country's competitiveness in global markets, results of the methodology presented can be used by policy planners/makers to help in realizing higher economic competitiveness levels. Policy implications of our results will likely vary from country to country at any point in time. Clearly, strategies for countries with a high score will differ from those with low score values. For example, military expenditures may have a positive effect on high score countries and have the very opposite effect on those with a low score. Such expenditures can create value as the result of exports and Technology development, while in the latter; they are more likely an unproductive drain on limited resource.

It's noted that Taiwan's industry is superior to product adjustment and process improvement. It thus results that Taiwan's economy falls into the "incremental innovation-based economy". In order to transform such an economy into "radical innovation-based economy" so as to get new momentum to push for economic growth, Taiwan's 2003 Science and Technology Meeting of the Executive Yuan concluded that implementation of "innovation-based economy" was a very desirable next step for Taiwan to take. Following this policy, the industry technology R&D would evolve from a system based on "incremental innovation" to the one based on "radical innovation". Since patents are so important to the development of high-tech industry, how to improve our multi-infrastructures to increase our patents competitiveness is very important. In that way, we can make our country go into the highest competitive countries group, like Japan and US.

However, in a bid to promote the development of "innovation-based economy" demands a comprehensive system. Major innovation activities in Taiwan's manufacturing industry (electronics or non-electronics) fell within categories such as products, technology and manufacturing processes. Innovations in organization, management and marketing recorded only a small portion as observed in Table5-1 and Table 5-2.

Table 5-1 Categories of innovations for manufacturing industry of Taiwan in 2003

Manufacturing Industry	Products	Technology	Manufacturing Process	Organizational Management	Marketing
Electronics	49%	33%	15%	0%	3%
Non-electronics	34%	30%	17%	9%	10%

Source: Conference materials of 2003 Science and Technology Meeting of the Executive Yuan, R.O.C, investigated by Industrial Economics and Knowledge Center (IEK), ITRI

Table 5-2 Categories of Innovations for Service Industry of Taiwan in 2003

	Contents of Services	Procedures of Service Providing	Organizational Management	Marketing	Customization
Service Industry	33%	22%	15%	16%	13%

Source: Conference materials of 2003 Science and Technology Meeting of the Executive Yuan, R.O.C, investigated by IEK, ITRI.

Although Taiwan now enjoys high economic power and as a member of Group 2 in terms of its score, we can find that Taiwan has high potential to improve itself to group1. On the other hand, we also found that Taiwan has competitiveness problems. The most important part for us is to face our challenge and improve it!

To develop an innovation-based economy, the first step is to adjust the institutions and operational mechanisms of existing industrial technology R&D system, consisting of universities, industrial technology research institutes, industry and the government.

5.1. Industry

It's important to note that the process of innovation starting with an idea for a new technology, product and service may originate in a variety of areas including R&D, manufacturing, marketing, sales and in organizational infrastructure and management.

The process will be complete only when there is beneficial use by customers. This implies that in general an innovation will be delivered by industry. It's very important for government to provide policy incentives to strengthen innovation capabilities of industry, especially those that could gear up the innovation capabilities powered by industrial technology R&D. Policy measures in reinforcing innovation capabilities of industrial technology R&D include:

1. Enhancing industrial R&D organizations and functions：

   In order to intensify the R&D activities for industry, Taiwan's government entices local and overseas enterprises to establish innovative industrial technology R&D centers in Taiwan so as to enhance industrial R&D organizations and functions. 66 innovative industrial technology R&D centers have been set up by local enterprises since 2002. The multinational companies establish 22 innovative industrial technology R&D centers, as shown in Table 22.

2. Strengthening innovative industrial technology R&D：

   The overall budget allocation for innovation industrial technology R&D of industry have soared up for 5 years. The more innovative R&D companies do, the more subsides could obtain from the government.

3. Reinforcing networking between industry and universities：

   Taiwan’s government encourages enterprises to form industrial technology R&D alliances. 45 alliances have been made up since 2001.

4. Fostering development of industrial technology R&D support and peripheral industries：

   A good development of industrial technology R&D support and peripheral industries would accelerate the time to market for developed technologies. 66 cases are promoted including product design, IP management, incubator, digital content market place, silicon IP mall and design platform, and contract research organization and so on.

5.2. Universities

With the accumulation of R&D resources, universities should play the role of promotion in the development of the innovation-based economy. Universities should endeavor to increase not only paper publications but also innovative and frontier patenting. R&D activities should take into consideration both economic and technological development. Universities should establish their professional specialties with different R&D orientations. Deregulation and institutional reform should be continued in order to reduce restrictions on the mobility, remuneration, appraisal, and promotion of related personnel.

5.3. Industrial technology research institutes

Industrial technology research institutes would be catalysts that transform Taiwan's economy into the one based on "innovation-based economy". It's therefore government should increase the percentage of innovative industrial technology R&D budget. Other than the development of technologies, innovative industrial technology R&D should also cover the development of services. Furthermore, government should increase implementing institutes for innovative industrial technology R&D projects.

It's also very crucial for industrial technology research institutes to integrate industrial technology R&D across different categories among industry, universities and research institutes. To network with the worldwide innovation fountain, it is also very important to encourage industrial technology research institutes to commence global communication of technology and technical cooperation with overseas organizations.

Most importantly, industrial technology research institutes should enforce themselves in organizational reinvention to stimulate originality and creativity in the organizations.

5.4. The government

The government maneuvers the process of "institutional reform" and "deregulation" for the industrial technology R&D system. It's recommended that government convene a meeting for cooperation between industry and universities for the Ministry of Economic Affairs, Ministry of Education, and National Science Council to discuss related regulatory reform and institutional change.

Chapter Six
Conclusions

6.1. Limitation

Although we can use the equation to conjecture the other countries, yet there are too many factors that will affect the result. So the equation does not have such a high explanatory power. The results of this paper can be used by policy planners/makers to help in realizing higher economic competitiveness levels. But the biggest problem of the data collecting is that some is not complete or some is hard to get.

6.2. Future

Taiwan's government has been started reorganizing the industrial technology R&D system to promote an innovation-based economy by improving innovation networking. The government has focused on deregulation and institutional reform in order to provide a foundational environment to establish corresponding cultures for innovative R&D. A culture for innovative industrial technology research was established gradually inside the industrial technology R&D system. Outcomes of the system with those adjustments are promising. This reshuffling process has likely set an example for the rest of government agencies that would like to promote the "innovation-based economy".

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