

## International Comparative Analysis of the Innovation Evaluation System - Focused on the Evaluation of the COSTII of Korea

Hye-Jung Joo<sup>1\*</sup>, Yong-Hee Kim<sup>1</sup>, Herin Ahn<sup>1</sup>, Seahong Oh<sup>2</sup>

---

### Abstract

The objective of this study is to compare European, Northern European and Korean innovation evaluation systems, to examine the related discussions, and to make realistic contributions to improve COSTII in Korea. For this purpose, the following will be examined – the developmental process of science technology innovation indicators, the process of associating with the policy, problems in the process, development and limitations of the composite indicator of score-boarding and benchmarking, the difference of science technology innovation indicator of each stage of innovation. Moreover, three innovation evaluation systems are compared to study the background and objective of each system, the conceptual background, classification of items and composition of detailed indicators, and the method of presenting the main characteristics, analysis and results.

All three indices were promoted in order to evaluate the innovation performance, understand the strengths and weaknesses, and deduce the political implications. They all attempted to overcome existing statistical limitations through the effort to reflect new trends on the concept of the innovation system, and the mutual learning process. Nevertheless, the result, composition of the index system and method of presenting implications varied in accordance with each objective, promotional background, and the stage of innovation development.

The intention is to propose that the COSTII of Korea should create more an elaborate and unique system, which stresses distinctive characteristics as a newcomer rather than rushing to simply introduce innovation indicators from advanced countries through these discussions. Further studies are anticipated on the association with new innovation concepts and response to common methodological problems.

**Keywords:** composite indicator; S&T competitiveness evaluation; innovation capacity

---

### 1. Introduction

It has been constantly identified that science technology and innovation is an important factor in the economic growth, national development and

promotion of welfare within the fierce international competition of the knowledge based society (Lindholm, Stevenson, 2007; Norden, 2009; Tijssen & Hollanders, 2006). Nevertheless, policy makers and researchers demand tangible bases on the kind of required effort

---

<sup>1</sup>S&T Analysis and Information Division. Korea Institute of Science & Technology Evaluation and Planning (KISTEP), Seoul, 137-130, Korea

<sup>2</sup>HRST Policy Division. Korea Institute of Science & Technology Evaluation and Planning (KISTEP), Seoul, 137-130, Korea

\*Corresponding author. E-mail: [hjoo@kistep.re.kr](mailto:hjoo@kistep.re.kr)

to identify their positions and to develop into a better level. The science technology statistics provide essential background information that would be used in making decisions and designing appropriate policies to ensure accountability and transparency (Tijssen & Hollanders, 2006:3). As a response, various reports have been published and have been intended to measure national competitiveness, innovation, and innovation performance. In particular, the studies have been accumulated on the science technology and innovation indicators to enhance the application of results. Although the competitiveness and evaluation of the international comparison of IMD and WEF is getting a lot of attention, the disputes still exist about the reliability of international performance comparison and utilization in establishing policies in Korea. The criticism is related to the ways data and methodologies are used in comparisons (Loikkanen et al., 2009: 1178).

In this study, we will look at how each country diagnoses its position through the framework and compare the tangible index system and ranking, and conceptual background. Until now, the focus was on studying examples of the international index system itself to introduce the index system of the advanced country. However, through a systematic examination on how related discussions had been developed and what part of the issue became problematic, it will be possible to recognize the difference between the composition of tangible indicator and the result of analysis. This is not a simple summary of existing studies but it is to provide answers to the following questions to proceed into future analytic studies. The questions are: why does each country put much effort in developing science and innovation indicators and benchmarking? What is the influence of accepting the evaluation systems or indicators uncritically on us? And what is the point that we need to concentrate on in order to create our own evaluation indicators?

Therefore, we focused on the Nordic Innovation Monitor, which is made by top ranked countries in several competitiveness reports that is relatively new, and the European Innovation Scoreboard, which was the model in many evaluation indicators to induce more diverse discussions.

If there is no single standard in evaluation indicators and nothing is perfect, the systematic overview into the characteristics and emphasis on each analytical system is a more feasible plan. Moreover, diversity of disputes proposed in the process of policy application and the development of science and technology innovation indicators will provide an insight to using these results. In particular, the case studies on the index systems of advanced countries cannot be simply applied into the Korean system because this could neglect the context. This study is an evaluation of the Composition Science and Technology Innovation Index (referred as COSTII hereinafter) that has been developed by Korea and tested for the last 5 years from a new perspective to identify differentiated characteristics and provide the plans to complement its limitations.

## 2. Relevant Studies

### 2.1. *Foregoing studies in Korea*

Let's briefly check studies carried out by scholars in Korea before making a literature-based analysis. In Korea as in other countries, interest in science and technology related indicators have steadily increased in connection with the need for establishment of proper science and technology policies. Many have made surveys, including the Ministry of Education, Science and Technology, concerning traditional science and technology related indicators for collection of substantial data. Surveys concerning corporate innovation have also been added to the effort recently. Also, there has been a gradual increase in the collection of individual indicators concerning science and technology related patents, intellectual properties, scientific publications, and technology trading, etc. Such indicators have come to be used as a crucial basis for evaluating overall competitiveness or technological level of a country as well as to establish individual science and technology policies or appraise individual projects. However, it is judged that the development of the indicators related to innovation processes and performance, or operation of indicators that correspond to policy issues have a long way to go and they are

not sufficient for result analysis on the national level, although indicator statistics concerning R&D input and resources are maintained and managed systematically (Yun-cheol Yim et al., 2004:24-25).

Next, scholars have carried out Empirical studies based on concrete indicators. Their patterns are as follows: first, it is to reveal the influential factors on competitiveness or technological innovation by focusing on some of the existing indicators or devised indicators, for example, by carrying out correlation analysis between national competitiveness and research competitiveness with the focus on the number of SCI (Science Citation Index) publications (Hee-Yun Yoon, 2007), or by shedding light on the impact of the local industrial structure and the network of cooperation on technological innovation of the local business (Gyeong-A Kim, 2008). Second, it is to make research on foregoing studies about indicators and provide implications or measures to make direct improvement on statistical surveys or competitiveness studies for developing new index system. For example, through the analysis on characteristics concerning the several ranks of world-famous universities with a view to developing competitiveness indicators related to higher education (Hyeon-Seok Shin, et al., 2008); the analysis on the feasibility of changes in existing statistical surveys (Seong-Pyo Cho et al., 2009); the development of models that can diagnose the capability of research institutions (Man-Hyung Cho and I-Su Kim, 2010) and the development of systems and indices related to commercialization of state-owned technologies (Seong-Ho Choi and Hye-Seon Moon, 2006).

Existing empirical analyses and studies appear to focus only on specific aspects of competitiveness or innovation that are relatively easy to measure such as input and performance indicators. Statistical or methodological studies also appear to stress the need for introduction and adoption of overseas cases in specific sectors. The development of internationally comparable science and technology related indicators is a difficult task for which international studies also failed to provide clear solutions. It is true that studies have been carried out with the concentration on how to apply overseas case studies with relatively little attention paid to the development of indices that can

measure the level of Korea's inherent science and technology, and innovation capability at the current stage. Then, how should we comprehensively adopt overseas studies carried out so far? What is a way of measuring and diagnosing the country's inherent science and technology, and innovation capability?

## *2.2. Development of science and technology innovation indicators*

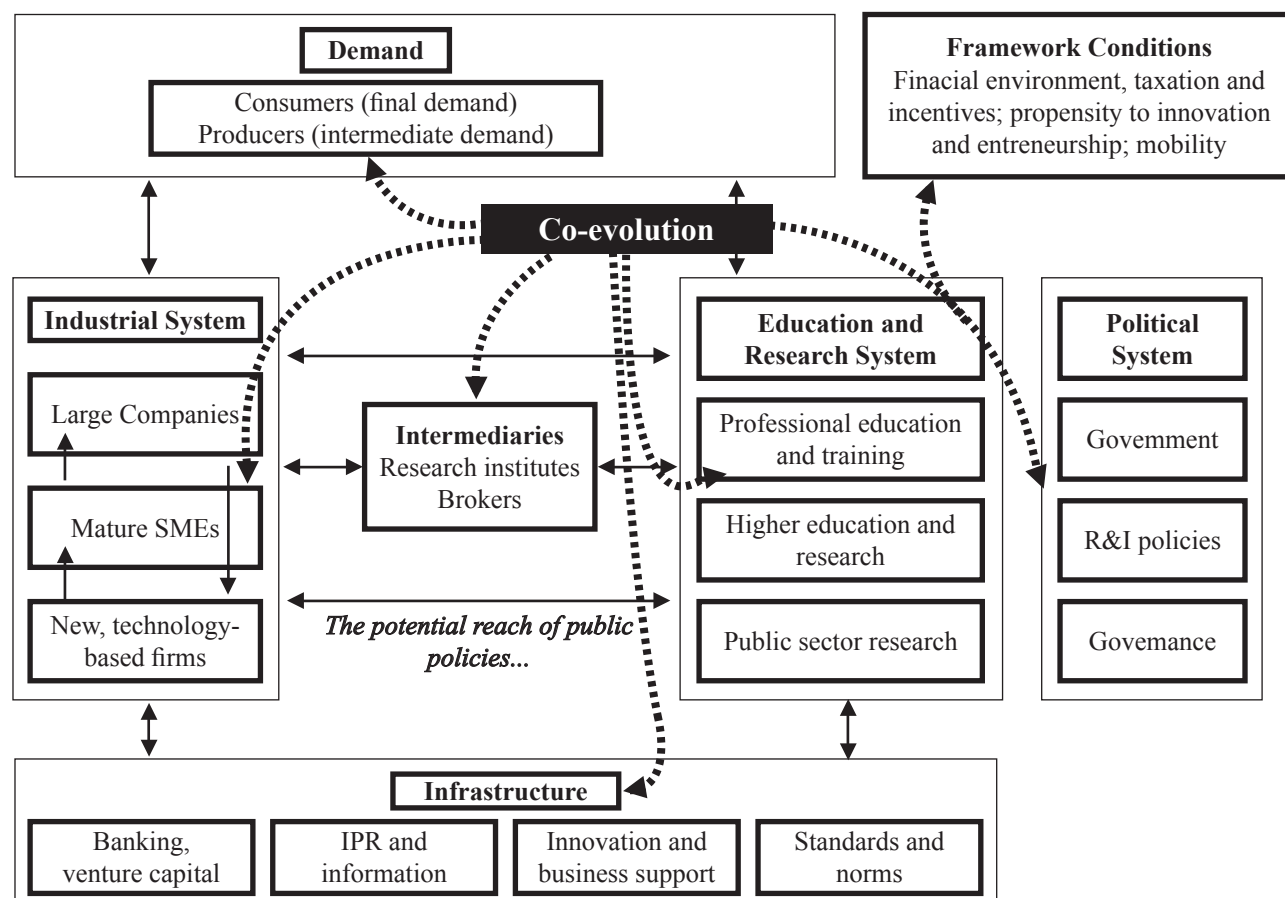
In order to check the level of science and technology of a country, it is necessary to select comparable indicators that can represent the country's science and technology and set up a framework with which to make systematic comparisons. However, it is not easy to find and define representative performance indicators as their effects appear only after a certain period of time unlike the economic achievements. Although a successful indicator should be clear without an excessive simplification process, each indicator has its own strengths and weaknesses, and inevitably reflects only a part of very complicated social and economic phenomenon. After all, the indicators should be selected differently, depending on what the questions or problems are, and should consider the context surrounding them. (Tijssen & Hollanders, 2006:3, Grupp & Mogege, 2004). However, Individual science and technology indicators are usually not expressed in monetary terms, but rather are measured in units like patent counts, innovation counts, or number of paper citations and may not be comparable to each other. As a well-defined correspondence between relevant S&T data is lacking, the multidimensional profiles cannot be easily aggregated into an overall scalar figure (Grupp & Schubert, 2010:69). Thus, in many studies, input-related R&D expenditure, which is relatively clear as a traditional indicator, and data analysis concerning output-related patent and publication data have been used widely (Lavoie, 2007). Among indicators used in science and technology, representative input-related indicators are: GOVERD as a percentage of GDP, private investment, and R&D intensity. Representative performance-related indicators are: the number of patents, papers and citation frequency. Especially, thanks to the use of the Frascati Manual, OECD

countries have come to use a relatively common framework for collection of R&D related indicators and relevant statistics. However, discussions on science and technology, and R&D, based on the linear model started recognizing their limitations and included the perspective of innovations, expanding their area to non R&D sectors, management ability, such as entrepreneurship, process improvement, interaction, state-owned resources and institutional characteristics (Grupp&Mogee, 2004). More so than others, the EU and the OECD started using Science, Technology and Innovation (STI) as a unit. In the third revised edition of its Oslo Manual, the OECD defines innovation as a “new or importantly improved product (goods or services) or a process, a new marketing skill, a new way of organizing a business practice, or a new way

of operating a workplace organization or external relations” (OECD & Eurostat 2005: Oslo manual, 3rd edition).

The innovation policies, which first started getting attention in the mid-1990s, began with science and technology policies (OECD, 2006). If the first generation of innovation policies focused on provision of support for science-based research carried out mostly by universities and government-run research institutes stressing science push or a linear model, its second-generation policies adopted a demand-led perspective based on the interaction between users and producers of innovation; named the National Innovation System (NIS). Its third generation policies stressed strong linkage with entrepreneurship as an important component of the NIS, pursuing horizontality

### The heuristic of national innovation systems



Source: Frietsch (2006)

**Figure 1** The heuristic model of national innovation systems

and coordination and integration between innovation and other sectors (Lindholm, Stevenson, 2007:2-3).

Under such background, researchers started recognizing innovation as a process influenced by diverse factors, such as science, research, finance, regulation and policies, while paying attention to each country's inherent characteristics. Accordingly, the scope to be covered by science and technology related innovation indicators has gone beyond simple R&D, and expanded to human resources and education policies (policies related to education, training, life-long learning, immigration policies, etc), process innovation in key industry players, such as SMEs, infrastructural venture capital and framework conditions comprised by political systems. Such indicators with a new perspective connote innovation and innovation capability that is not quantifiable or cannot be measured directly, and has to be used to measure potential variables (Frietsch, 2006). Innovation indicators are often indirect, because the underlying phenomenon of interest, innovation, is intangible or not directly observable (Grupp & Schubert, 2010:68). Thus, the measurement of science, technology and innovation has become a much more difficult subject.

### *2.3. Linkage between science and technology related indicators and policies*

The reason for the growing emphasis on the influence and importance of science and technology indicators is an increase in the demand for their use concerning policies. Customers of science and technology indicators have become diversified and expanded to the EU nations, support organizations and researchers. Such customers came to need indicators to evaluate their positions, define their strategic policy-making processes, and support their interest. That is to say, indicators became part of political debates and struggle for power and thus an arena of brisk criticisms and debates<sup>1)</sup> (Lepori, et al., 2008:36).

Under such circumstances, attempts have been made

to apply benchmarking or score-boarding, which were frequently used in strategic decisions of microscopic businesses or single projects. Benchmarking is important in a political context. A policymaker needs to know each country's status quo, along with its detailed merits and demerits. They exist only as relative concepts. A country judged to be good in a scoreboard, functions as the best practice case, with its successful R&D policy recognized. (Schibany & Streicher, 2008:717). However, the judgment has a clear problem, as it lacks a definite theoretical model that enables the selection of indicators and the decision on weighted value, and the usefulness of the data is too limited to deal with differences between countries. The use of scoreboards or benchmarks may be dangerous, because the numbers are taken for granted with little discussion of their validity, as Pavitt (1988) pointed out, Considerable room exists for manipulation by selection, weighting and aggregating indicators (Grupp & Mogege, 2004; Grupp & Schubert, 2010:69). Concerning interpretation, analysis and use of indicators, it is a noteworthy fact that there has been conflict as a result of statistics producers, such as state-run statistical institutions, which attaches importance to the accuracy and reliability of statistics related to an agenda item, while policy makers, who are the users of statistics, who put stress on usefulness, substantiality and comparability. (Graversen & Siune, 2008:4).

Gault (2007) pointed out that the issue now is the making of this information more policy relevant: 1) indicators should be able to tell what can be obtained through Science, Technology and Innovation (STI) activities in connection with the currently high interest in official accountability; 2) More impact indicators should be produced and they should be integrated with the activities-linkage-outcomes index system; 3) The power of integration of information to be obtained from a considerable power of analysis and diverse resources is required to make a proper index system; 4) It is possible to try an international comparison by

---

1) The problem of economy crisis and resources evoked the problem on the responsibility on the efficiency of R&D expanded by the support in the public sector; it became the background for introducing performance evaluation systems from many countries. Ultimately, the discussions on 'selection and concentration' was introduced in R&D investment which also gave rise to introduction to the interest groups which tries gain R&D and national government and ministries that tries to promote the performance of their own country.



applying the same technique to the analysis of other countries' microscopic data, as the ability to compute microscopic as well as macroscopic data has improved and 5) Science of Science Policy should be pursued through the development of database, models and visualization technique based on the improvement of the ability to compute large-scale data (Gault, 2007: 276-277).

#### *2.4. Development of composite indicators and limitations*

The “eye-catching property” of simple index numbers may force public awareness by providing such a big picture, which may not be mastered by a large number of single indicators, difficult to understand for a layman.

Thus, composite indicators are tried by many organizations and countries, despite the criticism about their inability to reflect diverse aspects (Grupp & Schubert, 2010:69). After all, current sophisticated applications of S&T indicators involve a mixing and matching of indicators. The constituent statistics and sub-indicators are restructured and aggregated into indexes and composite indicators (Tijssen & Hollanders, 2006:2).

Composite indicators have the following merits: 1) They can check policy trends at a national/international level, draw attention to specific issues, and support for decision-making; 2) They are easier to interpret than to be identified among many individual indicators; 3) They help make it easy to rank countries for benchmarking in a complicated issue; 4) They make it possible to evaluate the degree of a country's progress made with the elapse of time; 5) They make it possible to decrease the number of indicators or include more information with the limited number of the present; 6) It is possible to locate the issue concerning a country's performance or progress at the center of a policy debate and 7) They make it possible to communicate with the general public easily and enhance accountability (Frietsch & Karlsruhe,

2006). However, it is by no means easy to integrate individual indicators into significant composite indices, and a theoretical framework is required for the selection of factors and decision on weighted value, but the theoretical basis for most of the composite indices have yet to be developed (OECD, 2003). Over the past few years, efforts were made by organizations, such as the EU, to arrive at a common procedure for calculation of composite indicators, and as a result, down-to-earth reports, such as European Innovation Scoreboard and Biotechnology Innovation Scoreboard or manuals containing diverse mathematical methods, including Tools for Composite Indicators Building, were published (Nardo et al., 2005).

However, such efforts do not mean a complete agreement is reached concerning composite indicators. The following are pointed out as criticisms against composite indicators: 1) Impact factors and actors are reduced as a small or only one figure; 2) Temporal comparison concerning composite indicators assumes continued linkage or interaction between individual indicators; 3) Criteria like these are not met in a very dynamic system; 4) Uniqueness of a country is not considered and 5) Omission of information occurs. (Frietsch & Karlsruhe, 2006)

In discussions about statistical aspects that bring forth composite indicators, the following factors are pointed out continuously: the lack of proper data in the selection of variables; comparability between countries; the number of countries able to utilize data; the use of qualitative data; the oversight of the difference in scale between countries; inclusion of missing values; changes in the result due to methods used to process missing values; high correlation between indicators; and interchangeability between factors (OECD, 2003; Archibugi et al., 2009: 7-8). Many empirical studies have raised the robustness problem concerning a great difference in the ranks or annual changes, depending on standardization or integration of composite indicators and the way missing values are handled and weighted values are imposed<sup>2)</sup> (Grupp & Schubert, 2010; Schibany & Streicher, 2008; Frietsch

2) The representative case is the study of Grupp & Schubert (2010). In order to monitor the changes in ranking according to the changes in the weights, three methods used in major references are used to compare 2005 EIS results. Three methods are: 1) un-weighted averages;

& Karsruhe, 2006; Grupp & Moge, 2004, Archibugi et al., 2009). Also, if structural variables that evolve on a long-term are mixed with many indicators, it is difficult to change them within a short term. Occurrence of a short-term change is highly likely to be a result of measurement noise caused by a change in the measurement method. An innovation policy should consider a country's specific institutional and economic situation. Inter-country comparison based on indicators looks only at important aspects of the innovation system and thus it has limitations to cover all with the quantitative indicators developed so far. In this case, the relevant policy implications given can only be limited (Schibany & Streicher, 2008:727-728; Hollanders & Cruysen, 2008).

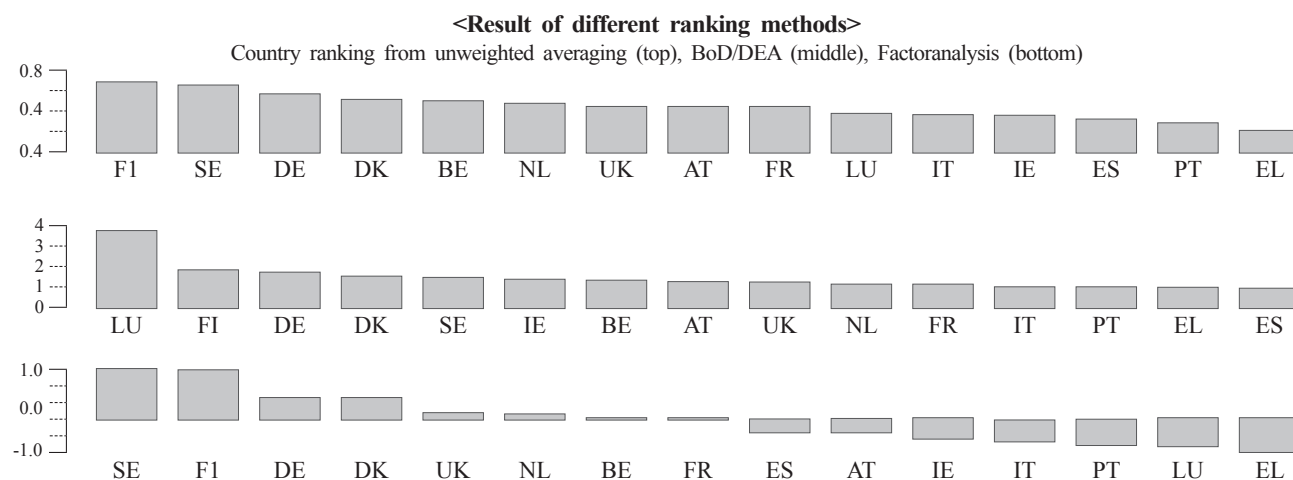
## 2.5. Science and technology innovation indicators at each stage of innovation

At present, the need is recognized for production and use of high-quality science and technology indicators in as many countries as possible. It is also pointed out that underdeveloped countries are underrepresented in international science and technology

statistics. Thus, voices are raised for the need to reduce such an information gap. Currently, many of the developing countries systematically collecting S&T data are complying with the international standards and protocols that were designed for, and adopted by advanced industrialized nations. Oftentimes, the practices and methodologies outlined under these protocols are limited and incompatible with the research, management and information systems found in many developing countries (Tijssen & Hollanders, 2006:6).

Although the historical, cultural and political systems of a developing country are diverse, their level of institutionalization remains low and inter-learning and the linkage between official systems and information systems remains weak. Recent studies point to the existence of strong interrelations between "technological capability and innovation-friendly governance" and social and cultural factors. There have not been many studies concerning the switch from the stage of inception to a mature innovation system. It can be expected that if all systems evolve in a different way (being path-dependent partially) they will follow different patterns. It is very important

2) BoD/DEA methods (Benefit of Doubt / DEA methods); 3) principal component and factor analysis. The second method is to choose the weight in order to maximize the composite index value in each country based on the linear program in which the weight is selected specifically to each country. The characteristic is that the maximization of the composite index value does not necessarily refer to the maximization of the ranking. The third method is a method of preventing repeated calculations by including index of higher relativity. It integrates into a factor that better represents the related index. The result is as in the following figure. The difference in ranking is clear. Luxembourg that was ranked 10th by the EU weight was ranked 1st on BoD/DEA method, and 14th on the factor analysis.



Source: Grupp & Schubert, 2010:73

to compare countries and regions temporarily and spatially in a systematic way to see what the major components of a system are and what the major motives of such changes are. However, the best practices in one specific system cannot be or should not be transplanted elsewhere (Rodrik, 2008). Policy learning should be accomplished by experiments. In many countries, particularly underdeveloped countries, R&D or innovation surveying has not been carried out. Surveys made by even the countries that have developed indicators have covered the form of STI (Science, Technology and Innovation), but not the form of DUI (Doing, Using and Interacting). It has not been long since indicators (in the DUI form), such as organizational change or users, were included in the innovation surveys. (Lundvall et al., 2010:14-15).

It is an important matter as to how the system of indicators should be composed in latecomer countries or how a country's individual characteristics and innovation systems should be considered. We interpret this as a significant difference in the kind of innovative system developed in a latecomer country seeking to catch-up from that in an advanced country. The role of public R&D expenditure can be seen both as a source of innovative capacity in itself, and as a guide to steer the utilization of limited resources in latecomer countries. (Hu & Mathews, 2005:1323-1324).

## 2.6. Framework of comparative analysis

Let's compare actual cases of evaluation of science and technology innovation capability carried out in the EU, northern European countries and South Korea, based on the foregoing discussion. First of all, the EU's European Innovation Scoreboard is the oldest one of those adopted by the three and has become the benchmark in many cases of innovation policies. The Nordic Innovation Monitor of northern European countries that rank high in various competitiveness sectors is the first case carried out to check out their merits and demerits. It is a noteworthy attempt in that it includes joint efforts of the countries in the region

and pursues its own model. However, this article does not aim to judge which detailed composition of indicators excels above the others or to improve statistical methodologies, such as weighted values or standardization through it. Instead, it aims to pay attention to problem consciousness in the stage preceding the development of indicators, the process of changes and major characteristics that go unheeded by many index development-related studies. It is a significant part of this research and simultaneously the most significant limitation of it. Detailed verification of what is asserted will be left for ensuing studies.

The purpose of this study is to check the problems faced commonly by different cases of composite indicators methods that are the most widely used among science and technology innovation indicators and see how composite indicators are composed and why they are used, along with the characteristics of each evaluation and analysis system. This article also intends to examine what should be complemented concerning the direction to be pursued by COSTII of Korea, which is a latecomer in both science and technology innovation policies and indicators as a non-European country, along with what should be noted to use the result of such a check in the decisions made fairly and properly. The comparative analysis will be carried out as follows: first, to check the purpose pursued by each evaluation index and the conceptual background; second, to check the composition of indices and detailed indicators used to measure them and finally, to check the composition of the result of evaluation and characteristics of policy suggestions.

## 3. A Comparative Analysis of Innovation Evaluation Systems

### 3.1. European innovation scoreboard; EIS<sup>3)</sup>

#### 3.1.1. Overview and purpose

The Directorate-General for Enterprise and Industry (DG ENTR) has been publishing the "European Innovation

3) The index system and methodology, method of composition without separate notes in this chapter are all summarized from European Commission Enterprise and Industry (2010) and European Innovation Scoreboard (EIS) 2009.



Scoreboard (EIS)” every year since 2000 as part of the Lisbon Strategy that aims to reach the 3 percent level of economic growth and the 70 percent level of employment by 2010. The leader of each nation suggested a new tool for intervention as well as the “Lisbon process” at the Lisbon Summit. Referred to as the open method of coordination (OMC),” the new tool aims to complete or strengthen the EC measures. It was viewed as a “learning process for all” and the EIS, as part of OMC, aims to strengthen the logic of “mutual learning, benchmarking, best practice, and peer pressure” (Schibany & Streicher, 2008:718). In other words, the report was provided to assess the relative innovation performance EU member nations have made since 2001 and benchmark them.

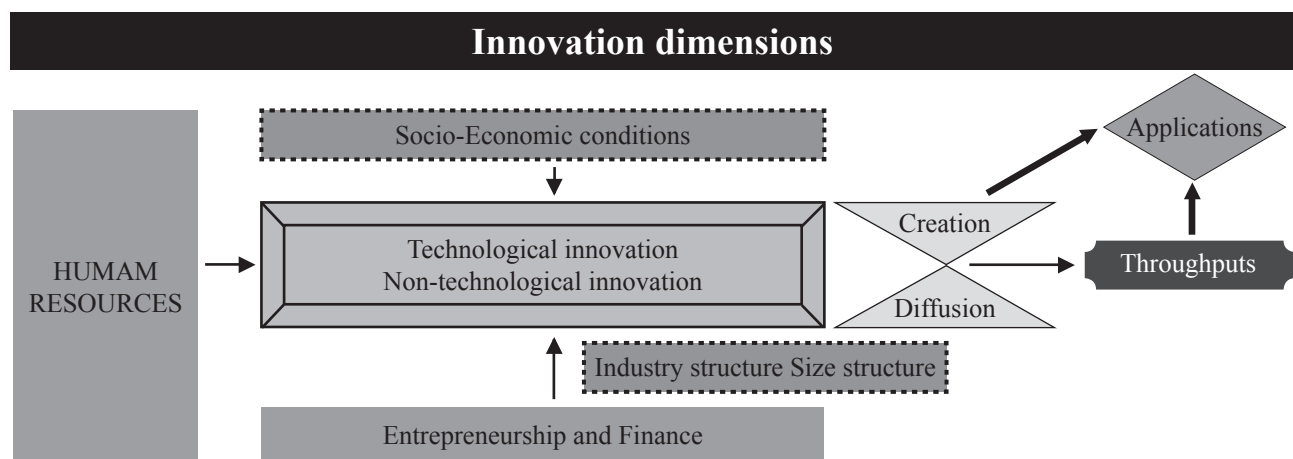
### 3.1.2. Background

It is rather clear that the EIS was pushed forward in order to review the current situations and prompt action in order to achieve practical goals. In fact, the report with suggestions for the improvement of the EIS workshop contains the following remark.

*One of the main criticisms over the years has been that the EIS lacks an underlying model of the innovation process. The main purpose of such a model would be to explain the innovation process, its inputs, throughputs and outputs, and how these are related. But explaining the innovation process has never been*

*the direct purpose of the EIS. The aim of the EIS is to measure innovation performance, and for measuring such performance we do not need a detailed model fully explaining the innovation process. Sufficient is a more general understanding of the factors which play a role in the innovation process and how they might be related. Apart from the “input” and “output” reflecting the creation of new knowledge, it refers to the expansion of knowledge (redistribution within the system), and this is measured by throughput indicators that include the cooperation among many actors and corporations, purchase of knowledge and new organizational allocation. Also, this model includes environment, systems and industrial structure influential to the innovation process to consider the context of innovation (Hollanders & Cruysen, 2008:8-9)*

However, the Lisbon strategy includes the Neo-Schumpeterian Economics in its fundamental theoretical background, which focuses on the smooth dynamic process through entrepreneurship and innovation. In other words, it emphasizes the importance of education, knowledge, and the systematic environment that influence the growth, employment, and the European socio-economic structure. Also, it considers the fact that the network of the social interaction with the idea of NIS and the participating body play a decisive role in influencing economic performance and the innovation process (Hartmann, 2007). It is interesting to note that the EIS stresses systematic



Source: Hollanders & Cruysen, 2008: 9

**Figure 2** Innovation Process-Dimensions

**Table 1** A list of Detailed EIS Indicators

Indicators	Source
<b>Enablers</b>	
<i>Human resources</i>	
1.1.1 S&E and SSH graduates per 1000 population aged 20-29	Eurostat
1.2.2 S&E and SSH doctorate graduates per 1000 population aged 25-34	Eurostat
1.1.3 Population with tertiary education per 100 population aged 25-64	Eurostat
1.1.4 Participation in life-long learning per 100 population aged 25-64	Eurostat
1.1.5 Youth education attainment level	Eurostat
<i>Finance and support</i>	
1.2.1 Public R&D expenditures (% of GDP)	Eurostat
1.2.2 Venture capital (% of GDP)	EVCA/Eurostat
1.2.3 Private credit (relative to GDP)	IMF
1.2.4 Broadband access by firms (% of firms)	Eurostat
<b>Firm Activities</b>	
<i>Firm investments</i>	
2.1.1 Business R&D expenditures (% of GDP)	Eurostat
2.1.2 IT expenditures (% of GDP)	EITO/Eurostat
2.1.3 Non-R&D innovation expenditures (% of turnover)	Eurostat
<i>Linkages &amp; entrepreneurship</i>	
2.2.1 SMEs innovating in-house (% of SMEs)	Eurostat
2.2.2 Innovative SMEs collaborating with others (% of SMEs)	Eurostat
2.2.3 Firm renewal (SMEs entries + exits) (% of SMEs)	Eurostat
2.2.4 Public-private co-publications per million population	Thomson
<i>Throughputs</i>	
2.3.1 EPO patents per million population	Eurostat
2.3.2 Community trademarks per million population	OHIM/Eurostat
2.3.3 Community designs per million population	OHIM/Eurostat
2.3.4 Technology Balance of Payments flows (% of GDP)	World Bank
<b>Outputs</b>	
<i>Innovators</i>	
3.1.1 SMEs introducing product or process innovations (% of SMEs)	Eurostat
3.1.2 SMEs introducing marketing or organizational innovations (% of SMEs)	Eurostat
<i>Eurostat</i>	
3.1.3 Resource efficiency innovators	Eurostat
3.1.3a Reduced labour costs (% of firms)	Eurostat
3.1.3b Reduced use of materials and energy (% of firms)	Eurostat
<i>Economic effects</i>	
3.2.1 Employment in medium-high & high-tech manufacturing (% of workforce)	Eurostat
3.2.2 Employment in knowledge-intensive services (% of workforce)	Eurostat
3.2.3 Medium-tech and high-tech exports (% of total exports)	Eurostat
3.2.4 Knowledge-intensive services exports (% of total services exports)	Eurostat
3.2.5 New-to-market sales (% of turnover)	Eurostat
3.2.6 New-to-firm sales (% of turnover)	Eurostat

approach, process and industrial structure and system, even if its intention is mainly the assessment of each nation and learning for the promotion of the Liston Strategy.

### 3.1.3. Classification of items and detailed indicators

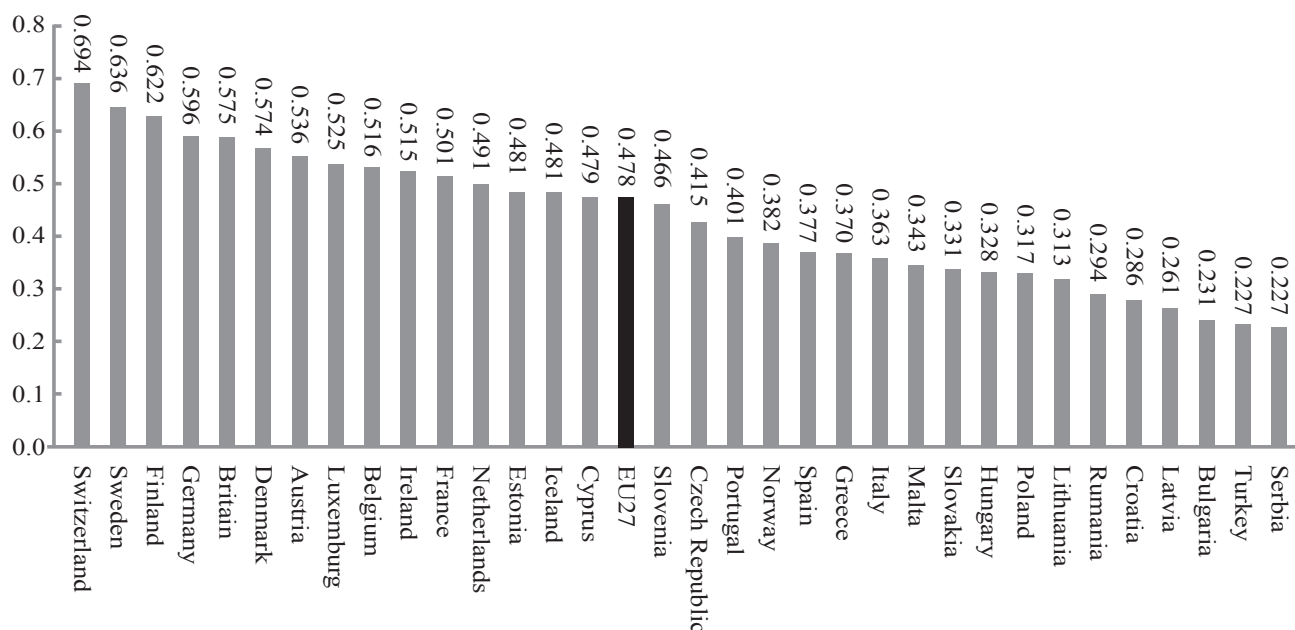
The EIS 2009 compares and analyzes the innovation performance the 27 EU member nations, Croatia, Serbia, Turkey, Iceland, Norway, and Switzerland have made by classifying their innovation activities into three dimensions and seven sectors with 29 indicators. The three dimensions include enablers, firm activities, and outputs and each of these areas has seven sectors, which include human resources, finance and support, firm investments, linkages and entrepreneurship, throughputs, innovators, and economic effects. Table 1 is the list of detailed items and indicators.

Among the three dimensions, the “firm activities,” which embraces process and intermediate products, was added later as the innovation process became more complicated, a move to adopt different models in accordance with various innovation processes and each nation’s context after the methodology workshop in 2008.

In fact, the outcome of the Community Innovation Survey conducted in the EU was included and the indicators that are still controversial, such as design, trademark, innovative SMEs, marketing, organizational innovation, knowledge-intensive service export and sales resulting from new business innovation, were actively accommodated. The relatively early adoption of such new concepts seems to be attributable to the fact that the OECD survey that includes the majority of the EU nations, the scientific technology shared by the EU nations, innovation surveys and inquiry, has developed considerably.

### 3.1.4. Major characteristics and analytical methods

The Summary Innovation Index (SII) is the index that integrates all indicators into one in order to make a comparison of the performance easier. Figure 3 shows the SII value of each nation in 2009. According to the figure, Switzerland is the nation with the most active innovation activities as Switzerland’s SII in 2009 marks 0.694 points, a year-on-year increase of 0.111 points, followed by Sweden (0.636 points), Finland (0.622 points), Germany (0.596 points), and Britain (0.575 points). On the other hand, Serbia (0.227 points),



**Figure 3** Summary Innovation Index in 2009

Turkey (0.227 points), and Bulgaria (0.231 points) are relatively inactive.

The average SII of the 27 EU nations marks 0.478 points and the EU nations with higher than the average account for 45.5 percent (15 out of 33 nations).

Since innovation is a phenomenon with diverse aspects and a non-linear process, the EIS Index can show the overall assessment of each nation's performance. Especially, the assessment of the ability for innovation is not limited to R&D and includes all factors that are considered decisive to the effort for efficient innovation since the creation of new ideas and the commercialization of long-term innovative technologies are regarded as system capacity (Veugelers, 2007). The annual EIS is advertised in mass media and attracts public attention mainly because of the easily understandable national ranking the EIS offers. However, there is skepticism about the utility of the EIS (Schibany & Streicher, 2008:718).

The rationale of the skepticism was well summarized during the EIS workshop for the improvement of methodology for 2008-2010, which was held in 2008:1) The set of indicators that tend to lean toward the realm of high technology and specific technologies; 2) the indicators with ambiguous definitions and a lack of relevance, low-

quality indicators, improper criteria for selection, such as the inclusion of both structural indicators and microeconomic indicators, or omitted indicators; 3) inaccessibility to the data in many countries and the poor quality of the data; 4) different criteria for the optimal value from nation to nation and the fact that the high value of an indicator does not necessarily mean good, and 5) statistical problems, such as singular value, the viability of international comparison, national diversity, missing values, standardization, and weight value (Hollanders & Cruysen, 2008). These problems have not been solved completely, but the workshop was productive as it prompted an increase in the number of dimensions from five to seven, and the number of indicators to 29, and solved some methodological problems.

The ultimate goal of the EIS was to categorize the nations into groups based on their similarity to compare them. The EIS classifies the nations into four groups through the cluster analysis of the ranking, index, and the SII scores for the last five years. The EIS categorized the nations into four groups, including innovation leaders, innovation followers, moderate innovators, and catch-up countries based on their SII scores and classified them into three types, including growth leaders, moderate growers, and slow growers based on the SII increase.

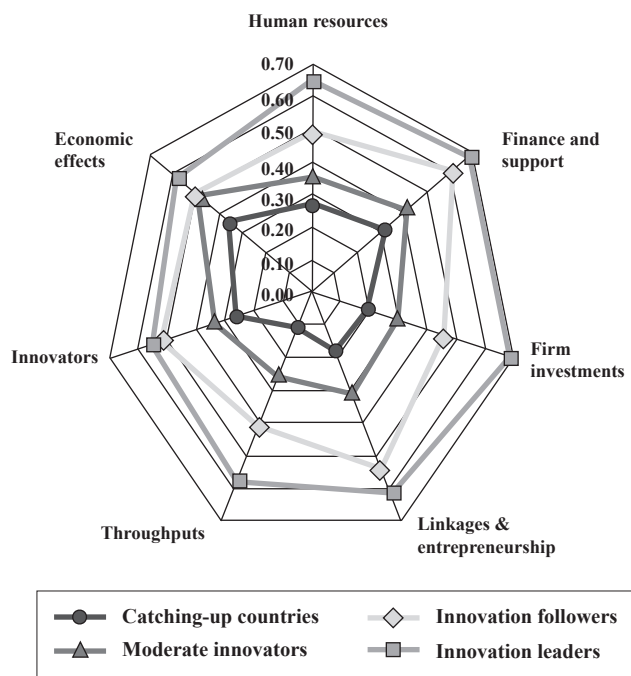
**Table 2** SII Classification by Nation

Group	Increase (%)	Growth leaders	Moderate growers	Slow growers
Innovation leaders	1.5%	Switzerland (CH)	Finland (FI), Germany (DE)	Denmark (DK), Sweden (SE), Britain (UK)
Innovation followers	2.7%	Cyprus (CY), Estonia (EE)	Iceland (IS), Slovenia (SI)	Austria (AT), Belgium (BE), France (FR), Ireland (IE), Luxemburg (LU), the Netherlands (NL)
Moderate innovators	3.3%	Czech (CZ), Greece (GR), Malta (MT), Portugal (PT)	Hungary (HU), Lithuania (LT), Poland (PL), Slovakia (SK)	Italy (IT), Norway (NO), Spain (ES)
Catching-up countries	5.5%	Bulgaria (BG), Rumania (RO)	Latvia (LV), Turkey (TR)	Croatia (HR)

\* note: the rate of increase on average for the last five years

As shown in Figure 4, the analysis of the characteristics of the groups in each sector shows that the high level of innovation with high performance cannot be attainable unless innovation in all sectors can be properly carried out because there is relatively little difference between the innovation leaders (0.22%) and the innovation followers (0.37%). Also, the innovation leaders show weaknesses in business investment, while moderate innovators are strong in finance and the support sector while weak in knowledge products. Last but not least, the catch-up countries are rather weak in all areas in general, but they are relatively strong in economic effect although weak in knowledge production.

The EIS compares the major rivals, the U.S., Japan, and BRICs among the 27 EU nations and covers the innovation performance in each industry, user innovation, globalization, and local innovation performance. Finally, it features the relatively strong and weak areas of each nation along with the major driving force of innovation of each nation in a profile format.



**Figure 4** Comparison of each group in all sectors

### 3.2. Nordic Innovation Monitor (NIM)<sup>4)</sup>

#### 3.2.1. Overview and purpose

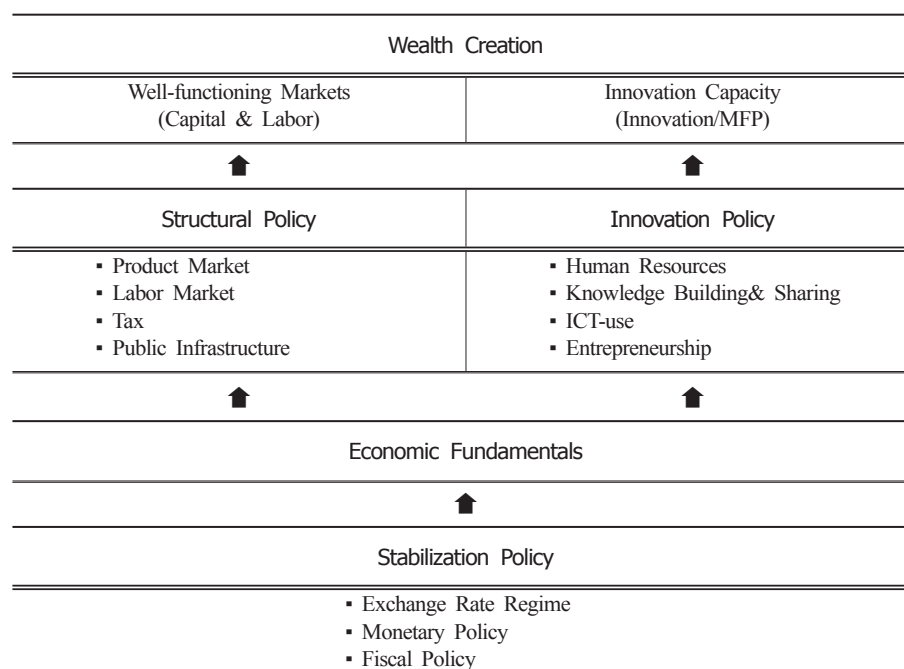
As an innovation model unique to Northern Europe that assesses the innovation capacity of the OECD nations, the NIM is designed to examine the innovation leaders' initiatives to upgrade the framework conditions through which to exert influence on overall innovation performance. The NIM published by the Nordic Council of Ministers is important in that the Northern Europe countries came up with a common framework of innovation-related policy making for the first time. Accordingly, the NIM is interested in the common issues shared by the Northern European countries as well as the ranks of the Northern European countries among the 25 OECD nations, aiming to identify the factors that play decisive roles in making Northern Europe wealthy and the micro-policy realm to maintain and increase the wealth they enjoy now by comparing them with those in other regions.

#### 3.2.2. Background

The ultimate goal of the NIM is "wealth creation" and Figure 5 shows a model for it. The OECD's benchmark study (Growth Follow-up: Micro-Policies for Growth and Productivity, 2001) started measuring a nation's innovation capacity as part of the micro-policy sector and identified four factors, including human resources, knowledge production and sharing, ICT, and entrepreneurship. The study assumes that these four factors lead to growth and wealth by contributing to more advanced multi-factor productivity (MFP). It is particularly noteworthy that unlike other benchmark systems, this study includes the environmental and national human resources as an important engine of growth for entrepreneurship. Moreover, it takes entrepreneurship seriously as an important factor for the improvement of the quality of the human resources that comprise the workforce in social science

4) The contents on methodology, background and composition methods on NIM in this chapter are summarized from Norden (2009) and Nordic Innovation Monitor 2009.





Source: FORA, 2007

**Figure 5** Model for Wealth Creation

and business administration as well as the intellectual laborers in natural science.

The most unique feature of the study is that it took the traditional national ranking-centered index to another level by distinguishing performance from framework conditions. The difference in the indicators for framework conditions and that of performance may be able to show the policy realm for competency building by identifying the common characteristics of the top-ranking nations. The important assumptions of this analysis are first, the governmental initiatives exert powerful influence on the indicators of framework conditions and second, the positive interrelationship between the indicators for performance and those for framework conditions may result in improvement in performance through the improvement of framework conditions (Norden, 2009).

### 3.2.3. Classification items and detailed indicators

The NIM index system is the most comprehensive

innovation measurement, consisting of 165 indicators in total, including 30 indicators in nine realms for performance measurement and 135 indicators in 42 policy realms. There are no clear guidelines for the number of indicators for benchmarking models, but the NIM argues that the more ambiguous the goals are, the more indicators the study needs to encompass all aspects the index system aims to measure. Each indicator is collected from the data pool provided by the OECD, WEF, IMF, IMD, ILO, and Eurostat.

### 3.2.4. Major characteristics and analytical methods

The major characteristics of the NIM are as follows: 1) Unlike other national index systems, the NIM distinguishes innovation performance from framework conditions for analysis; and 2) It emphasizes entrepreneurship and human resources as important driving forces for innovation, in addition to ICT and knowledge production other index systems value, by stretching the meaning of

**Table 3** The index system of NIIM

1. Human Resources			
performance	Knowledge Workers	Framework Conditions	Education Expenditure
	Organization and Management		Incentives
	Strategic Management		Basic Education Higher Education Lifelong Learning Conditions for Organization Management Skills
2. Knowledge Creation			
performance	Knowledge Building	Framework Conditions	Size of Public Research Quality of Public Research Relevance of Public Research Knowledge Transfer Co-operation in R&D Competencies of Workers Tax Incentives and Subsidies Skills among Customer and Suppliers Competition Access to technology
	Knowledge Sharing		
3. Information and Communication Technology			
performance	Corporate Digitalization	Framework Conditions	Telecom Prices Infrastructure ICT Competencies among Employees Digital Consumers Digitalization of Educational Institutions Data Security Digitalization of Public Institutions
	Digital Citizen		
4. Entrepreneurship			
performance	Growth	Framework Conditions	Technology Transfer Regulation Entry Barriers Access to Foreign Markets Loans Venture Capital Exit market Wealth and Bequest Tax Capital Taxes Restart Possibilities Entrepreneurship Education Traditional Business Education Personal Income Tax Business Tax Bankruptcy Legislation Administrative Burdens-Start-ups Administrative Burdens-Production Labour Market Regulation Culture
	Start-ups		

Note) Only the sectors and realms are presented and the detailed indicators are omitted as they are too many.

innovation to apply comprehensively. Especially, the NIM's differentiation of innovation performance from framework conditions makes it possible to understand the policy focused realms more accurately to identify each nation's important framework conditions based on the understanding.

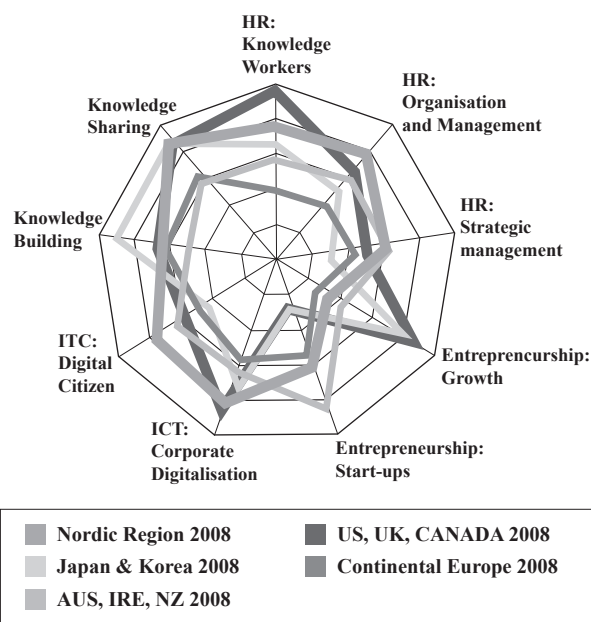
The analysis embraces the new ideas suggested by the traditional scoreboards and benchmarking rather comprehensively without adhering to the ranking of simple performance and framework conditions. For instance, the analysis classifies<sup>5)</sup> the 25 OECD nations into groups by considering their cultural and local similarities and calculates the total innovation performances of Northern Europe for comparison with other industrial regions.

As shown in Figure 6 and Figure 7, the national rankings in regional innovation performance, in which the leading English-speaking region tops, followed by Northern Europe and the other English-

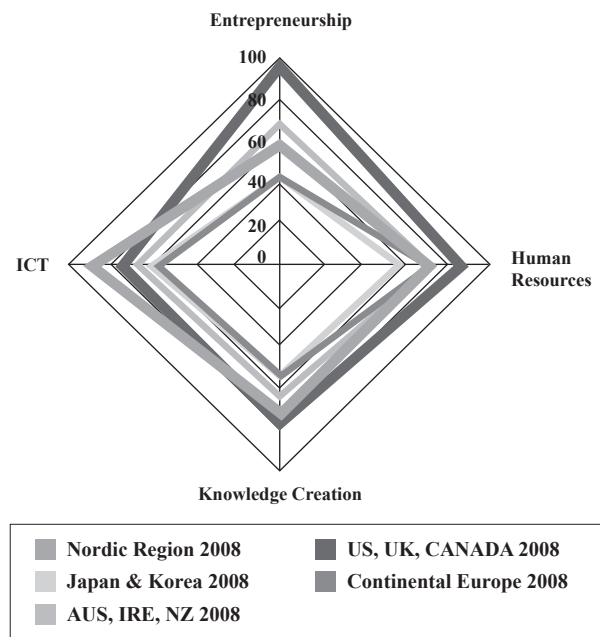
speaking region, can give a deeper understanding of regional characteristics by classifying the nations according to the four factors identified by the NIM (human resources, knowledge production, ICT, and entrepreneurship). According to the NIM's analysis, the Northern European region may gain more if it improves its performance in producing mature entrepreneurs by improving the framework conditions of entrepreneurship.

Another analytical method is shown in Figure 8, which ranks individual countries in accordance with performance, framework conditions, and the four factors and compare the top-ranked nation with others to determine the best practice. .

The last but not least analytical method is the analysis of each Northern European nation through a peer review for the comparison of the framework conditions and performance of the top nation with those of other Northern European nations. The result

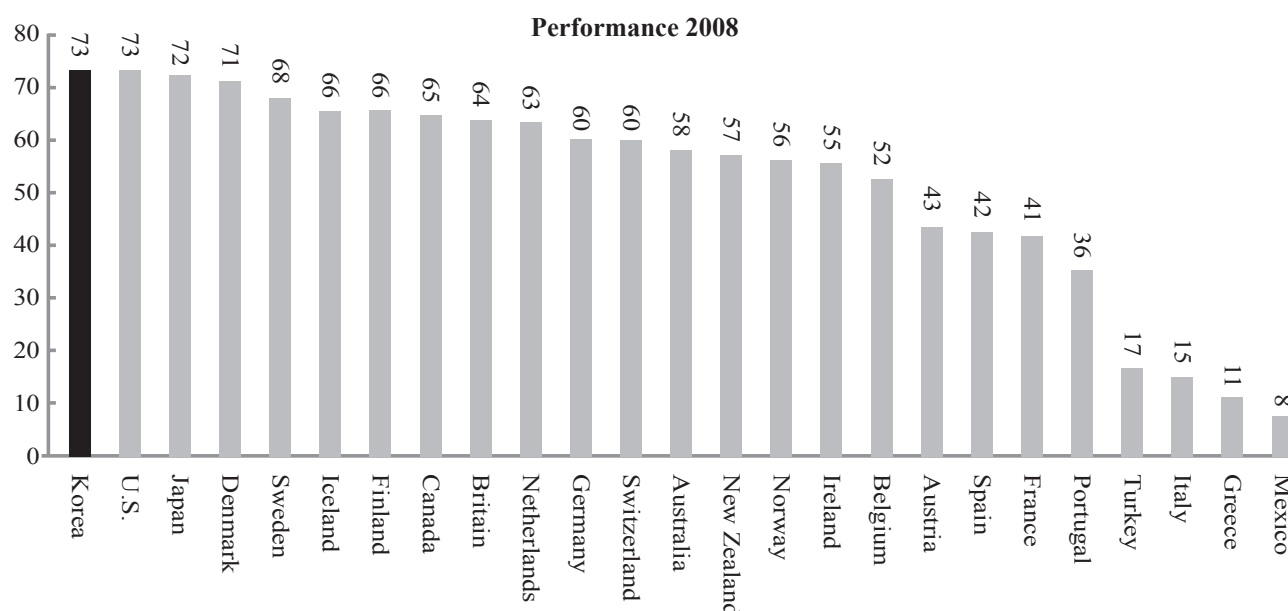


**Figure 6** Regional Differences in Innovation Performance



**Figure 7** Regional Differences in Innovation Performance

5) The classification of the group are divided into a) advanced English –speaking countries (USA, England, Canada), b) Nordic countries (Denmark, Finland, Iceland, Norway, Sweden), c) Japan and Korea, d) other English-speaking countries (Australia, Ireland, New Zealand), e) continental Europe (Austria, Belgium, France, Germany, Italy, Netherlands, Portugal, Spain, Switzerland). Greece, Turkey and Mexico are excluded from this classification due to the fact that their performances and framework conditions are all on the lower group and they use different indicators from 22 OECD countries. Hence, the European countries have little to learn from comparison. Moreover, the innovation of the region is determined by the weight of national standardized value related to GDP. Therefore, USA among the advanced English-speaking countries and Norway in Nordic countries occupy a relatively larger proportion.



**Figure 8** The NIM's Innovation Performance by Nation (2008)

is elaborated by policy experts and analyzed in terms of the quality of the micro- and macro-policies that support innovation efforts by nation. In addition to the three methods mentioned above, the study suggests the policies each nation should consider.

It is interesting that the study of the innovation capacity of the Northern European region highlights the challenges the Northern European region face in common and its strengths, assuming that the nations in the region can improve their innovation capacity through "cooperation." The study points out that the biggest challenge is how the Northern European nations can utilize their citizens' progressive activities through growth-oriented businesses and discover the unique aspects of the Northern European value system that accommodate the forward-moving action and danger. In addition, the study warns that the stagnation of human resources could pose a potential challenge, while it admits that ICT, human resources, and knowledge production possess ideal framework conditions and share a strong innovation capacity. It urges one to pay attention to the statistical index system that supports the effort to understand the

new trends of North European innovation and the cooperative culture of the Northern European models.

To conclude, the NIM study suggests the following: 1) promotion of enterprising behavior; 2) training of youth and the development of the education system that meets the global demand for youth training; 3) the Northern European efforts to make the region an attractive place for foreign knowledge workers; 4) the experiment of policy framework for the accommodation of new innovation trends, such as user participation and open innovation partnership and 5) communal efforts for the measurement that stresses the strengths of the models of Northern European welfare states.

### 3.3. Korea's Composite Science and Technology Innovation Index (COSTII)<sup>6)</sup>

#### 3.3.1. Overview and purpose

Major advanced countries and international organizations are publishing indexes related to science and technology or innovation indicators, which have increased the importance of science and technology

6) The contents on methodology, background and composition methods on COSTII in this chapter are summarized from the National Science and Technology Innovation Evaluation 2006 and 2009 (Ministry of Education and Science and KISTEP (2006, 2010)). Some internal documents attained as a researcher in charge are included.

indexes used as a tool to analyze and evaluate the science and technology innovation systems in Korea. Therefore, it is necessary to analyze the strengths and weaknesses of Korea by comparing the results of the Composite Science and technology Innovation Index (COSTII) implemented on the thirty OECD countries to come up with the policy measures. Especially, when COSTII was first implemented during the Roh, Moo-Hyun government, it was necessary to have an accurate analysis and evaluation on the current system because the government was aiming to establish the National Innovation System (NIS). To achieve this, the first research was done in 2004 and after the trial evaluation in 2005, improvements were made to the index model to be fully implemented in 2006. The COSTII was carried out by the Ministry of Science and Technology (currently the Ministry of Education, Science and Technology) and the Korea Institute of S&T Evaluation and Planning and the result was reported to the National Science & Technology Council. The reason behind the COSTII was to develop and provide a model that can analyze the strengths and weaknesses of Korea more stably and objectively against the policy makers who are agitated over the results of the evaluation on IMD and WEF.

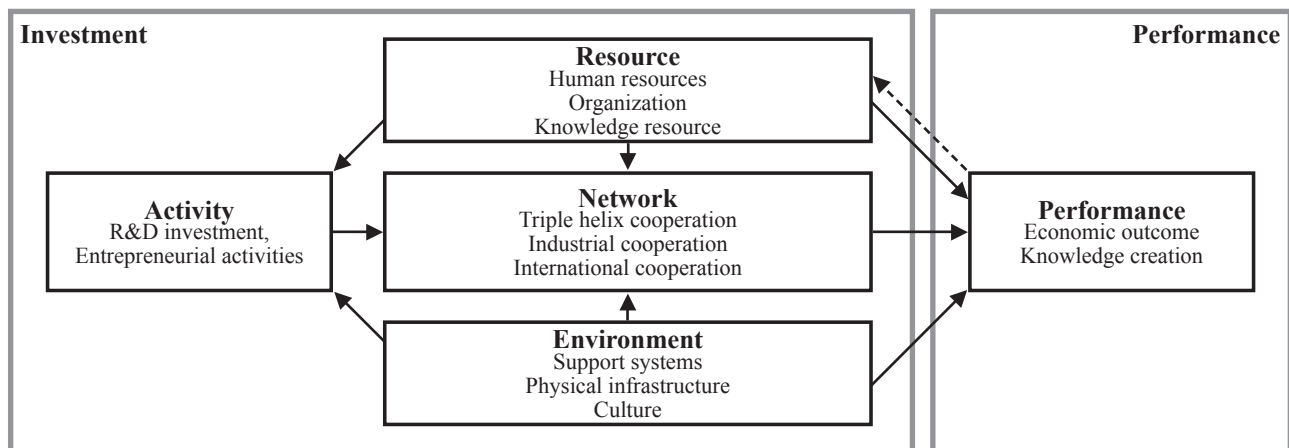
### 3.3.2. Background

The competitiveness and innovation index was defined within the framework of NIS by referring to the studies and reports from the advanced

countries. The NIS forms and identifies the national innovation through the innovation of the subject, the innovation of factors, the innovation of performance and expansion, the innovation of system and the innovation of foundation, and also the innovation index is considered to be the capabilities of a country of an economy that can achieve a series of innovations with economic values (Porter & Stern). Therefore, the COSTII is defined as the “the subject of innovation utilizing the innovation resources effectively under an innovation environment to implement innovation activities and performance”. As a latecomer to the science and technology innovative index, there were many prior researches done on the references and reports of advanced countries, and we attempted to draw up a concept that can analyze the current status of national science and technology in line with the governmental policy to promote innovation at the time.

### 3.3.3. Classification of items and detailed indicators

After dividing the framework of NIS into the five dimensions of resource, activity, process (network), environment and performance, each dimension was broken down into thirteen items, including human resources, organization, knowledge resources, R&D investment, entrepreneurial activities, triple helix cooperation, industrial cooperation, international cooperation, support systems, physical infrastructure, culture, economic outcome, knowledge creation.



**Figure 9** Basic Framework of COSTII



**Table 4** COSTII Detailed Indicators and Data Source for the Year 2009

Category			Data Source
Resource	Human resources	Total no. of researchers	OECD, MSTI 2009_1
		No. of researchers per 10,000 population	OECD, MSTI 2009_1
		Ratio of Ph.Ds per population	OECD, STI Scoreboard 2009
	Innovative organization	No. of organizations that issued USPTO patents	USPTO (cit. Korean Intellectual Property Office, USPTO patent analysis data)
		No. of universities ranked in the world's 100 best universities	The Times, www.topuniversities.com/university-rankings
	Knowledge resources	No. of SCI papers in the past 15 years (STOCK)	Thomson ISI (cit. 2008 KAIST SCI research analysis)
		No. of patents in the past 15 years (STOCK)	USPTO
			Triad
Activities	R&D investment	Total amount of R&D investment	OECD, MSTI 2009_1
		Ratio of total R&D investment per GDP	OECD, MSTI 2009_1
		R&D investment per researcher	OECD, MSTI 2009_1
		Ratio of industrial R&D investment vis-a-vis industrial added value	OECD, MSTI 2009_1
		Government R&D investment vis-a-vis GDP	OECD, MSTI 2009_1
	Entrepreneurial Activity	Total entrepreneurial activities (TEA)	The Global Entrepreneurship Monitor_by Year
		Ratio of investment of venture capital vis-a-vis GDP	OECD, STI Scoreboard_2009
Network	Triple helix cooperation	No. of patents jointly issued by industry, academia, and research institute per researcher	USPTO(cit. Korean Intellectual Property Office, USPTO patent analysis data) OECD MSTI 2009_1
		Ratio of private R&D investment out of government, academia R&D investment	OECD, MSTI 2009_1
	Industrial cooperation	Industrial Cooperation*	IMD, The World Competitiveness Yearbook_2009
	International cooperation	No. of international joint patents per researcher	USPTO (cit. Korean Intellectual Property Office, USPTO patent analysis data) OECD, MSTI 2009_1
		(Overseas investment + foreign investment) ratio vis-a-vis GDP	OECD, Fact Book 2009: Economic, Environmental and social Statistics OECD, MSTI 2009_1
Environment	Support System	I-B index (tax support for R&D)	OECD, STI Scoreboard_2009
		Protection of intellectual property*	IMD, The World Competitiveness Yearbook_2009
	Social infrastructure	Average advertised broadband download speed	OECD, Broadband Statistics_2008
		Overall quality of social infrastructure*	WEF, The Global Competitiveness Report_2008-2009
	Innovative culture	Attitudes toward new cultures*	IMD, The World Competitiveness Yearbook_2009
		Emphasis of science in school education*	IMD, The World Competitiveness Yearbook_2009
Performance	Economic outcome	Industrial added value per capita	OECD, MSTI 2009_1
		Ratio of export in high-tech industry to manufacturing sector	World Bank IMD, The World Competitiveness Yearbook_2009
		Technology export	OECD, MSTI 2009_1

**Table 4** COSTII Detailed Indicators and Data Source for the Year 2009 (cont'd)

Category			Data Source	
Performance	Knowledge creation	Annual no. of patents	USPTO	USPTO
			Triad	OECD, MSTI 2009_1
		Ratio of no. of USPTO patents to annual GERD (per mil. USD)	USPTO	USPTO
			Triad	OECD, MSTI 2009_1
		No. of SCI papers per researcher and level of referencing	No. of papers	Thomson ISI(cit. 2008 KAIST SCI research analysis results)
			Citations per paper	

\* Survey indicator

innovative culture, knowledge creation and economic outcome. In order to establish simple and credible statistics and data that can accurately explain the foundation and changes of COSTII, the whole process, including the resource stock, application, process, foundation and performance, of the science and technology activities were all included to effectively identify the factors that have an important effect on the innovation capacity. (Figure 9)

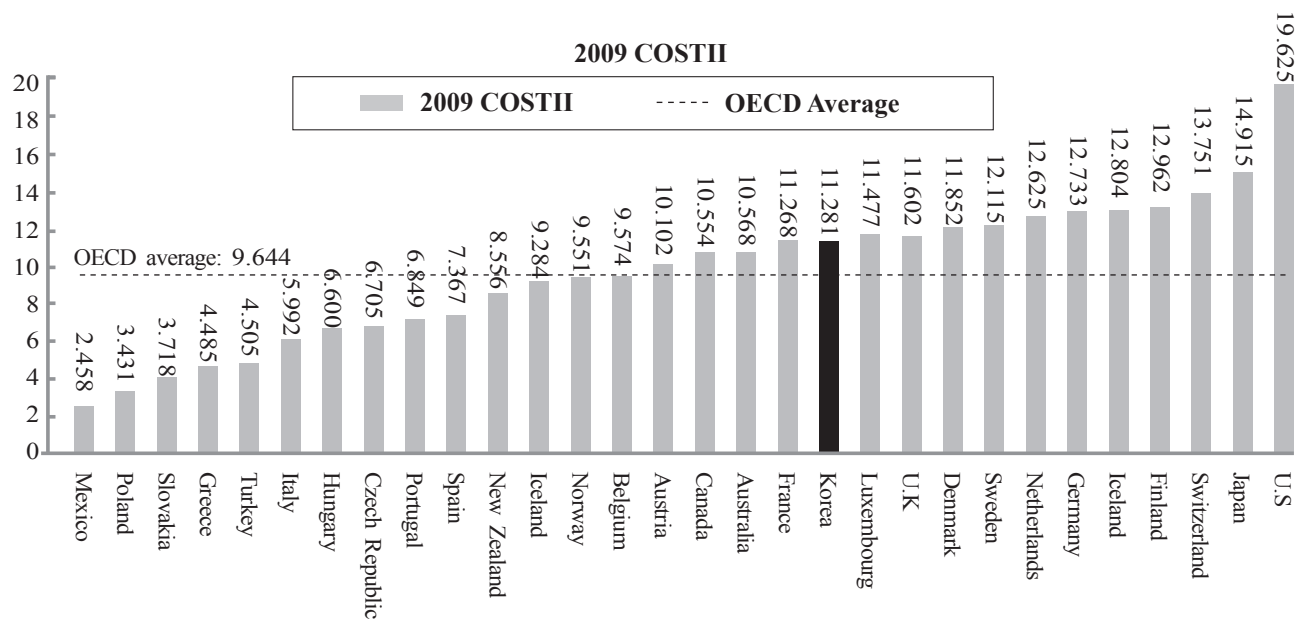
The detailed indicators consider the representativeness of the variables and the sufficiency of the data to decide on thirty one items as shown in Table 4 by conducting a survey and consulting a survey and consulting with the local and overseas experts and a committee of experts through a top-down method that best suits the definition of Innovation Index among the pool of various indicators. Since it was still in the early stages, the basic framework was maintained as a principle to ensure consistency, but some indicators such as outside environmental changes and change of the raw materials have been adopted according to each situation. However, most data related to innovation is still not at a stable standard compared to the other thirty OECD countries, which is why there are no attempts to add more items to ensure the data acquisition, and possibility of comparison and continuity. If one looks at the source of the data, most of the data used are from internationally credible institutions like the OECD, World Bank, USPTO and the IMD. Additionally, the indicators related to companies, such as corporate process improvement, innovative SMEs and new market innovation; are not included because the focus is on the public sector

to identify the science and technology fields and the policy implications.

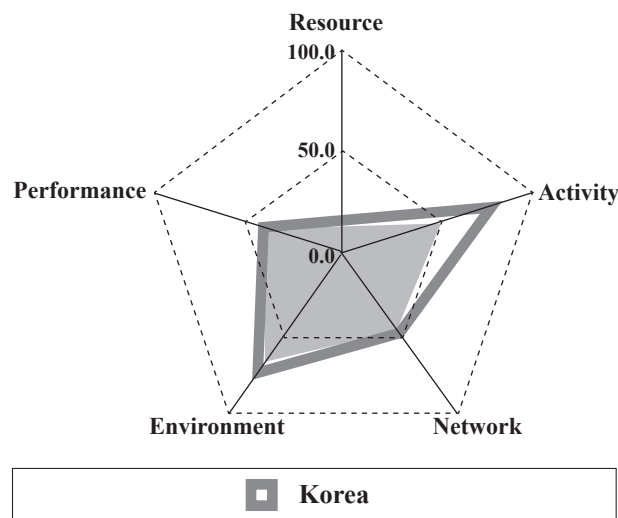
### 3.3.4. Major characteristics and analytic method

First of all, the characteristics of the index system matches the stages of science and technology with the framework of NIS, including the resource, process, environment and performance of science and technology in the framework for the index. To show the difference between the advanced countries and the latecomers, the patents and scientific publications of 15 years were included as the accumulation of knowledge resources in the resource dimension. Also, the survey items were reduced to five out of the thirty-one indicators because the evaluation result showed a huge difference every year according to the perception of the entrepreneur. Additionally, instead of focusing on the corporate aspects like the improvement of corporate environment and corporate internal processes, the overall public sector was evaluated to link with the policies and the science and technology fields as the public sector is carried out with the Ministry of Education, Science and Technology.

In terms of drawing up the report, the ranking of the country was shown first as in Figure 10, but besides the number and the ranking, the comparative level compared to the number one country and the OECD average were both provided to identify the characteristics by item and the difference with the advanced countries. In Figure 11, Korea ranked 12<sup>th</sup> place, but showed a relatively high ranking for the activity dimension but a low ranking for resource and



**Figure 10** COSTII Ranking and Indexes by Country for the Year 2009



**Figure 11** Comparison between Korea and the OECD Average for Five Dimensions

network dimensions. Additionally, in the 2009 report, there was a comparison of the national and economic size with the average increase rate of COSTII according to different types as well as a comparison of the five Asian countries.<sup>7)</sup>

Lastly, the correlation analysis and the analysis of convergence or divergence were carried out to certify the credibility of COSTII and for each item, the innovation capacity was analyzed and policy suggestions were presented.

### 3.4. Result of comparative analysis

#### 3.4.1. Ranking of three composite indexes and analysis of correlation between indexes

First of all, the similarity and the correlation have to be analyzed to look at the similarity and difference

**Table 5** Analysis of Basic Statistics of Composite Indexes

Variable	N	Average	Standard Deviation	Minimum Value	Maximum Value
SII	33	0.43	0.129	0.227	0.694
COSTII	30	9.64	3.864	2.458	19.625
NIM	25	51.68	20.110	8	73

7) 5 Asian countries are not OECD members. It was not possible to ensure 31 data. Although the categorization by type was attempted similarly to the contents of other evaluation systems or EIS, it failed to provide the clear conceptual frames of itself. Hence, it is dealt with in the appendices by collecting expert's insights from the advisory committee.

between the results of the three evaluations<sup>8)</sup>. EU's SII in 2009 calculated the composite indexes implemented on 33 countries and the average and the standard deviation was 0.43 and 0.129, respectively. Korea's COSTII had an average of 0.43 and the standard deviation was 3.864, and the average and standard deviation of NIM was 51.68 and 20.110, respectively. The comparison was relatively similar to that of OECD countries and major EU countries, but there was a difference in the unit of standardization, which resulted in the difference in the average and standard deviation.

If one looks at the correlation between the composite indexes, Switzerland ranked first and third place for SII and COSTII, respectively. On the other hand, it showed a huge difference in NIM by ranking 12<sup>th</sup> place. Also, Austria ranked 16<sup>th</sup> and 18<sup>th</sup> places for COSTII and NIM, respectively, but it ranked 7<sup>th</sup> place in SII. Korea also ranked 12<sup>th</sup> place for COSTII, but it ranked first place for NIM. COSTII and SII showed a lot of similarities in terms of actual items and indicators, but NIM was different because it provided a separate framework condition.

It is difficult to identify which one of the composite indexes is accurate, because they all have different indexes and calculation methods according to their purposes. However, each composite index showed almost similar rankings except for these several countries, which are also shown in the analysis of correlation in Table 7.

If one looks at Table 7, the analysis of correlation between the composite indexes and the per capita GDP that shows the economic power of each country resulted in a close relationship with a similarity of 5%. Especially, the correlation coefficient between SII and per capita GDP was 0.663 ( $p < 0.001$ ). Therefore, a country with higher SII will have a higher level of per capita GDP.

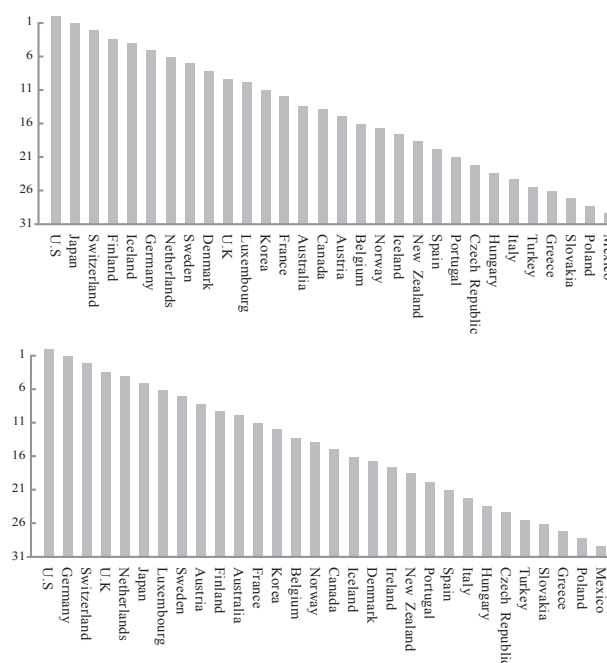
Since the correlation coefficient between SII and COSTII was the highest at 0.889 ( $p < 0.001$ ), and the COSTII and NIM was 0.863 ( $p < 0.001$ ) and the SII and NIM was 0.774 ( $p < 0.001$ ). This means that each time SII increases by one point, COSTII increases by

0.889 points, which shows that the correlation between the two indexes are very high.

Generally, the weight placed on the composite indexes is very arbitrary. For example, the weight of COSTII was calculated by applying the Fuzzy Set Theory to get the index figure for each item and section, but each individual indicator is applied with the same weight.

If the results are the same when you calculate through another method, the COSTII method will be quite robust. Let's compare the ranking of COSTII from applying the Grupp & Schubert (2010) study on EIS index using the existing method and the ranking calculated from the factor-analysis method.

First, we can find the common factors by analyzing the factors by item, and then we can come up with the ranking of the countries by summarizing the twelve representative indicators from the thirty-one individual indicators. The result showed Iceland dropping from fifth place to 17<sup>th</sup> place, and also there were changes in the ranking for Denmark (9<sup>th</sup>→18<sup>th</sup>), Finland (4<sup>th</sup>→10<sup>th</sup>) and the U.K. (10<sup>th</sup>→4<sup>th</sup>). However, most countries didn't show any big changes in their



**Figure 12** Unweighted average (top), Factor-analysis (bottom)

8) NIM divided into the performance and framework conditions. Here, it only deals with the performance index.

**Table 6** Correlation of Composite Indexes

Country	COSTII	SII	NIM	COSTIIRank	SII Rank	NIM Rank	Median Rank	St.Dev.Rank
U.S.	19.625		73	1		2	1.5	0.707
Japan	14.916		72	2		3	2.5	0.707
Switzerland	13.751	0.694	60	3	1	12	3.0	5.859
Finland	12.962	0.622	66	4	3	7	4.0	2.082
Iceland	12.804	0.481	66	5	13	6	6.0	4.359
Germany	12.733	0.596	60	6	4	11	6.0	3.606
Netherlands	12.625	0.491	63	7	12	10	10.0	2.517
Sweden	12.115	0.636	68	8	2	5	5.0	3.000
Denmark	11.852	0.574	71	9	6	4	6.0	2.517
U.K.	11.602	0.575	64	10	5	9	9.0	2.646
Luxembourg	11.477	0.525		11	8		9.5	2.121
Korea	11.281		73	12		1	6.5	7.778
France	11.268	0.501	41	13	11	20	13.0	4.726
Australia	10.568		58	14		13	13.5	0.707
Canada	10.554		65	15		8	11.5	4.950
Austria	10.102	0.536	43	16	7	18	16.0	5.859
Belgium	9.574	0.516	52	17	9	17	17.0	4.619
Norway	9.551	0.382	56	18	20	15	18.0	2.517
Ireland	9.284	0.515	55	19	10	16	16.0	4.583
New Zealand	8.556		57	20		14	17.0	4.243
Spain	7.367	0.377	42	21	21	19	21.0	1.155
Portugal	6.849	0.401	36	22	19	21	21.0	1.528
Czech Republic	6.705	0.415		23	18		20.5	3.536
Hungary	6.600	0.328		24	26		25.0	1.414
Italy	5.992	0.363	15	25	23	23	23.0	1.155
Turkey	4.505	0.227	17	26	33	22	26.0	5.568
Greece	4.485	0.370	11	27	22	24	24.0	2.517
Slovakia	3.718	0.331		28	25		26.5	2.121
Poland	3.431	0.317		29	27		28.0	1.414
Mexico	2.458		8	30		25	27.5	3.536
Estonia		0.481			13		13.0	
Cyprus		0.479			15		15.0	
Slovenia		0.466			17		17.0	
Malta		0.343			24		24.0	
Lithuania		0.313			28		28.0	
Rumania		0.294			29		29.0	
Croatia		0.286			30		30.0	
Latvia		0.261			31		31.0	
Bulgaria		0.231			32		32.0	
Serbia		0.227			34		34.0	



**Table 7** Analysis of Correlation of Composite Indexes

	SII	COSTII	NIM	Per capita GDP
SII	1	0.889***	0.774***	0.663***
COSTII		1	0.863***	0.540**
NIM			1	0.492*
Per capita GDP				1

\*p&lt;0.05, \*\*p&lt;0.01, \*\*\*p&lt;0.001

**Table 8** Overall Comparison of Each Evaluation System

Classification	EIS	NIM	COSTII
Overview and Purpose	<ul style="list-style-type: none"> <li>- Evaluate the innovation performance of EU member countries and expand the benchmarking of these countries.</li> </ul>	<ul style="list-style-type: none"> <li>- Provide the first common basis for the policy making of innovations for North European countries.</li> <li>- Identify the factors that determine the current wealth of North European countries and provide micro political areas that need to be focused on to maintain and improve them.</li> </ul>	<ul style="list-style-type: none"> <li>- Analyze the strengths and weaknesses of Korea through comparison with 30 OECD countries and seek policy initiatives.</li> <li>- Establish an evaluation system focusing on quantitative and objective science and technology.</li> </ul>
Background	<ul style="list-style-type: none"> <li>- Expand the application and calculation of knowledge.</li> <li>- Consider the context of innovation.</li> </ul>	<ul style="list-style-type: none"> <li>- Four factors of creating wealth (human resources, knowledge creation, ICT and entrepreneurship).</li> <li>- Make the assumption that the government initiative has an impact on the framework condition and a positive relation between the performance and the framework conditions.</li> </ul>	<ul style="list-style-type: none"> <li>- Introduce the whole process of innovation in five dimensions based on the basic background of the national competitiveness and NIS concept.</li> </ul>
Classification of Items and Detailed Indicators	<ul style="list-style-type: none"> <li>- Divide the major driving force, entrepreneurship activity and performance of innovations.</li> <li>- Include the indicators for innovative activities of SMEs in the entrepreneurship item and the factors of organizational and marketing innovation like trademark, design and innovative enterprise in the intermediary item.</li> </ul>	<ul style="list-style-type: none"> <li>- Divide between the performance (9 areas and 30 indicators) and framework conditions (135 indicators for 42 political areas).</li> <li>- Include the most indicators to measure the ambiguous concepts.</li> <li>- Tries to include new innovation indicators because it sees the most important factors as ICT and entrepreneurship.</li> </ul>	<ul style="list-style-type: none"> <li>- Five dimensions of resource, activity, network, environment and performance with 13 items and 31 indicators.</li> <li>- Focus on traditional indicators by emphasizing the possibility of comparison and data availability. Many indicators related to governmental R&amp;D to show the knowledge resource as a latecomer.</li> </ul>
Major Characteristics and Analytic Methods	<ul style="list-style-type: none"> <li>- Provide the SII and ranking to compare with other countries.</li> <li>- Tries to compare by classifying by types into similar groups.</li> <li>- Compare with the U.S., Japan and BRIC countries besides the 27 EU countries.</li> <li>- Identifies the most important theme on the report by theme.</li> <li>- Provide the strengths and weaknesses and profile of each country.</li> </ul>	<ul style="list-style-type: none"> <li>- Provide the strengths and weaknesses by region and area based on the cultural and regional similarity. Provide the common characteristics and challenges of Northern Europe.</li> <li>- Provide the common efforts made in developing the indicators showing the spirit of Northern Europe.</li> <li>- Focuses on the weaknesses of entrepreneurship and tries to manage the potential challenges of decline shown in the areas with outstanding performance.</li> </ul>	<ul style="list-style-type: none"> <li>- Implements COSTII indexes and ranking, correlation comparison with the number one country and the comparison with OECD average.</li> <li>- Analyzes each item and provides policy implications.</li> <li>- Divides the national size and COSTII indexes by type and provide the trial comparison with five Asian countries.</li> <li>- Interest on certifying the credibility of the index.</li> </ul>

rankings, especially, the bottom-ranking countries that are below the top 20 didn't show much difference. Therefore, the current COSTII weight method shows the same limitations that EIS has and we can't say that it shows more errors.

### *3.4.2. Overall analysis of the innovation index system*

Analyzing and evaluating the innovation performance of the country or region for the three indexes helped identify the strengths and weaknesses in order to come up with the policy implication and direction we need to move towards. Also, there were continuous efforts made to reflect the new concept of NIS or innovation, and attempts were made to introduce diverse comparisons and analysis by region realizing the problem with just ranking the countries. However, there were some differences found between the indexes. This is summarized in Table 8.

First, the EIS stresses the announcement of rankings to identify the status of each country and encourage the benchmarking of other countries in the process of implementing the Lisbon Strategy. However, based on its long history of diverse organizations and active theoretical research, it has continued to make improvement to accept new innovation concepts and the differences between countries. As a result, the methodology workshop was held in 2008 to increase the number of items and the number of indicators by accepting new concepts.

Second, the NIM has the purpose of providing an active joint countermeasure to identify the characteristics of Northern Europe. Therefore, it is used mostly to compare with the advanced western countries according to regional classification and so long-term measures are drawn to concentrate on the areas of decline even if the country is in the leading position. This index was created most recently and it tries to reflect the recent trends of innovation and encourage interest in the framework conditions that can affect the political initiatives by dividing the performance and the framework conditions. Additionally, it provides peer comparison and policy advice besides the ranking as well as mentioning the joint development of indicators that can realize the

characteristics and value of Northern Europe.

Third, the last index is COSTII, which provides the policy recommendations by analyzing the weaknesses and strengths of Korea by comparing with 30 OECD countries. In particular, the index eased the flexibility of evaluating the competitiveness through surveys as a latecomer and focused more on science and technology. The whole process of innovation is included to suit the concept of NIS, but the new innovation index of Europe wasn't included because of data availability and possibility of comparison. Additionally, the indicators that can show the difference with the advanced countries like the knowledge resources and the indicators that are related to R&D activities of the public sector, which are characteristics of Korea, were included.

There can be a difference in systematizing the science and technology for the advanced countries and the latecomers. The science and technology of western advanced countries started as an academic field, but it has the economic and social potential to be systematized in the form of an enterprise or governmental research institute. However, a latecomer like Korea will focus on the economic potential of the science and technology at the beginning stage and then start the science and technology activities with the help of the government. According to the technical innovation theory of a latecomer, the country that is trying to catch up will not gradually stabilize the uncertainty of the technology like the advanced countries. Instead the latecomers will introduce the technology that has already had its achievements certified in these same advanced countries and so start from the assembling stage to follow the path in the opposite direction from the technology development of advanced countries (Song Wi-Chin, Kim Byeong-Yoon, 244:587). Actually if we recognize the difference of NIS, it is obvious that although the evaluation system and the ranking are quite similar, there's a difference in the detailed composition and the implications. In fact, we should look back on whether we hadn't focused too much on copying and introducing the advanced countries' systems without considering the context or characteristics of COSTII. From the result of NIM, although the correlation of the framework

conditions and performance was low, Korea and Japan ranked high. Therefore, it is our job to find out what sort of additional research can be done so that we can learn from these special circumstances.

### 3.4.3. *Implications of the analysis*

We were able to find the following implications from the comparison and analysis of the three evaluation systems. First, the North European countries that ranked high in the evaluation of competitiveness and innovation were analyzed further through the performance and framework conditions, and this showed that they made a joint regional effort to maintain their advantage from a long-term perspective. Therefore, developing common indicators that can highlight strengths of the model and value of North European countries has become an important task. On the other hand, Korea's COSTII established an objective evaluation system compared to the 30 OECD countries that didn't fluctuate greatly by the survey, which is unfavorable to a latecomer, so that the strengths and weaknesses of Korea can be analyzed and the policy implications can be drawn up. According to the definition of NIS, the whole process of innovation is included in the items, but the new innovation indicators were not well received because of the data availability and the possibility of comparison<sup>9)</sup>. Additionally, the index system reflected the unique characteristic of Korea that is different from other advanced countries, including the difference between the advanced and the late-coming countries through R&D in the public sector and the knowledge resource. However, this shouldn't be implemented to increase the ranks of Korea by including indicators that are advantageous to us. In this case, we will not be able to identify the exact position that we are currently in.

Therefore, Korea's COSTII needs to look at why it is more meaningful to make the governmental R&D efforts as a latecomer and also seek ways to find out where we are lacking instead of hastily introducing

innovative indicators of advanced countries. Also, it is necessary to think about how to connect the new concept of innovation in the post catching-up stages as well as how to deal with the methodological problems faced by the advanced countries' index system. To achieve this, we should consider a framework that can show the current position, potential problems, short-term vitalization plans and the resolution of long-term structural problems like the North European's distinguishing between performance and framework conditions. One option would be to carry out a common study on developing a science and technology innovation index system for Asia or Northeast Asia, which has the similarities of focusing on R&D in the public sector, strong centralized power, and weaknesses in indicators related to DUI (Doing, Using, Interfacing) learning and network.

Another important thing is that to utilize the science and technology innovation index directly in policies, it is necessary to always consider the limitations of the index, the pros and cons of the relevant persons and the necessity of continuous improvement. The wrong interpretation of index or position can bring a negative effect on establishing the direction of the science and technology policies. It is necessary to be cautious and careful about the tension and trade-off relation that exists between the quality and usability of indicators. We can improve the COSTII in the future through a better understanding about the context of the existing discussions, in-depth and systematic analysis of the original characteristics, recognition of the limitation of the statistics and indicators and the various improvement plans, and the cooperation with other countries in the similar development stages.

## 4. Conclusions

In the current situation where the science technology innovation indicators are perceived as an important elements in national economic growth, development, and promotion of welfare and the attempt to utilize the result in policies, the objective of this study is to

9) This is because it uses the reliable data from international organizations based on the quantitative indicators in the situation where it is difficult to conduct independent indicator surveying on OECD countries.

compare European, Northern European and Korean innovation evaluation systems, to examine the related discussions, and to make realistic contributions to improve COSTII in Korea. For this purpose, the following were examined – the developmental process of science technology innovation indicators, the process of associating with the policy, problems in the process, development and limitations of the composite indicator of score-boarding and benchmarking and the difference of science technology innovation indicators of each stage of innovation. Moreover, three innovation evaluation systems are compared to study the background and objective of each system, the conceptual background, classification of items and composition of detailed indicators, and the method of presenting the main characteristics, analysis and result.

The result shows that the development of science, technology and innovation indicators in EU, Northern Europe and Korea takes a markedly similar path but at the same time reflecting unique characteristics. First, the accurate diagnosis on the position of their country is a key issue in the science and technology index in international economic competition. As the innovation outside the linear technology development model is emphasized, there is a common need to put attention into cooperation, process, intangible assets, and policy relevance to a broader area. Second, in order to associate the index and statistics with the policy, a process of determining the ranking, selecting the top country, and analyzing the characteristics is required. These are precedents in most systems and the limitations and improvement are partially recognized. Third, although the composite index is preferred as a simple and clear index inducing interests, it is recognized that various discussions should be attended to. Fourth, there have been some discussions in regards to the issue of lack of a unique index system that could be used in each stage of innovation, and that a successful system in one country is not always applicable to other countries. Despite these discussions, it has however not led into a new index system developmental stage.

Therefore, the following implications have been proposed through the comparative analysis on each characteristic. First of all, the composition of an index

system fitted to each objective is required in each innovation and development stage. Moreover, careful analysis and discussion on the problems in the context and application prior to introducing the internationally developed indicator is needed. It is also proposed as another plan to promote the development of these new tools and indicators through cooperative studies among similar post catch-up countries.

However, the limitations and statistical discussions on the composite index or the individual indicator have not been discussed in detail in regards to the comprehensive discussions and comparison of the science, technology and innovation index. It is because this study is an exploratory one aimed to create awareness that there are national context and innovation stage differences and to not focus only on introducing the indicators of advanced countries. Therefore further research, study and discussion are needed. This study didn't cover the various new methodologies such as the Technology Barometer– the evaluations based on the indicators only deal with the ex post studies; therefore, it is necessary to integrate prospective surveys of the expert group as in the example of Finland (Loikkanen et al., 2009). Further studies are required in the policy diagnosis plans that can be utilized in many ways beyond the composite index.

## 5. Reference

- Archibugi, Daniele, Mario Denni and Andrea Filippetti, (2009), The Global Innovation Scoreboard 2008: The Dynamics of the Innovative performances of Countries, Measuring Innovation Thematic Paper.
- Cho, Man-Hyung and Kim, I-Su (2010), A Study on the research capability diagnosis model and development of index in research institutions, *Government and Policy*, 2(2):77-107.
- Cho, Sung-Pyo, Park, Sun-Young, Han, Gi-In and Roh, Min-Sun (2010), A Plan to Writing Corporate R&D Activities on Sample Surveys, *Technology Innovation Study*, 17(2).
- European Commission Enterprise and Industry, (2010), European Innovation Scoreboard(EIS) 2009, PRO INNO EUROPE PAPER No 15.
- Frietsch., Rainer, G. Karlsruhe, (2006), Measuring and benchmarking innovation performance, <http://www.oecd.org/>

- dataoecd/29/6/37737701.pdf
- Gault, Fred, (2007), How Far and Fast can we go?, Eurostat 32nd CEIES Seminar: Innovation indices-more technology?
- Graversen, Ebbe Krogh, Karen Siune, (2008), Statistical Indices for R&D and Innovation: A Guide for Interpretation and Valuation, NIND Policy Relevance Nordic Innovation Indices Synthesis Report Deliverable D10 WG Innocate, NIND.
- Grupp, Hariolf, Torben Schbert (2010), Review and new evidence on composite innovation indices for evaluating national performance, *Research Policy*, 39:67-78.
- Grupp., Harolf, Mary Ellen Moguee (2004), Indices for National Science and Technology Policy: Their Development, Use, and Possible Misuse, H.F Moed et al.(eds.), *Handbook of Quantative Science and Technolgoey Research*.
- Hartmann, Dominik (2007), Understanding the Lisbon Strategy and policies from a Neo-Scuumpeterian point of view, *Revista Universitaria Europea*.
- Hollanders, Hugo & Adriana Cruysen (2008), Rethinking the European Innovation Scoreboard: A New Methodology for 2008-2010.
- Hollanders, Hugo & Adriana Cruysen (2008), Rethinking the European Innovation Scoreboard: Recommendations for further improvements, Input paper for the workshop on Improving the European Innovation Scoreboard methodology(Revised version)
- Hu, Mei-Chin, John A. Mathews (2005), National innovative capacity in East Asia, *Research Policy*, 34:1322-1349.
- Hwang, Suk-Won (2006), Evaluation of SCI and R&D Performances, STEPI.
- Kim, Gyeong-A (2008), Influence of local industrial structure and cooperative network on market-leading technology innovation, *Korea Governance Journal*, 15(1).
- Lepori, Benedetto, Rémi Barré and Ghislaine Filliatreau (2008), New perspectives and challenges for the design and production of S&T indices, *Research Evaluation*, 17(1):33-44.
- Loikkanen, Torsti, Toni Ahlqvist, Pekka Pelline, (2009) "The role of the technology barometer in assessing the oerformance of the national innovation system, *Technological Forecasting & Social Change*, 76:1177-1186.
- Ludvall B-A, Jan Vang-Lauridsen, KJ Joseph, in Lundvall, B-A., Joseph, KJ., Chaminade, C. and Vang, J. (2009), Innovation policies for development: towards a systemic experimentation based approach, *Handbook of Innovation Systems and Developing Countries*, pp. 360-379. Edward Elgar.
- Ministry of Science and Technology and KISTEP (2007, 2010), 「2006, 2009 National Science and Technology Innovation Evaluation」.
- Norden (2009), *Nordic Innovation Monitor 2009*
- OECD & Eurostat (2005), *Oslo manual*, 3rd edition
- OECD (2003), *Composite Indices of Country Performance: A Critical Assessment*.
- Park, Dong (2004), Concept and promotion strategy of Innovation-leading economy, *Applied Economy*, 6(2).
- Patel, P., Pavitt, K. (1999), Their measurement and interpretation, In: Stoneman, P., (Ed), *Handbook of Economics of Innovation and Technological Change*, Blackwell Handbooks in Economics, Oxford.
- Rodik, D. (2008), *The New Development Economics: We Shall Experiment, But How Shall We Learn?*, Working Paper, [Http://ksghome.harvard.edu/~drodrik/](http://ksghome.harvard.edu/~drodrik/).
- Schibany, Andres, Gerhard Streicher (2008), The European Innovation Scoreboard: drowning by numbers?, *Science and Public Policy*, 35(10):717-732.
- Shin, Hyuk-Suk, Um, Jun-Yong, Roh, Myung-Soon, Choi, Bo-Yun and Kim, Yun-Jin (2008), A study on the higher education competitiveness index (I): Comparison and implications of competitiveness index of international universities, *A Study on Human Resources Development*.
- Song, Wi-Jin and Kim, Byun-Yun (2004), Characteristics and changes in the science and technology activities in the public sector in Korea, *Technology Innovation Journal*, 7(3).
- Sung, Ji-Eun (2006), Changes in policies and administration system in the post catch-up stage, *A Study on Science and Technology*, 6(2):45-75.
- Tijssen, Robert, Hugo Hollanders (2006), *Using Science and Technology Indices to support knowledge-based economies*, Policy Brief, United Nations University, 2.
- Veugelers, R (2007), Developments in EU statistics on science, technology and innovation: takinnng stock and moving closer to evidence-based policy analysis, In OECD (2007), *Science and Technology and Innovation Indices in a Changing World: 33-45*. Paris: OECD.
- Yim, Yun-Chul (2004), *A Study on the Development of National Innovation Evaluation Index*, Ministry of Science and Technology.