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R&D Trends Monitoring through Scanning Public R&D Investments: The Case of Information & Communication Technology (ICT) in Meteorology and Climatology

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Abstract Public R&D investment information has diverse implications for researching R&D trends. Also, as it is important for the establishment of R&D policy to grasp the current situation and trends of R&D to improve science and technology level, science and technology information service system, such as NTIS (National Science & Technology Information Service), is operated at a national level in most countries. However, since the data forms provided by current NTIS are raw data, it is necessary to develop the R&D performance indicator or to use additional scientometric methods by analyzing scientific papers or scientific R&D project information for grasping R&D trends or analyzing R&D task results. Thus, this study applied public R&D investment information to investigate and monitor R&D trends in the field of information & communication technology (ICT) of meteorology and climatology by using NTIS data of Korea and NSF (National Science Foundation) data of USA.

Keywords Public R&D investment, public R&D, R&D trend monitoring, meteorology, climatology, ICT

I. Introduction

In a knowledge-based society, it is important not only to create new knowledge but also to manage and systemize existing knowledge and deduce implications for its utilization. Since it is one of the key factors that improve national competitiveness of science and technology, the concept of National Knowledge Management System emerged as a significant notion of national

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strategy (Jang, 2002). In order to keep pace with this situation, National Science & Technology Information System (hereafter NTIS) was constructed in 2006 and has been providing diverse information about national science and technology in Korea (Yang et al., 2013).

In the early part of NTIS, its system was aimed primarily at R&D managers such as policy decision makers, persons in charge at R&D management institution, and so forth, because of the fact that its objective was to provide the information infrastructure for establishing and supporting the R&D ecosystem of virtuous circulation to enhance R&D investment efficiency and spread R&D achievement. However, with the passing of time when the demands for opening and sharing R&D information increase, currently NTIS provides R&D information and various services to any citizens of South Korea (Ministry of Science, ICT and Future Planning, 2013).

Nevertheless, since the data provided by current NTIS are raw data, it is necessary to develop an R&D performance indicator or to use additional scientometric methods by analyzing scientific papers or scientific R&D project information for understanding R&D trends or analyzing R&D task results (Ha et al., 2009). If so, it will enable R&D planning to be upgraded and evidence-based through heightening the practical value of data provided by NTIS.

Thus, this study examines the current situations and trends of R&D by utilizing the information of public R&D investment and applying scientometric methods. In particular, this study adopts the field of information and communication technology (hereafter ICT) related to meteorology and climatology as the research object, because public concern comes to the fore in these fields. Through this research, this study offers the method for validating R&D trends more objectively and reliably.

II. Theoretical Background

1. ICT on Weather and Climate Research

There is vibrant research on climate change carried out across the world because of abnormal climate status like El Niño, La Nina, and so forth. Many research and investment are ongoing to predict climate changes by using climate change model based on ICT and database to find strategies to cope with risk factors of climate change (Leiserowitz, 2006). Researches on climate change prediction modeling by using ICT are also performed actively in fisheries and the agricultural sector (Shaik et al., 2011).

The field of 'Green-by-IT', which means technologies to cope with climate changes by utilizing ICT, is also one of the biggest research flows on weather and climate-related ICT. These technologies enable many industries to conduct their operation in the most efficient way and reduce harmful effects on environment simultaneously by using ICT in many industrial areas that can affect to climate change, such as transportation, construction, and manufacturing (Kim et al., 2009).

2. Technology Foresight Activity and R&D Trend Monitoring

Technology foresight activity consists of all processes that synthetically connect the relative variables and various factors that get involved in planning policies, making decisions or establishing strategies of R&D (Martin, 2010). In contrast to technology forecasting that focuses on the just methodology to find out which technology would emerge or where each technology operates, technology foresight has the objectives to comprehend the diverse relations of dynamics surrounding each technology clearly (Jung et al., 2015). Miles et al. (2008) defined five generations of the development of technology foresight and revealed characteristics respectively, as described in Table 1.

Table 1 Five generation of technology foresight

Generation	Key words	Innovation Theory	Core knowledge/ Participants	Rationale
1st	Technology forecasting	Linear model	Experts of technology or futurology	Economical scheme
2nd	Interaction between technology and market	Mode2 knowledge (Gibbons et al.,1994)	Scholar, Researcher and manger in company	Market failure
3rd	Expansion to widespread society, Expansion of Methodology	Mode2 knowledge (Gibbons et al.,1994)	Interest groups, Consumer groups, etc (Diverse social stakeholders)	System failure
4th	Distributed role in the science and innovation system	Industrial ecosystem, Open innovation	Multiple organizations beyond a single policy sponsor	System failure
5th	STI (Science-Technology-Innovation) system	Innovation system theory	Collaboration between experts of science and technology and diverse stakeholders	System failure

Note: Georghiou et al., 2008

The Korea Institute of Science and Technology Information (hereafter KISTI) carried out the research, which makes it possible to structure the evidence-based technology pool that has a possibility to be promising by utilizing this technology foresight activities to establish national strategic planning system for exploring future emerging and promising technologies. It is important for discovering emerging technologies to secure relative source data. Based on these source data, such as patents, papers, and diverse public R&D data, scientometric R&D trend monitoring can be performed by more objective and evidence-based methods as part of the 5th generation foresight activity (Kang, 2015).

This study monitors R&D environment by utilizing technology foresight method and investigated R&D trends in the field of ICT relative to meteorology and climatology by using scientometric methods.

3. National Science and Technology Information Service (NTIS)

3.1 Data Quality Research

NTIS consists of databases regarding national research and development (R&D) information including R&D project, infrastructure, and project output from 17 departments and ministries (16 specialized national institutes) since 2006. After 2010, NTIS tried to provide high-quality national R&D data through the NTIS enhancement project. (Yang et al., 2013)

NTIS is providing service to find meaning among each national R&D object by using the semantic web. This is based on proceeding research about meaning-base service. Those meanings are extracted from national R&D ontology by using relationship among information objects. (Yang et al., 2012)

Shin et al. (2011) drew significant results on qualifying national R&D database of NTIS. They designed integrated model of the database for providing real-time service and set the data selection standard to remove errors can lower error rate and enhance overall quality.

3.2 NTIS Service Enhancement Research

As user groups become diversified, research on service differentiation according to information types, patterns, and ways of presentation has been started (Lee and Son, 2013). Those researches include user differentiation methods, user interface research to provide appropriate information to users (Nam et al., 2016).

Ha et al. (2009) pointed out that raw data of NTIS couldn’t provide comparison data of R&D output from the point of view of users, so they suggested that NTIS need to introduce R&D performance indicators.

Lee et al. (2014) developed 14 customer value indicators for NTIS to maximize the information customer values of national R&D information service and they also found that time-saving factors, such as value gained versus effort, reduced time for research idea investigation are the most significant for customer satisfaction.

3.3 NTIS Link and Application Research

As demands on the link with R&D management system and R&D information convergence service increase, researches to meet those needs are ongoing in many different ways.

Choi et al. (2011) analyzed the existing information link system to connect NTIS and independent systems of each department and ministry. Lee et al. (2013) investigated the case of the information navigation system to develop a method to link between National Digital Science Library (NDSL) and NTIS as part of the project for developing the national R&D information convergence services.

Hwang et al. (2015) suggested data analysis method for enhancing R&D pre-planning by using network analysis with statistic software in the case which NTIS had been applied to set up the strategy for utilizing plasma technology.

Han et al. (2015) concluded that information analysis using NTIS R&D database could satisfy the demands of information analysis from industry. Based on this conclusion, they proposed NTIS information analysis service plan and discussed platform link plan as well.

Shin and Kim (2015) found long-term R&D trend of dentistry by using national science and technology statistic data of NTIS, discussed problems of R&D of dentistry and their solutions.

III. Research Methodology and Structure

1. Data Collection and Refinement

Raw data concerning national R&D information of South Korea were collected through the NTIS system. The data regarding projects, which are carried out by relevant departments or ministries as well as the Meteorological Agency in South Korea in the field of meteorology and climatology from 1994 to 2014. The total projects are 6,037 cases, and 75 cases are extracted and analyzed which are classified as the field of ICT according to National science & technology standard classification. Additionally, to complement the small size of data, 1,181 R&D paper data were used collected from Web of Science (hereafter WoS, Thomson Reuters, Philadelphia, USA).

In the case of collecting data from the National Science Foundation (hereafter NSF) of the United States, STAR METRICS® system (Science and Technology for America's Reinvestment Measuring the Effects of Research on Innovation, Competitiveness and Science. www.starmetrics.nih.gov) is used in this study. They stored and provided the information on public R&D investments in the US. A total of 756 project cases were downloaded relative to research objects and performed from 1995 to 2016.

2. Data Analysis

So as to understand the current R&D situations of relevant fields, keywords, which are extracted from each project, are analyzed. Each keyword has the information of fractional budget, which is allocated to it. In this study, the fractional budget allocated to keywords has the operational definition which means already invested R&D budget scale.

Embodying R&D topographic map is one of the scientometric analytic methodologies based on co-occurrence matrix method. This study utilized visualization system which can embody similarity measurement and clustering technique simultaneously. Vantage Point® (Search tech, Inc) system is used for extracting each element from field and VOSViewer system (Leiden University, the Netherlands) for finally visualizing the R&D contour map.

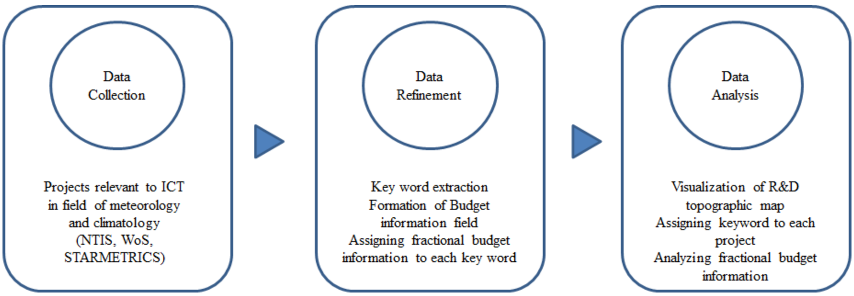


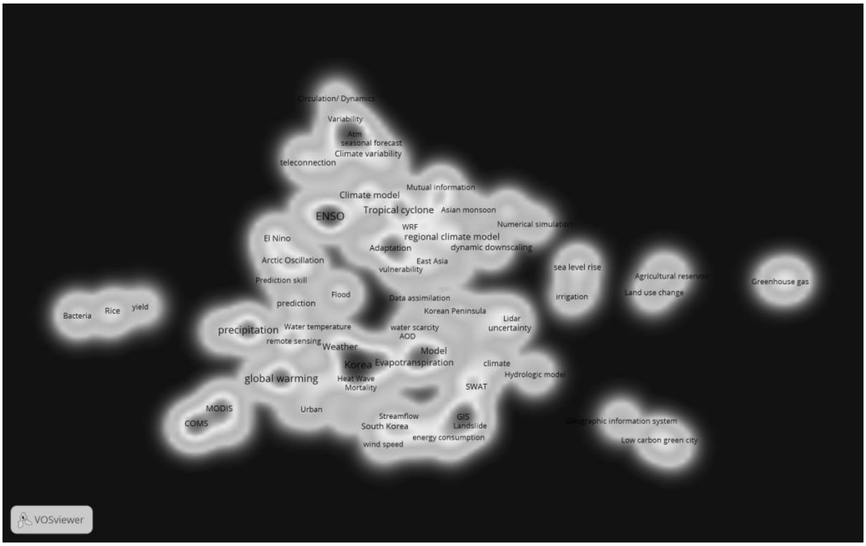
Figure 1 Process of analyzing the data

IV. Research Results

1. R&D Topographic Map Results

1.1 R&D Topographic Map of South Korea

R&D contour map regarding ICT relevant to meteorology and climatology of South Korea is presented in Figure 2. The article data of relevant fields, supplied by WoS, are used for this analysis. The number of keywords in this map is 176.



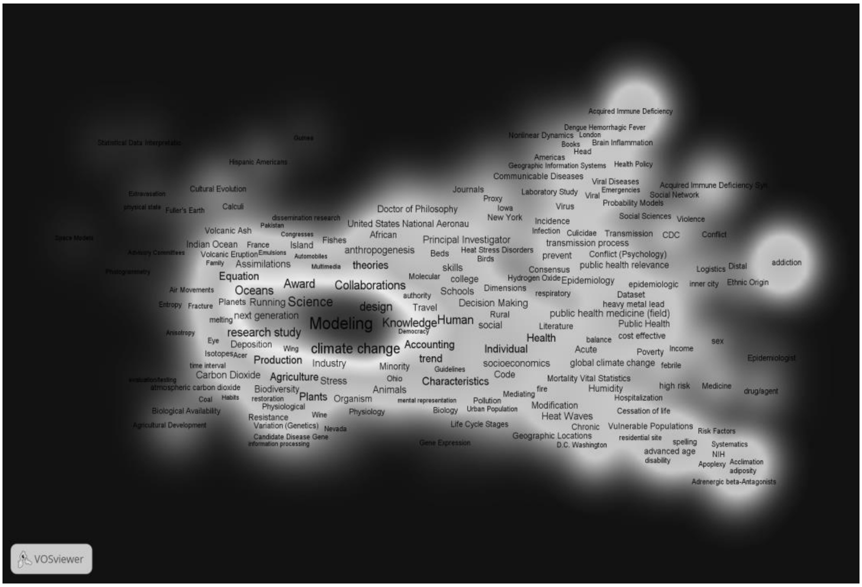
Note: Article data of the Web of Science by the keyword co-occurrence matrix

Figure 2 ICT on meteorology and climatology, South Korea

In South Korea, this R&D contour map shows that research regarding weather information, weather forecasting / modeling, meteorological telecommunication, and meteorological satellite is actively carried out. Judging from the fact that there are a number of keywords concerning natural disasters in this R&D contour map, this research is mainly concentrated on predicting, observing or preventing the climatic damage.

1.2 R&D Topographic Map of USA

R&D contour map regarding ICT relevant to meteorology and climatology of USA is presented in Figure 3. The project term data of relevant fields, provided by STARMETRICS, are used for this analysis. The number of keywords used in this map is 3,219.



Note: NSF data by the keyword co-occurrence matrix

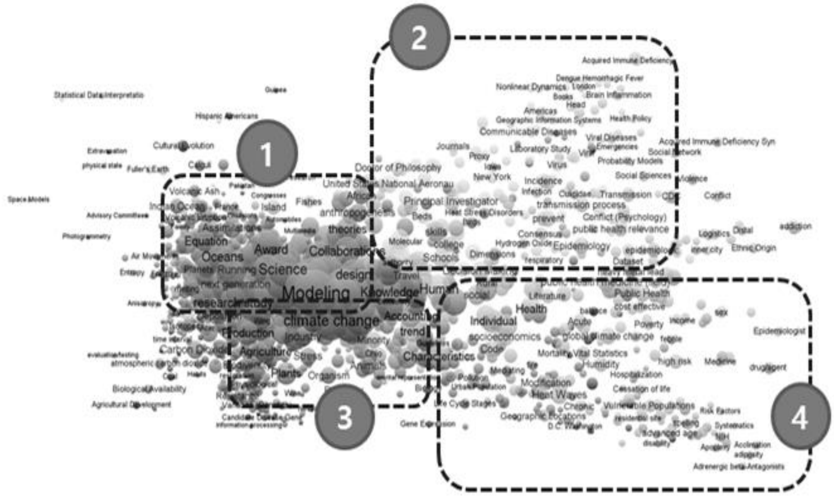
Figure 3 ICT on meteorology and climatology, USA

In the case of the US, the focus on 'climate change modeling' is the research subject. To examine more specific research fields, the additional clustering analysis was conducted. Based on the criteria of the cluster over a certain size, there are four clusters in this clustering map as shown in the following Figure 4.

The red cluster (number 1 in the figure), can be regarded as the research field of modeling the climate change and the number 2 yellow cluster consists of the keywords concerning the biology or medical science for diseases and epidemics arising out of the climate change.

In the number 3 blue cluster, there are key words about agriculture and food production which may be changed because of climate change. Finally, the number 4 green cluster is comprised of keywords regarding public health research. Judging from the clustering map, research projects of USA can be looked upon far-sighted national research programs to cope with climate change.

Figure 5 shows the R&D contouring map embodied on the basis of keyword weighted with the fractional budget. The research field invested over-whelmingly with a big budget is modeling climate change in common with the results of R&D contour map based on keyword co-occurrence matrix. Also, budget over a certain size is invested to polar and oceanic researches.



Note: NSF data by the keyword co-occurrence matrix

Figure 4 Clustering map of ICT on meteorology and climatology, USA

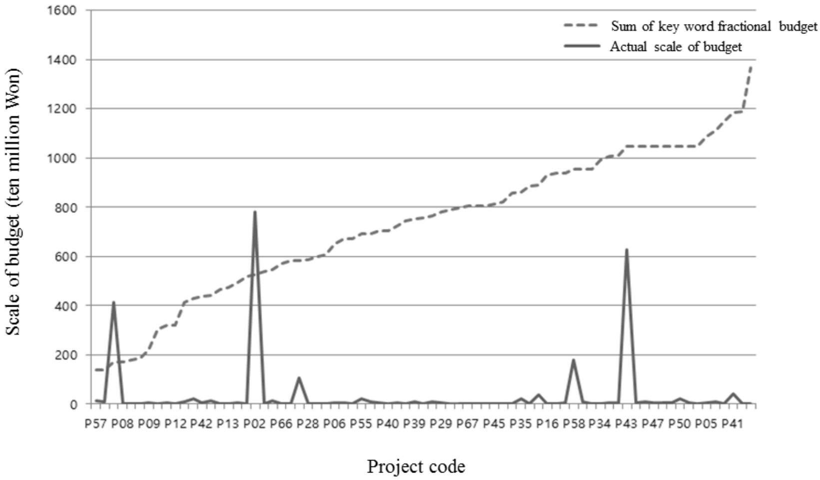
Note: NSF data

Figure 5 ICT on meteorology/climatology by keyword weighted with budget, USA

2. R&D Trend Monitoring Results

2.1 R&D Trend of ICT on Meteorology and Climatology of South Korea

The investigation of R&D trend in relevant research field is conducted to give weight to each keyword with fractional budget and sum up these values in accordance with respective projects based on the data of NTIS (Figure 6).



Note: NTIS data

Figure 6 Budget of ICT on meteorology and climatology of South Korea

The more frequently used the keywords, the larger the sum of the fractional budget given to keywords. Namely, it means that the projects located on the right side of the graph have already been invested considerably.

In fact, most of the projects situated at the left side of the graph, which have a small fractional budget, is the research regarding weather-observing satellite, weather satellite sensors and so on which are at the early stage of R&D and can be regarded as source technology. On the other hand, most of the projects situated at the right side of the graph, which have a big fractional budget, are the researches regarding weather forecasting service, decision making in the event of natural disaster and so forth which have already been advanced.

However, in this study, since the only small size of NTIS data (75 project cases) were collected, it is impossible to draw a conclusion from these results rashly. To get the accurate analysis, it is necessary to collect additional relevant data set.

Table 2 Examples of project title according to the location of graph (Based on NTIS)

Project code	Project title
Project Examples having Low Sum of Fractional budget (Left side of graph)	
P57	Prediction of solar flare and developing the model analyzing CME
P04	Development of Satellite/TETRA Service Testbed for manage disaster
P07	Development of the Oceanic and Meteorological Communication Satellite
P09	Measuring the change of the surface of the earth by utilizing Satellite SAR
Project Examples having High Sum of Fractional budget (Right side of graph)	
P65	Strategies for Advancement of Oceanic and Meteorological Information Service
P33	Simulation of Regional Disaster and Modeling of the response system
P17	Decision Making Support System in the Situation of Volcanic Eruption

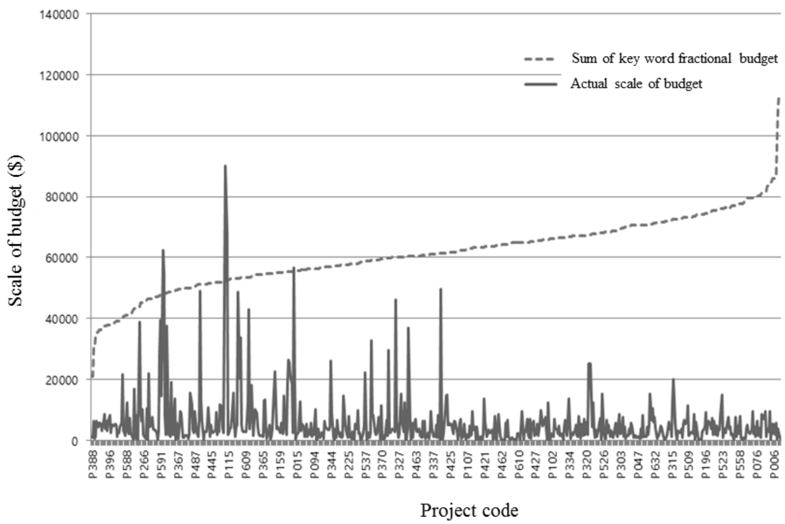
2.2 R&D Trend of ICT Relevant to Meteorology and Climatology of USA

In the same method, R&D trend of USA in the relevant field is analyzed (Figure 7).

Table 3 Examples of project title according to the location of graph (Based on NSF)

Project code	Project title
Project Examples having Low Sum of Fractional budget (Left side of graph)	
P398	The impact of climate and climate change on west nile virus transmission
P033	Vulnerability to health effects of wildfires under a changing climate in western
P268	Extreme events impacts on water quality in the great lakes: prediction and management of nutrient loading in a changing climate
Project Examples having High Sum of Fractional budget (Right side of graph)	
P078	Climate feedbacks in the Antarctic from stratospheric balloon gps radio occultation soundings
P093	Application of a successful laboratory model to atmospheric science
P232	Idealized modelling of stratospheric impacts on weather and climate
P336	Current climate and numerical weather prediction,mn General Circulation Models (GCMS)

Under the premise that these results also show the same aspect like the former analysis, the project titles located at the right or left side of the graph are examined (Table 3).



Note: NSF data

Figure 7 Budget of ICT on meteorology and climatology of USA

The research subjects of projects on the right side are mainly regarding atmosphere or meteorological condition in certain regions. Also, in these researches, modeling of climate change has the big-budget scale and is prominent. The research subjects of projects on the left side are the researches which investigate diverse possible risky events and disasters affected by climate change and provisions or management for coping with them.

In addition, according to Figure 7, the actual budget scale of the left-side projects are bigger than the right side. It means that R&D investment trend in the US reaches forward to take a long-term view and they invest the large parts of their R&D budget in the research studying the actual influence to humankind.

V. Conclusions

This study performed R&D trend monitoring as part of the technology foresight activity by utilizing public R&D investment information in the field of ICT relative to meteorology and climatology. As a consequence, South Korea has carried forward public R&D projects designed to focus on technology, hardware and big science. In particular, technologies relevant to weather satellite and its sub-techniques are allocated substantial budget.

On the other hand, based on the results of NSF data analyzed, the US has invested in the research area concerning climatological and oceanic condition modeling for a long time. They have consistently investigated the impact and mechanism of climate change.

These results allow us to know that this field-related policy direction of South Korea may focus on the short-term and tangible results excessively rather than secure the source technology or improve the overall national level of science and technology.

However, since collected public R&D data of ICT relevant to Meteorology and Climatology of South Korea was quite a small size, these results are undeterminable. Nonetheless, by qualitative analysis for research projects of both South Korea and the USA, it is certain that there are significant qualitative differences between two countries.

On the basis of the methodologies used in this study, it is possible to monitor R&D trend in the diverse field of science and technology by utilizing the information of public R&D investment.

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