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Reflection and Challenge for Science and Technology Policy Studies in Korea[1]

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Abstract We have identified the paradigm, the knowledge structure, and the roles of S&T policy studies in Korea by empirical analysis and focus group interviews. First, it provisionally concluded that S&T policy studies in Korea are still in the pre-paradigm stage. Specifically, the level of consensus among scholars about the "academic definition of discipline" and "research scope", which is essential for an independent discipline, is still low. Next, a great part of the existing S&T policy studies in Korea is excessively weighted in specific research scopes and researcher groups. For a balanced development as an academic discipline, such imbalance must be overcome. Third, the studies in Korea showed that much of the research in the earlier stage was fragmented at the micro-level. More recently, however, S&T policy studies show co-evolutionary patterns, which increase the responsiveness of the society. Based on this analysis, the future direction of studies should form a unique flow of our own, building Korean policy cases and models rather than following those developed countries.

Keywords Science and technology policy, S&T policy studies, paradigm, role, knowledge structure

I. Introduction

Korea's science and technology policy has achieved remarkable growth and development owing to the interaction between the policy field and the academic community for the last 50 years. Especially notable is the fact that the academic

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community has contributed considerably to solving the emerging policy issues during the past years. Despite the achievements in the subject in terms of the policy itself, there has been a question whether the same thing can be said of its academic side. Even though the need for a modern science and technology policy came to light in Korea some 50 years ago, and subsequently 30 years of research has been done on the topic, it is our view that only those pressing issues on the surface have been dealt with by academia that essentially neglected to establish theories that would help secure the identity of this field as an independent discipline and enhance its ability to solve problems. It is from this point of view that we raised the following research questions:

1. Is the science and technology policy studies (hereafter, S&T policy studies) recognized as an independent discipline and differentiated from others?
2. What subjects have been covered during the development of S&T policy studies and what type of a knowledge structure was formed by the findings?
3. Do S&T policy studies reflect social issues thoroughly and in a timely manner, and are the findings reflected in the government policy at the right time?

Both quantitative and qualitative methods were employed for the current study. In the quantitative study, we analyzed the knowledge base manifested in books and research papers published by the academic community, and policy reports produced by the authorities for the past 30 years. In the qualitative study, we conducted a Focus Group Interview (FGI) with a total of 6 participants, who represented a government-funded research institute, a research agency, a university professor, and a postgraduate student. The participants discussed the Fourth Industrial Revolution, directions for science and technology policy, and the roles of the researchers in the future. Through the FGI, we identified the problems the direct stakeholders were aware of and the kinds of their expectations and ideals of science and technology policy. We also learned about the various views of the researchers, in the field of science and technology policy.

A mixed method of a quantitative-qualitative model is ideal for S&T policy studies, which is a highly interdisciplinary field of study. By utilizing this method for our research, we aimed to prove that the description of the current situation (the diagnosis) and the solutions (the prescription) do not run against each other. We also hoped that the findings of this research would strengthen the identity of S&T policy studies as an independent discipline and help increase policy utilization in the future.

II. Empirical Analysis for Status of S&T Policy Studies

1. Aims

The main purpose of the current study was to analyze the paradigm, the knowledge structure, and the role of S&T policy studies in Korea. We started out by reviewing the literature to answer the first research question: Is S&T policy studies recognized as an independent discipline and differentiated from others? We drew the definition of science and technology policy as a field of study in Korea and its research scope, both of which are central to its paradigm formation. We then made suggestions based on our findings for a new definition and a new research scope for the discipline. The second purpose of our research was to analyze the knowledge structure by building a data set from the literature in order to understand what role the research in science and technology policy plays in helping comprehend its identity and concept. To answer our third research question concerning the role of S&T policy studies, we examined how the social issues, academic research, and science and technology policies have interacted with one another since research in the topic started to vitalize the field in Korea. The findings showed whether the demands for policies regarding social problems have ultimately been linked to the government's policy-making decisions with the help of academic research.

2. Method

2.1 Research Objects

Three types of objects were employed for the quantitative study: books, research papers, newspaper articles on science and technology policy, R&D management, and technology innovation, and policy reports from the Ministry of Science and Technology. Nineteen Korean textbooks were reviewed for exploring the discipline paradigm. They were selected because they covered the general subjects concerning science and technology policy in Korea across the board. These literature varied in their topics depending on the authors' academic background and their research perspectives, which we classified into three groups: policy sciences perspectives, technology innovation perspectives, and technology management and economic perspectives. Out of the 19 titles, six were written from the policy sciences perspective (Lee, 1990; Kim, 1993: Yoon, 2006: Choi, 2011; Lee et al., 2011; Hong, 2016); seven from the technology innovation perspective (Kim & Lee, 1982; Park, 1983: Seol et al., 1997; Lee, 2000; Song, 2006; Lee, 2008; Seol, 2011); and six from the technology innovation perspective (Park et al., 2001; Kim, 2003; Lee et al., 2005; Hyun et al., 2006; Jeong, 2006; Lee & Jo, 2013).

Table 1 The handbook of S&T policy studies

No	Author	Year	Title	Perspective
1	Insoo Kim & Jinjoo Lee	1982	Process and Policy of TI	TI
2	Yongchi Park	1983	Diffusion Process of innovation	TI
3	Gajong Lee	1990	Strategy of TI	PS, TI
4	Jongbeom Kim	1993	Theory of S&T Policy	PS
5	Sung-Soo Seol et al.	1997	TI and Industry, S&T Policy	TI, TE
6	Gongrae Lee	2000	Overview of TI Theory	TI
7	Woohee Park et al.	2001	Studies on TE	TM, TE
8	Jeonghong Kim	2003	Economics of TI	TM, TE
9	Jongok Lee et al.	2005	R&D management	TM, TE
10	Byunghwan Hyun et al.	2006	Theory of New R&D Planning	TM, TE
11	Seonyang Jeong	2006	Technology and Business Management	TM, TE
12	Jinhyo Yoon	2006	Korea's Theory of Technology Policy	PS
13	Wejin Song	2006	TI and S&T Policy	TI
14	Wonyoung Lee	2008	Economics of TI	TI
15	Seoksik Choi	2011	Theory of S&T Policy	PS
16	Janghae Lee et al.	2011	S&T Policy: Phenomenon and Theory	PS
17	Sung-Soo Seol	2011	TI	TI
18	Youngdeok Lee & Seokhong Jo	2013	TM	TM, TE
19	Heung Deug Hong	2016	Theory of S&T Policy	PS

* Note: Science and Technology (S&T), Technology Innovation (TI), Policy Sciences (PS), Technology Economics (TE), Technology Management (TM)

* Source: Yi et al. (2018: 9), arranged by year

We observed in these books that science and technology policy as a field of discipline has developed in a balanced fashion in Korea to this day. Table 1 shows a summary of these publications.

To analyze the knowledge structure of S&T policy studies, we limited the research objects to the research papers that focused on S&T policy studies and have been published in either of the two main journals on science and technology policy: The Journal of Korea Technology Innovation Society (JKTIS) by Korea Technology Innovation Society (KOTIS) and The Journal of Technology and Innovation (JTI) by Korea Society for Innovation Management and Economics (KOSIME)[2].

To investigate the role of S&T policy studies, we analyzed newspaper articles, research papers, and policy reports from the Ministry of Science and Technology in order to learn about the interaction between social issues and government policies. Hankyoreh, which represents the progressive press, and Chosun Ilbo, which represents the conservative press, were selected for the analysis of newspaper articles.

[2] According to Nam et al. (2005), these two journals shared similar topics on technology and technology innovation. A total of 1,166 research papers published between 1993 and 2016 were analyzed

Table 2 Research objects: knowledge structure

Journal title	Publisher	Period	Number of papers
JKTIS	KOTIS	1998-2016	661
JTI	KOSIME	1993-2016	505
Total			1,166

Table 3 The research object of the role count by period

Period	Year	Newspaper Article		Research Journal		Government
		Chosunilbo	Hankyoreh	JKTIS	JTI	Report
Period 1	2000	54	0	28	17	1
	2001	1,028	0	24	16	1
	2002	1,044	0	34	19	1
	2003	199	0	27	22	1
	2004	394	0	30	34	1
	2005	407	893	53	34	1
	Sub-total	3,126	893	196	142	6
Period 2	2006	283	343	39	29	1
	2007	373	295	34	19	1
	2008	520	521	27	19	1
	2009	336	308	35	16	1
	2010	463	289	37	19	1
	2011	433	349	45	21	1
	Sub-total	2,408	2,105	217	123	6
Period 3	2012	430	289	39	27	1
	2013	410	381	49	31	1
	2014	341	325	34	36	1
	2015	281	345	28	33	1
	2016	405	319	32	21	1
	2017	405	422	-	-	1
	Sub-total	2,272	2,081	182	148	6
Total		7,806	5,079	595	413	18
		12,885		1,008		

The keyword phrase of the search for the newspaper articles was "science and technology", which was intended to be broad so that it returns as many reports on various topics related to science and technology as possible. Out of a total of 12,885 articles our search retrieved, about 1,000 from each year were analyzed to balance out the materials. In Hankyoreh, articles published after 2005 only were available for search, so we collected more articles from Chosun Ilbo published before the year 2005 to match the numbers. In addition, for the analysis of S&T policy studies, a total of 1,008 articles were selected solely from

JKTIS and JTI, the two main academic journals in the field. Their abstracts databases were searched rather than the titles and authors for more detailed search results. To analyze the science and technology policy agendas, we collected the policy reports submitted to the Ministry of Science and ICT[3]. A total of 18 reports submitted to the department of science and technology policy between 2000 and 2017 were analyzed. The main goal was to scrutinize the policy design and planning of the Ministry, currently the Ministry of Science and ICT.

2.2 Research Methods

First, to discuss the paradigms, the books were reviewed to draw a definition of science and technology policy as a field of study and to measure its research scope. Next, for the analysis of the knowledge structure, both descriptive statistics and network analysis were carried out. More specifically, a trend analysis was done to review and compare single- or co-authored papers, regions, institutions, and research performance in each area of study. A keyword network analysis and a cluster analysis were carried out to identify the knowledge structures and examine how the knowledge structures shifted in time with the changes in the government regimes. The appearance frequency and the metrics of the keyword phrase were calculated in KrKwic[4]. The metrics then clustered the keywords in VOSviewer 1.6.5, software highly effective in visualizing and grouping information, so the knowledge structure could be analyzed. A separate analysis was run for each of the governments, based on the assumption that the policies change with the regimes.

To analyze the role of S&T policy studies, the knowledge structure was examined through a keyword network analysis and a cluster analysis, and then the knowledge structure for each period was examined. There were three chronologically equally-spaced periods of six years: (1) 2000-2005, (2) 2006-2011, and (3) 2012-2017. This division was made to rule out any interference of our own views on the social, political and economic contexts and to maximize the objectivity of our research. In order to analyze the semantic structure of the text, the co-word matrix was drawn using Krkwic, and then degree centrality

[3] Although the Ministry of Science and ICT has shifted in terms of its mission and policy areas along with the changes in the government regimes over the years, as is reflected in its many names - 'the Ministry of Science and Technology,' 'the Ministry of Education, Science and Technology,' and 'the Ministry of Science, ICT and Future Planning', they were all regarded as the same Ministry.

[4] KrKwic, short for Korean Key Words in Context, is software adapted from Fulltext for use on Korean texts (Park & Leydesdorff, 2004)

was measured using NodeXL5. Next, a cluster analysis6 was conducted to identify the meaning of the keyword clusters from each period, and a meaning cluster grouped by keywords close in meaning was named "a frame", which refers to the cognitive structures of each domain of social issues, research, and government policies. After that, the degree of interaction among the three domains was measured by comparing the priorities of the keywords cluster. For example, if a keyword cluster was of the same priority during the same period, it was considered that the framework of the three domains was very similar.

2.3 Results and Discussion

2.3.1 Paradigms

1) Reviews of the definition and research scope of S&T policy

This section serves as a starting point for discussing the paradigms of S&T policy studies. The existing literature was reviewed to determine whether it includes a definition of discipline and its research scope, two core elements a field of study needs to be identified either as "the theory of (~론(論))" or "the study of~ (~학(學))", in other words, as an independent discipline, and to examine what details they cover if they do[7]. None of the 19 books had an explicit definition of "S&T policy studies". When no clear definition is given to a particular field of study as an independent discipline, setting the definition of the discipline and its research scope is possible based on the definitions of the subjects and their criteria they used. Therefore, in this study, we examined the definition and the scope of science and technology policy of Korea, which is the

[5] NodeXL is an Excel-based open source software application developed for analysis of social networks, which visualizes the networks according to the values that denote the relationship between words. It is widely used in network analysis for its practicality.

[6] Clustering algorithms are a type of cluster analysis, which utilizes Modularity Q (Neman & Girvan, 2004). Modularity Q calculates the overload in a given network link and selects the network structure as the cluster structure when it peaks. In this theory the density of the link is high within the cluster structure because the nodes are closely connected, while the inter-cluster link is rare and thus the connection between clusters is overloaded.

[7] "~론(論) (The theory of)" and "~학(學) (The study of)" are often cross-used rather than strictly distinguished. According to the National Institute of Korean Language (2016), 'The theory of' is a suffix used for academic fields of studies, while "a study of ~학(學)" is a noun that refers to organized knowledge based on certain principles. When this is applied to the definition of research on science and technology policy as a specialty area of the policy sciences, it would be defined as "the theory of science and technology policy". If, however, research on science and technology policy covers research topics related to science and technology policy, technology policy, innovation policy and stands alone as an independent domain of research, then it could be defined as "S&T policy studies"

topic of S&T policy studies. A total of three out of the 19 books were found to include a definition of science and technology policy as well as its scope (Choi, 2011; Lee et al., 2011; Hong, 2016), all of which were written from the policy sciences perspective. All the other books, on the other hand, were written from the technology management and economics perspective or from the technology innovation perspective, and neither did mention the definition and scope of science and technology policy or partially mentioned the scope only. We determined from this result that the common ground the researchers share concerning S&T policy studies or the policy itself is quite limited. However, some books published after 2010 provided a definition and the research scope of science and technology policy (Choi, 2011; Lee et al., 2011; Hong, 2016) and showed more mature discussions on this topic.

Table 4 Analysis whether there is definition

Definition of S&T policy studies	S&T Policy		Field of Study			Period			Total
	Definition	Scope	Technology Management /Economics	Technology Innovation	Policy Sciences	Before 2000	2000-2009	since 2010	
×	○	○	0 (0.0)	0 (0.0)	3 (50.0)	0 (0.0)	0 (0.0)	3 (60.0)	3(15.8)
×	○	×	0 (0.0)	0 (0.0)	1 (16.6)	1 (20.0)	0 (0.0)	0 (0.0)	1(5.2)
×	×	○	4 (33.3)	4 (57.1)	1 (16.6)	2 (40.0)	5 (55.6)	2 (40.0)	9(47.4)
×	×	×	2 (66.7)	3 (42.9)	1 (16.6)	3 (40.0)	4 (44.4)	0 (00.0)	6(31.6)
Total			6 (100.0)	7 (100.0)	6 (100.0)	5 (100.0)	9 (100.0)	5 (100.0)	19 (100.0)

Next, we reviewed the scope of science and technology policy by examining how science and technology policy was defined in the four books that were found to give a definition of science and technology policy. The result showed that the scope of science and technology policy was gradually expanding from inside to outside of science and technology. Lee (1990), who first defined science and technology policy, limited the scope of science and technology policy to the inside of science and technology; however, Choi (2011) increased the scope of science and technology policy by adding promotion of science culture to Lee's definition and scope. During the same period, Lee et al., (2011) and Hong (2016) also enlarged the scope of science and technology policy from inside to outside by including societal and national problems solving.

Many of the books that discussed the scope of science and technology policy did so from various academic points of view, regardless of which they considered science policy, technology policy, and innovation policy as the core of science and technology policy (Kim, 2003; Lee, 2008, Seol, 2011; Lee et al., 1986).

This view was supported in many other books as well, which included all government policies in the scope of science and technology policy (Ki, 1993; Seol et al., 1997; Seol, 2011; Choi, 2011; Hong, 2016). Some other books,

however, showed tendencies to vary according to the authors' academic background, one of which limited the scope of science and technology policy to the expanded technology management at the national level (Jung, 2006; Lee and Cho, 2013). Therefore, it is necessary to understand that the focus of science and technology policy, as a complementary concept to science policy, technology policy, and innovation policy, depends on the weight of the policy issues the current society and the state have to deal with.

2) Proposals for a new definition and a new research scope of S&T policy studies

In this section, we discuss and propose a new definition and a new research scope of S&T policy studies with a view to securing its domain as an independent discipline in the future, while at the same time embracing the opinions of the existing researchers. "New" because, despite basing our proposals on the existing studies, we expect the national and societal demands of the changing roles science technology policy in the government policy processes to be reflected in the newly-proposed definition and research scope.

(1) The definition of S&T policy studies in accordance with the changing roles of science and technology

S&T policy studies are a discipline that approaches the science and technology phenomenon from the point of policy sciences. While it promoted the development of science technology itself and concentrated on economic growth in the past, the focus has been shifting to the problem-solving perspective, which utilizes science and technology as a policy means to help solve various national, economic, social, and cultural issues around the world. Therefore, we define S&T policy studies as “an applied policy sciences” which (a) promotes the development of the science and technology itself and (b) utilizes the science and technology to enhance the problem-solving ability of the state and the public sector by analyzing and studying the various political, economic, societal and cultural phenomena relevant to science and technology and related activities. The proposed new definition can be further elaborated in terms of the research objects, goals, and application of S&T policy studies as follows: First, in addition to the basic “science and technology activities” such as science, technology, science and technology, and innovation, S&T policy studies should investigate the interaction between science and technology and politics, economy, society and culture. Second, the purpose of S&T policy studies should not be limited to the primary goal of seeking its promotion and quality development, but it should also aim at ultimately solving various policy problems in the public sector using science and technology. Third, the characteristics of S&T policy studies as applied policy sciences, should be emphasized so that it analyzes science and technology and its related societal

phenomena theoretically and helps enhance its own ability to solve the policy problems identified.

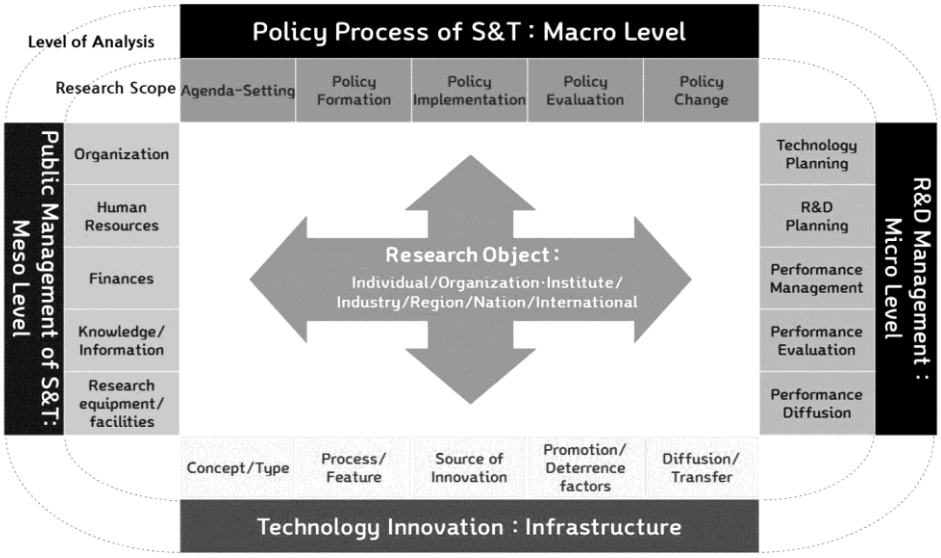
(2) The research scope of S&T policy studies

Based on the discussions so far, we propose the following as the new research scope; (a) policy process of science and technology, (b) public management of science and technology, (c) R&D management and (d) technology innovation. The scope of the discipline should be balanced among these four areas, according to the changes in the role of science and technology policy in the society. "Policy process of science and technology" and "public management of science and technology" are new areas that the current study suggests, reflecting on the newly proposed definition of S&T policy studies, and "R&D management" and "technology innovation" have been already dealt with in most of the existing studies. Each of these four areas of the studies contains more or less about five sub-areas. Although the analytic level of the four research scopes may somewhat differ depending on the specific analysis object, policy process of science and technology is mainly focused on the macro-level content of the whole country, public management of science and technology on the meso-level of the relevant government ministry and research agencies, and R&D management on the micro-level of national and public research institutes and individual researchers. On the contrary, technology innovation is not limited to some specific levels of analysis, but rather it will play the role of essential infrastructure in all levels of analysis. On the other hand, the analytic objects of the four research scopes will include all or some of the individuals, organizations, institutions, industries, regions, nations, and international affairs. That the analytic levels of S&T policy studies will cover various objects from individuals on the micro-level to nations and international affairs on the macro-level shows how interdisciplinary and complex the study is. Overall, putting together the four research scopes, the levels of analysis, and research objects, the relationship between the scope of science and technology policy and each research scope can be schematized as in Figure 1.

In the following section, we normatively discuss why the proposed four research scopes should be included in the research scope of S&T policy studies so that it forms the paradigms that are necessary for it to be recognized by the academic community.

We also suggest future directions for balanced development of the four scopes. First, "policy process of science and technology" should be set as an important research scope to study the overall policy activities such as policy formation, implementation, and evaluation that take place around the science and technology activities. The sub-scopes of the policy process of science and technology are similar to those of the general policy process, such as agenda-

setting, policy formation, policy analysis, policy implementation, policy evaluation, and policy change.



Source: Yi et al. (2018: 22)

Figure 1 Suggestion of research scope in S&T policy studies

The second research scope is the public management of science and technology, concerning the effective mobilization and management of resources required to implement S&T policies. In general, the sub-scope of studies in public management of science and technology include organizational management, R&D human resources management, financial management, and knowledge & information management using theories of public or business administration. In addition to the above-mentioned general resources in the public sector, large-scale research equipment and facilities are used as important resources in the field of science and technology. Therefore, organizational management, R&D human resources, financial management, knowledge & information management, and research equipment & facility management constitute the major sub-scope of public management of science and technology. Third, R&D management should be considered an important research scope in S&T policy studies, as it is directly linked to R&D and related matters, the keys to technology innovation. R&D management also needs to include a series of activities that take place in the field that shape up the contents of technology planning such as research planning, performance management, performance evaluation, and performance diffusion in the sub-scope of the studies, as well as technology forecasting, required by the nation and the society, and technology

planning that selects the technology areas that require government intervention. Lastly, technology innovation, the major subject of science and technology policy, will have to remain a core research scope in the future as has been. Included in the sub-scopes of technology innovation will be concept and type (Lee, 1990: Lee, 2000), process and feature (Lee, 2000), source (Seol et al., 1997), promotion and deterrence factors (Seol et al., 1997), and diffusion and transfer (Park, 1983; Park et al., 2001), all of which have been major research objects of technology innovation. Looking at the recent situation where technology innovation as well as overall innovation of the society is increasingly important, desirable policy for innovation and rational innovation for policy should be actively studied in the future.

2.3.2 The knowledge structure

In this section, we present our findings from two types of analyses: a content analysis and a keyword network analysis. The content analysis sheds light on the current status of research trends in science and technology policy and the keyword network analysis reveals the knowledge structure of S&T policy studies and the flow of knowledge that shows how the knowledge structure has changed over time. First, the research trends of S&T policy studies were analyzed using content analysis, which calculated the frequencies of appearance of the analysis criteria. Next, the knowledge structure was analyzed using a keyword network analysis, which examines the whole structure by running a cluster analysis of the research topic using a diachronic data set analysis. The flow of knowledge structure was examined for the individual government in order to understand how knowledge such as research topics has changed over time.

1) Research trends of S&T policy studies

As for the number of authors of the research journals, there were 339 cases (29.1%) of single-authored papers and 826 cases (70.8%) of co-authored papers, with the ratios of collaborative research increasing every year. As science and technology policy is highly integrative and complex, expansion of joint research among various fields is expected in the future. When classified by the region the first author was from, the research journals showed a strong regional bias, with about 40% of the studies conducted in Seoul, and about 30% in Daejeon. As for the organization to which the first author belonged, 52.7% of the papers were submitted by universities and 27.1% by government-funded research institutes, which showed that submission of articles by industry researchers or research groups was minimal. Therefore, it is highly advisable that industry strives to be more involved in S&T policy studies so that they can actively express its policy demands.

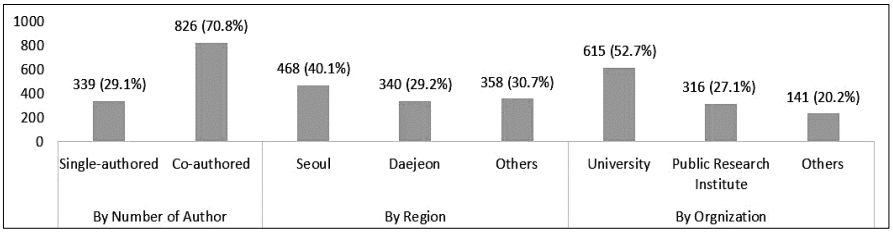


Figure 2 Research trend S&T policy studies

The research scope was classified into four criteria for an analysis according to the four newly-suggested research scopes earlier: policy process of science and technology, public management of science and technology, R&D management, and technology innovation. The results showed that the highest number of papers was written on R&D management and technology innovation, with a total of 403 (34.6%) and 404 (34.6%), respectively. Next up was public management of science and technology, with 239 (20.5%) papers in total, followed by policy process of science and technology, with 120 (10.3%) papers. A total of approximately 70% of S&T policy studies we reviewed focused on R&D management and technology innovation. In order for S&T policy studies to grow into a balanced academic discipline in the future, more research needs to be done on the topics of policy process and public management of science and technology.

Table 5 The research trend by research scope

Research Scope	Frequency (%)
Policy Process of S&T	120 (10.3)
Public Management of S&T	239 (20.5)
R&D Management	403 (34.6)
Technology Innovation	404 (34.6)
Total	1,166 (100.0)

Out of the papers in the sub-scope of policy process of science and technology, the highest number of papers was found to deal with policy evaluation, with 45% of the total. The main topics in this category were policy evaluation and suggestions for future policy, as well as systems and laws. Among the papers classified in the category of public management of science and technology, the largest number of papers (34.7%) focused on knowledge/ information management, followed by R&D human resource management, which accounted for 22.6%. Particularly, in the category of knowledge/ information management, a large number of papers were written on knowledge management system design

and standard system construction. As for the R&D management category, performance evaluation (33.3%) and performance management (29.5%) were the two at the top. In the category of technology innovation, 41.6% of the papers were related to process and feature, and 25.0% of the papers to facilitation/ deterrence factors. In this category, studies for technology innovation were conducted in diverse industrial sectors, with an especially large number of papers on technology innovation in ICT industries. To sum up the results from the sub-scope analysis of the research, it was found that research was most active on the topic of policy evaluation of the policy process of science and technology category; on knowledge/information management of the public management of science and technology category; on performance evaluation of the R&D management category; and on process and features of the technology innovation category. Notably, there have been many researches on evaluation such as policy evaluation and performance evaluation. It shows that S&T policy studies put a heavier weight on evidence-based practical research that can be applied in the R&D field.

Table 6 The research trend by sub-category

Policy Process of S&T		Public Management of S&T	
sub-research scope	Number of Papers(%)	sub-research scope	Number of Papers(%)
Agenda-Setting	32 (26.7)	Organization	42 (17.6)
Policy Formation	16 (13.3)	Human Resources	54 (22.6)
Policy Implementation	11 (9.2)	Finances	48 (20.1)
Policy Evaluation	54 (45.0)	Knowledge/ Information	83 (34.7)
Policy Change	7 (5.8)	Research Equipment/ Facilities	12 (5.0)
Total	120 (100.0)	Total	239 (100.0)
R&D Management		Technology Innovation	
sub-research scope	Number of Papers(%)	sub-research scope	Number of Papers(%)
Technology Planning	69 (17.1)	Concept/Type	53 (13.1)
R&D Planning	35 (8.7)	Process/Feature	168 (41.6)
Performance Management	119 (29.5)	Source of Innovation	42 (10.4)
Performance Evaluation	134 (33.3)	Promotion/Deterrence factors	101 (25.0)
Performance Diffusion	46 (11.4)	Diffusion/Transfer	40 (9.9)
Total	403 (100.0)	Total	404 (100.0)

2) Knowledge structure and knowledge flow in S&T policy studies

The results from the keyword network analysis for identification of the knowledge structure and the knowledge flow can be summarized as follows: First, the top five keywords for S&T policy studies in descending order of

frequency of appearance were: technology innovation, national R&D projects, technology, R&D, and technology transfer. A further network analysis using the top 50 keywords revealed that various research topics were interconnected in the central hub of “technology”, “R&D”, “innovation”, “industry”, “technology”. Next, a cluster analysis was conducted on the sub-structure of the knowledge structure with the author keywords, which yielded a total of 8 clusters. Clusters 1, 2, and 3 were all about R&D management, with a focus on performance management. Keywords in Cluster 3, in particular, were about the research objects of R&D management, such as ventures and small businesses, and major corporations as for the organization, and IT for technology. Cluster 4 was mostly comprised of topics about policy process of science and technology and public management of science and technology, clustered by science and technology policy, R&D expenses, R&D management, and government-funded research institutes. Lastly, Clusters 5, 6, and 7 were focused on technology innovation, particularly with Cluster 5 on innovation systems, Cluster 6 on types and diffusion of technology innovation, and Cluster 7 on open innovation. This empirical analysis of the research topics of S&T policy studies reconfirmed they can be classified into the four research scopes which were normatively suggested earlier. One thing to note here, however, is that the knowledge structure identified in the keywords analysis has mixed topics of research objects and research methods. Itemizing these two topics should help form more systematic research scopes for S&T policy studies.

2) The knowledge flow

In this section, we present the results of analysis of knowledge flow by the period. Early studies conducted during the Kim Young-sam government mainly focused on general topics on R&D human resource and R&D investment.

During the following government of President Kim Dae-jung, the major "takeoff" stage, studies on the construction of technology infrastructure was in the center of the research scene, with the case studies of developed countries such as Japan and the US being actively carried out. Especially during this period, researches about constructing innovation systems with topics such as innovation, innovation systems, region, national innovation system, regional innovation system emerged in earnest. During the Rho Moo-hyun government, when decentralization and balanced national development were the major national agendas, many topics on regional innovation structure such as 'cluster', 'region', and 'network' appeared. During the Lee Myung-bak government, with policy issues about green growth on the increase, the number of researches about “bio” and “energy” multiplied rapidly. Also, a lot of research was done on the topics of national R&D projects and patents.

Table 7 The knowledge structure of S&T policy studies (cluster analysis)

Research Scope	Cluster	Major Keywords
R&D Management	Cluster 1	management outcome, public research institute, collaborative R&D, national R&D projects, technology commercialization, technology transfer, industry-university cooperation, performance evaluation, R&D management, R&D performance, R&D, R&D investment, intellectual property rights, patents
	Cluster 2	analytic hierarchy process, technology, technology forecasting, technology evaluation, bio-technology, factor analysis, promising technology, data envelop analysis, IT, IT industry, efficiency
	Cluster 3	technical valuation, industry, enterprise performance, digital, venture, case study, small-medium enterprise, standard, Korea
Public Management of S&T Policy Process of S&T	Cluster 4	science, S&T human resources, S&T policy, network analysis, R&D expenses, government-funded research institute
Technology Innovation	Cluster 5	national innovation system, regional innovation system, innovation, innovation system, innovation cluster
	Cluster 6	technological innovation, type of technology innovation, diffusion
	Cluster 7	open innovation
-	Cluster 8	Input-output analysis

Lastly, during the Park Geun-hye government, with the arrival of creative economy issues, the application of R&D outputs was a much-stressed topic for research. In summary, S&T policy studies started with general topics such as R&D human resources and R&D investment issues in earlier times, and then gradually moved onto technology innovation, technology transfer, and technology valuation, and most recently to further subcategories, such as innovation systems and open innovation. The knowledge flow of S&T policy studies in the four research scopes moved from general public management of science and technology in the early stage to R&D management such as performance evaluation and performance application, and most recently to technology innovation, along with increasing interests in convergence research. In terms of the network structure, the knowledge structure was not so closely connected in the early days, nor did the research topics diversify. However,

analysis objects and research topics have varied and the knowledge structure has become tighter recently.

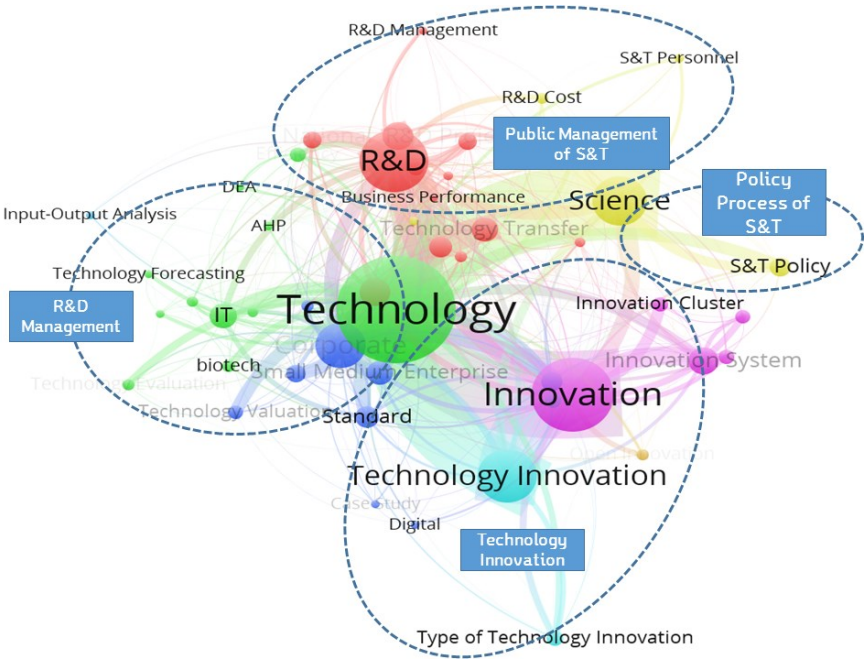


Figure 3 The knowledge structure network of S&T policy studies

2.3.3 Roles: relationship among society, government and academic research

In this section, we identified the three-way difference among society, government, and academic research by comparing the keywords clusters and their contents by the period in order to demonstrate the interaction among social issues, academic research and government policies related to science and technology. For this, the main keywords were extracted for a cluster analysis, and the meaning groups of the clusters were analyzed using the 'frame,' the consciousness or the structure of consciousness of each period and each of the three domains.

Next, we compared the time lag among social issues, academic research, and policy-making by the period in order to evaluate how S&T policy studies responded to the demands of the nation and the society in a timely manner. The ultimate goal of this analysis was to examine how the demands of our society were reflected in S&T policy studies and to what extent initiatives were taken in an effort to solve policy problems. The time lag approach is based on the fact that there is a time difference in policy makers' recognition of the occurrence of problems and changes in policy and that the difference in the time it takes for

policy makers to recognize the problems depends on the influence of the policy process (Jeong et al., 2017). The time lag in recognition means there is a difference between the public's understanding and the policy interest of the government about the social problems, and the time lag between policy-making and implementation means that there is an actual time difference between the government's decision and its implementation. The policy will be executed successfully when the three variables - recognition time lag, decision time lag, and implementation time lag - coincide. Academic research should play a role in increasing responsiveness of science and technology policies to the society by selecting the relevant social issues for research topics at the right time.

1) The first period (2000-2005)

The main topic of social issues related to science and technology at this time clustered into growth engines, national innovation system, science ethics, ICT, and gender. The frames of S&T policy studies clustered into commercialization of public technology, ICT industry, innovation clusters, and organizational capacity. For science and technology policy, the frames clustered into science and technology human resources, R&D centered on government-funded research, national innovation system, and infrastructure design of science and technology. The difference of the clustered frames by period and area is as follows: First, the frames of government policy has been mainly focused on large national R&D projects, hardware infrastructure building, and training of R&D human resources for scientific and technological growth of the nation whereas those of the social issues variously clustered mainly into the following: new growth engines, national innovation system, biosciences ethics, ICT, and gender. Whereas the topics related to economic growth such as new growth engines and biosciences were treated as important agendas for government policies, there was still no policy for bioethics and gender issues. On the other hand, academic research tended to concentrate more on industrial aspects such as public technology commercialization and organizational capacity based on industrial innovation system than on scientific ethics, which had frequently been discussed with regards to social issues. In other words, it can be interpreted as that the scope of academic discipline has been biased toward research focusing only on economic growth through the development of the industrial sector rather than covering the overall social issues.

In the first period (2000-2005) when ICT industry emerged as an active topic of discussion, all three bodies were highly interested in new growth engine and system construction for it. Especially, it was observed that academic research recognized and responded to new growth engine and system construction more proactively. Even though it was observed that the government policy actively responded to the needs for establishing the technology innovation system rather than ICT Industry, it did not appropriately address the social needs related to

science ethics and gender issues, for which no adequate academic research was done, either.

2) The second period (2006-2011)

The social issues related to the science and technology in this period clustered into the education system and innovation, ICT, election issues, and space science. Especially, the keywords related to mobile phones noticeably increased to form a cluster with the arrival of smart-phones, and so did election related issues due to the presidential election in 2007. As for S&T policy studies, commercialization of public technology and ICT industry were important topics and clustered as such. On the government policy side, green growth policy and education policy formed the main clusters. Since the Lee Myung-bak government in 2008, green growth policy has been emphasized, and with the reorganization of Ministry of Science and Technology into the Ministry of Education, Science and Technology, education policy in this period was recognized as relatively important. The cluster framework, therefore, was showing that policy ideas based on "green growth" emphasized sustainable science and technology innovation, and the policy was designed in the direction of connecting the creative education system and training science and technology human resources, which was received with great interest by the society. Therefore, during this period, government policy was affecting social issues. However, the government policy did not comprehensively handle the major social issues such as space science and science and technology education. In addition, the keywords related to eco-friendly science and technology innovation were not found in social issues even though they were the top priority in government policy. It can be inferred that the formation of policy agendas such as eco-friendly innovation and innovation of education system affects social issues, and the topic related to innovation of education system was attracting interest from the society. Academic research on ICT industry was active in this period. However, the research object in the academic research focuses mainly on corporations, limited to economic effects such as R&D evaluation for commercialization of public technology and intellectual property rights. It is difficult to say that the research topic reflects all of the social demands for science and technology policies such as research on policy issues for humanities integrated human resources development, and topics about space science.

3) The third period (2012-2017)

In the third period, a convergence innovation called the Fourth Industrial Revolution emerged. This was a period when global changes started with participation from government, businesses/corporations, science and technology

sectors, and civil society taking place concurrently to meet diverse social needs and to achieve sustainable development.

Table 8 Time lag among social issues, academic research and government policy

	Cluster	Social Issues	Academic Research	Government Policy
Period 1 (2000-2005)	1	New Growth Engine/NIS	Public Technology Commercialization	R&D Human Resources
	2	Science Ethics	ICT Industry	R&D centered on Government Funded Research Institute
	3	ICT	Innovation Cluster	NIS
	4	Gender Issues	Organization Capacity	Design of S&T Infrastructure
Period 2 (2006-2011)	1	Education System and Innovation	Commercialization of Public Technology	Eco S&T Innovation
	2	ICT	ICT Industry	Linking and Technology Commercialization and Human Resources Development
	3	Election Issues	New & Renewable Energy	Innovation of Education System
	4	Space Science	R&D Evaluation	-
	5	-	National R&D Project and Intellectual Property Right	-
Period 3 (2012-2017)	1	ICT and Start-up Business	Intellectual Property Rights	Job of Based on ICT and Social Problem-Solving
	2	The Fourth Industrial Revolution	Analysis Methodology	Commercialization of Public Technology
	3	Convergence Education	Catch-up and Post Catch-up	Start-up Business Ecosystem
	4	Space Science and North Korean Nuclear	Industry-University-Research Institute Collaboration	SW/ICT Infrastructure
	5	Social Risk	Social Problem and Convergence	-

At the same time, the social demand for science and technology is also forming a cluster frame in the form of fusion of various themes, contrastive to the previous periods. First, science and technology-related social issues in this period were clustered into ICT industry, entrepreneurship, the Fourth Industrial Revolution, convergence education, space science, North Korea nuclear issues, and social risks. Next, government policies were grouped into ICT-based job and social problem-solving, commercialization of public technology, the entrepreneurial eco-system, and SW/ICT infrastructure. Therefore, government policy was also designed to cope with social demand promptly.

Specifically, it was found that the government tried to design and implement policies that would help create more jobs and solve social problems in the day-to-day life and also policies that would help build entrepreneurial ecosystem. However, the government still focuses on economic growth and lacks efforts to provide adequate responses to social risks and unrest such as basic science like space science, North Korea's nuclear weapons and accidents of a nuclear power plant.

On the other hand, unlike the priorities of social issues and government policies, academic research focuses on the corporate-level micro-studies about intellectual property rights and analytical methodologies based on the results of technology development, and it is difficult to say that academic research in this period covered a wide array of topics corresponding to the policy demands. S&T policy studies did not respond adequately to solving social issues such as integrated education, space science, social risks of science and technology and societal problems such as low economic growth, lack of jobs, and climate change.

III. Focus Group Interview for Identity of S&T Policy Studies

In this part of the study we gathered the opinions of experts on the problems of science and technology policy and S&T policy studies so far in Korea and suggest future directions for them.

First, Korea's science and technology policy has been perceived until now as one of the obstacles to R&D because the performance evaluation is carried out in an overly rigid and formal way. Therefore, it will be necessary to drastically move away from the existing Project Based System (PBS) and change to a new system that is "Post-PBS," that takes on future challenges. For this, a useful and flexible evaluation system, instead of a formal and typical evaluation system, should be designed and implemented. In other words, switching from the formal and quantitative evaluation to a flexible and peer-review evaluation system would be essential. For this change, the socio-economic impact of science and technology achievements should be used as an evaluation criteria rather than quantitative evaluation indicators such as the number of papers and patents. Switching to the self-regulated system of evaluation in the research field must accompany an autonomous research system that manages only the vision and final goal of the research project, leaving all the other details with researchers. Science and technology policy should ultimately be transformed into people-oriented affairs.

Second, S&T policy studies should think around the problems arising from the industrial and research fields and aim at resolving them. This requires keeping an eye on social changes and predicting the effects of these changes on

the future society, which S&T policy studies need to make efforts to build a base to support by policy. With the recent arrival of the Fourth Industrial Revolution, IT-based social changes such as new IT-based industries like e-commerce and fin-tech, smart factories and smart cities are expected. In response to these social changes, it is necessary to establish a detailed plan for the scope of application and the users of new technology, and to actively identify what needs to be supported by policy.

Third, Korea's science and technology policy was the so-called "catch-up type" of policy that imitated developed countries in the past, but in the future, it must be able to identify and establish the kind of policies needed specific to the Korean situation. Therefore, the academic community dealing with science and technology policy should get out of the catch-up type of research which blindly imitates that of developed countries, explore the research topics needed for the society and become the leading body of research which takes the initiative to find policy issues and put them on the agenda.

Fourth, as for the research scope of S&T policy studies, many legal and institutional issues must be addressed. The empirical analysis revealed that nearly none of the legal issues were examined in any of S&T policy studies we reviewed. Science and technology policies are applied based on laws and regulations, but often in cases changes in laws do not keep up with those in society or science and technology. Typical cases are found in the Biological Ethics and Safety Protection Act and in the Personal Information Protection Act, of which old-fashioned regulations are hampering the technological advancement of health care and medicine. Therefore, legal research for technology innovation should be actively carried out so as to provide a theoretical basis to boldly abolish the regulations that impede the development of science and technology.

Fifth, the academic community needs to take the lead in research on inclusive innovation for those excluded from and victimized by such radical and destructive innovation as the current Fourth Industrial Revolution. In particular, research that prepares policies for small and medium sized businesses to adapt well to new changes will have to continue and those policies will have to be reflected in government policy to build an ecosystem where its various members can coexist.

Finally, the Fourth Industrial Revolution should be taken as an opportunity to deploy its positive and dynamic energy to further promote national and social growth and development, rather than questioning its nature. Therefore, academic interest and policy experiments on the Fourth Industrial Revolution should continue steadily, but it is a point in time where the academic community should think of ways to create a flow of knowledge that is new and unique to Korea, rather than blindly following the examples of developed countries.

IV. Conclusion and Implications

We have discussed the paradigms, the knowledge structure, and the roles of S&T policy studies through an empirical analysis and we examined the identity and future development of S&T policy studies on perspectives of the research field by FGI (Focus Group Interviews). In conclusion, the phenomenon and characteristics of the current status of S&T policy studies in Korea as of 2017 are summarized as follows:

First, it provisionally concluded that S&T policy studies in Korea are still in the pre-paradigm stage. Specifically, the level of consensus among scholars about the "academic definition of discipline" and "research scope", which is essential for an independent discipline, is still low.

Second, a large part of the existing research has been carried out by universities and government-funded research institutes in the Seoul and Daejeon areas. As for the research scope, more than 70% of the existing research was in "R&D management" and "technology innovation". The knowledge structure of S&T policy studies was clustered into "R&D management" and "technology innovation", "public management of science and technology", "public process of science and technology", in the descending order, which coincide with the research scopes that the current study proposes. As for the flow of research, the research topics were as general as researchers and R&D investment in the earlier stage, but they have diversified and subdivided into narrower topics such as technology innovation system, application of performance.

Third, in the analysis of the interaction among social issues, academic research, and government policy, S&T policy studies showed that much of the research in the earlier stage was fragmented at the micro-level, with an approach to respond quickly to the technology innovation rather than taking on a macro and integrated view. More recently, however, S&T policy studies show co-evolutionary patterns, which increase responsiveness of the society. Furthermore, a time lag was observed in the interaction among the three parts: social issues of science and technology, academic research, and government policy.

Fourth, through the FGI, we confirmed that S&T policy studies in Korea were merely a catch-up type of research, which imitated the policies of developed countries. Furthermore, innovation research lacked studies about inclusiveness for the victims of innovation or those who are alienated by radical or destructive innovation. It was our shared opinion that the overall policy process, such as policy planning, policy formation, and policy evaluation, focused too much on institutional matters, leaving the policy culture such as communication with policy targets relatively neglected.

Based on the results laid out above, the domain and the position of S&T policy studies in Korea at present in 2017 are summarized in Figure 4. To give more

details, S&T policy studies primarily belongs to the field of social sciences, and partly covers the fields of natural sciences and engineering in its characteristics. From the point of view of the purpose of social sciences, which is to explain the phenomena (facts) and to provide solutions to problems (value), the studies on sciences and technology policy in Korea are playing the role of merely seeking change through solving urgent policy problems, rather than proving scientific and systematic causal relationship in science and technology policy.

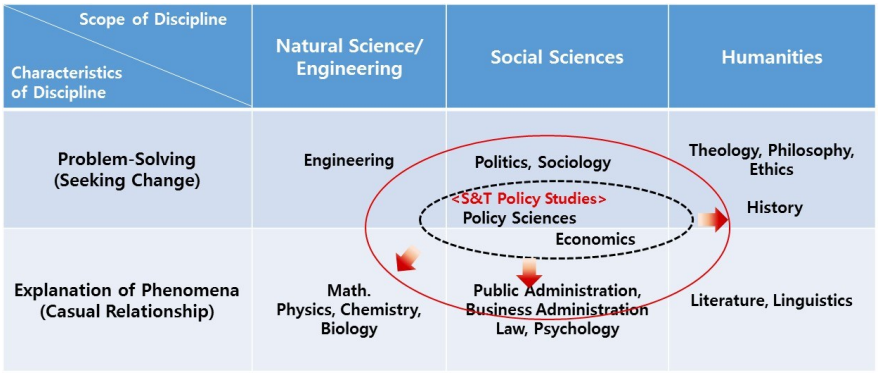
The main ground of this judgment is that S&T policy studies in Korea are still at a stage where a paradigm shared by the academic community is not formed yet, so the core research scope and original research methods and theories are yet to be established. On top of that, the research topics remained centered around those at the somewhat micro-level, such as R&D management and technology innovation, and S&T policy studies did not respond to social issues such as ethics, culture and perception sensitively as a result.

Scope of Discipline / Characteristics of Discipline	Natural Science/ Engineering	Social Sciences	Humanities
Problem-Solving (Seeking Change)	Engineering	Politics, Sociology <S&T Policy Studies> Policy Sciences	Theology, Philosophy, Ethics History
Explanation of Phenomena (Casual Relationship)	Math. Physics, Chemistry, Biology	Economics Public Administration, Business Administration Law, Psychology	Literature, Linguistics

Note: In this figure, the location of individual discipline is intuitively expressed to represent the typical orientation of the discipline.

Figure 4 The domain of S&T policy studies as of 2017

From this point of view, we declaratively propose future directions for S&T policy studies on science and technology policy in Korea (Figure 5). First of all, in addition to the ability to solve the existing problems, it should be able to explain the differentiated research scope more scientifically and systematically with original theories and methodologies. It is essential that the perspectives of humanities, such as philosophy and ethics, be emphasized in order for S&T policy studies to reflect on various social issues more effectively. By accentuating its perspectives of humanities in the future, S&T policy studies can establish its own identity as an independent discipline pursuing a balance between phenomenon explanation and problem-solving while maintaining multi-disciplinary characteristics.



Note: In this figure, the location of individual discipline is intuitively expressed to represent the typical orientation that the discipline pursues.

Figure 5 The desirable domain of S&T policy studies in the future

For the directions of development for S&T policy studies proposed earlier to be realized, the problems identified in the empirical analysis and FGI must be solved first in the order. The problems that need to be resolved are discussed in more detail below:

First, in order for S&T policy studies to have its own academic identity, priority should be to establish its academic definition and core research scope. We proposed to define S&T policy studies as a policy-oriented study that investigates and analyzes the overall phenomena of science and technology activities and technology-related politics, economy, society, and cultural matters (1) to seek development of science and technology itself and (2) to enhance the ability to solve problems of the nation and public sectors by utilizing the knowledge of science and technology. Applying this definition, we propose the following four areas as the research scopes of S&T policy studies as shown in Figure 1; (1) policy process of science and technology, (2) public management of science and technology, (3) R&D management and (4) technology innovation. The four research scopes then yielded a total of 20 research areas, with five sub-scopes for each. Among these, "policy process of science and technology" and "public management of science and technology" are newly proposed research scopes that reflect the academic definition of S&T policy studies, but "technology innovation" and "R&D management" are have already been included in most of the existing research. In the future, S&T policy studies in Korea urgently needs to shift from the catch-up type of the past to the pace-setter type, and for that research on policy process of science and technology, specifically agenda-setting and policy formation, should be first reinforced. Through this transformation, Korea's science and technology policy should be able to predict societal changes, actively identify policy issues to respond to such

changes, and develop preemptive policy goal and creative policy alternatives to solve those problems.

Second, S&T policy studies are currently excessively weighted in the Seoul and Daejeon regions, in researchers and university lecturers as the main research group, R&D management and technology innovation as the research scopes. For a balanced development as an academic discipline, such imbalance must be overcome. Therefore, in the future, S&T policy studies should expand its bases to Seoul and Gyeonggi area, Chungcheong area centered on Daejeon and Sejong, and Busan and Gyeongnam area. Also, in addition to universities and government-funded research institute, relevant industries also need to be involved in research more aggressively to get their demands to be reflected in government policy. In terms of the research scope, more research needs to be conducted in "policy processes of science and technology" and "public management of science and technology", which has not been studied much in the past.

Third, in order for S&T policy studies to be able to tackle the social issues more aggressively and for its findings to be reflected in the government policies, S&T policy studies should discuss balanced and integrated research perspective, and interdisciplinary and convergence research. First of all, society increasingly requires science and technology policy not only to enhance national competitiveness, but also to tackle all types of social problems in everyday life. Therefore, future S&T policy studies not only need to provide evidence-based policy research by the micro-empirical analysis at the enterprise level, but also need to secure balance in research topics by identifying research topics based on the social demands and suggesting national science and technology policy at the macro-discourse level. In order to increase the social acceptability of S&T policy studies, research for comprehensive response, which takes into account social ripple effects of science and technology such as technology risks and inhibitors of innovation diffusion need to be more conducted. Finally, it is necessary to strengthen the interdisciplinary characteristics of research in science and technology policy to consider various social, cultural, and political factors, such as risk governance and science and technology culture, and to move in the direction of a truly applicable study so as to secure practicality of science and technology policy.

Fourth, the future direction of S&T policy studies should form a unique flow of our own, building Korean policy cases and models rather than following the policies and theories of other developed countries. Further, it should convert its research basis to creating a happier world through inclusive innovation that embraces those who are harmed by or excluded from innovation and reinforce a policy culture, which is practically the key success factor of policies and systems.

We have discussed the ways for Korea's S&T policy studies to develop into an independent discipline that balances phenomena explanation and problem solving. It is difficult to predict at this point how S&T policy studies will move forward in the future, whether it will become a specialized area of policy sciences as in "Theory of Science and Technology Policy" or a study that is differentiated from other academic disciplines such as policy sciences, public administration, and science studies as in "S&T policy studies", while still covering issues in science policy, technology policy, and innovation policy.' Taking the discussions in the current study as the starting point, we anticipate that S&T policy studies will firm up its position as a brand new academic discipline, explain the phenomena of science and technology from interdisciplinary points of view by employing natural science, social sciences and humanities to resolve problems that arise, which will bring the biggest change to the environment of our future society.

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