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Development of Innovation Studies in Korea from the Perspective of the National Innovation System

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Abstract: The objective of this study is to explore how extant studies on innovation have contributed to the distribution of knowledge required for improving the national innovation system (NIS) in Korea. Korea was chosen as the context for this study because it is one of the leading countries that has succeeded in establishing an NIS. Using a systematic review method, we selected 739 articles published in two representative innovation journals in Korea, and analyzed the critical topics of these articles from the perspective of NIS studies. Overall, we found that these studies helped establish a knowledge base necessary for developing the NIS in Korea. Results showed that, over time, the scope of the studies shifted attention from building the NIS to implementing it. As a subsystem of the NIS, the industrial fields that sectoral innovation systems (SIS) were interested in were also changing in line with Korea's economic growth over time. This study contributes to innovation studies by offering a comprehensive picture of findings on NIS studies in the innovation literature in Korea, and providing a theoretical framework that organizes the literature. This study expands our understanding of the NIS, which has been recognized as an effective tool to compare and measure innovative performance and economic achievements.

Keywords: innovation studies; national innovation systems; research trends; Korean journals; knowledge distribution

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1. Introduction

The objective of this study is to explore whether extant studies of innovation have provided the knowledge required for improving the national innovation system (NIS) in Korea.

The topic of an NIS is a relatively new concept, introduced by Freeman in 1982 [1]. It was further developed by Lundvall [2], who analyzed different dimensions of innovation systems, and Nelson and Rosenberg [3], who conducted case studies by country [4] (p. 750). In the early 1990s, the OECD adopted the concept of an NIS as a tool to understand why there were differences in innovation and economic performance across countries, and it has since become widespread. Today, many countries establish and implement innovation policies based on this tool [5] (p. 3). Many researchers consider it important that the role of government include establishing innovation systems, and coordinating the activities of various innovation actors at the national level in order to enhance innovative performance. Initiated by Kim in 1993 [6], study of NISs has been steadily growing in Korea as well.

One of the fastest-growing academic disciplines today is innovation studies (IS). The concept of innovation, which is the vital force driving economic development, was first set forth by Joseph Schumpeter in his book *Theorie der wirtschafchaftlichen Entwicklung*, published in 1911 [7] (p. 2), [8] (p. 183). From there on, an increasing number of studies on technological innovation as a critical driver of economic development were conducted by neo-Schumpeterian economists such as Dosi [9], Freeman [10], Rosenberg [11], Nelson and Winter [12,13], Clark [14], and Dosi et al. [15]. Since then, academic interest in innovation has increased in earnest [8] (p. 184).

It seems, however, that there is not much effort in academia to further develop IS into an independent academic field. Even Fagerberg and Verspagen [7], Martin [16], and Fagerberg et al. [17,18], who are well-known scholars in this field, did not discuss in depth the definition, research scope, major theories, and research methods of IS. They instead traced the emergence of IS and addressed its future challenges. In the case of Korea, IS has been continually developing since academic journals on the topic were first established in the 1990s. Still, it is only relatively recently that IS trends in Korea have been researched [19–22].

There is a close link between an NIS and IS. Since NISs arose from great interest in IS, NISs are a field of IS. On the other hand, an NIS encompasses the entirety of IS at the national level [23]. It is imperative to research IS in order to enhance an NIS. IS conducts a comprehensive study of the entire innovation process, including innovative activities of individual actors, types of interactions among actors, and outcomes and diffusion of innovation [24,25]. In doing so, IS provides the theoretical bases for NISs.

Existing review papers have rarely discussed the topic of NISs. Although some studies have reviewed IS, they did not adopt an NIS perspective [19–22]. The few overseas studies that examined IS have also not evaluated from an NIS perspective, nor did they specifically focus on developing countries [7,16–18]. Conversely, another previous study did not review NISs but just evaluated the performance of each country's NIS [26–29]. In addition, some of those studies did not use the systematic review method, and the rationale for setting the analytical categories was unclear.

The objective of this study is to review IS research that explores the NIS in Korea. We will analyze the relationship between IS and the development of the NIS to propose the direction for IS in Korea. This study adopts a systematic literature review method and content analysis of the research published in two major academic journals in the field of IS in Korea: *Journal of Technology Innovation* (JTI) and *Journal of Korea Technology Innovation Society* (J-KOTIS). The analysis sequence will first identify authors with the most papers published in these two academic journals. Then the research topics of their published articles will be categorized under the concept of an NIS.

There are four contributions from this study. First, the literature for the systematic review was selected based on publication scores. This approach could better track academic interest in the field of IS in Korea, because it allowed the selection of studies from Korean researchers who are most active. Second, a systematic classification system was constructed to organize the results of content analysis. This assisted in coherently conducting the content analysis. Third, the findings of this study helped determine whether IS provided a knowledge base for the development of the NIS in Korea. Fourth, we present the challenges IS faces in improving the NIS in the future.

In the next section, we define the concepts of NISs and IS, and discuss limitations in existing research. The third section uses a systematic literature review method to select papers to explore the research trends regarding NISs and IS in Korea. In the fourth section, the findings are described, and in the last section, we discuss the implications and challenges of IS for enhancing Korea's NIS.

2. Theoretical Background

The theoretical background of this research is divided into two parts: NISs and IS. First, the concept and definition of an NIS will be reviewed as the theoretical basis to discussing IS from within NISs, in order to construct a framework based on the elements of NISs and mechanisms therefrom. Then, by going over existing literature on IS, a working definition of IS will be proposed to meet the purpose of this research paper. In order to verify the necessity of this paper, we will review existing research in which the current status of Korea's IS has been discussed.

2.1. National Innovation Systems

2.1.1. Concepts and Definitions

At the turn of the twentieth century, technological innovation differed by country, leading to economic development gaps. In the 1980s, an attempt to understand technological innovation at the national level emerged: a national innovation system. According to Freeman himself, the concept of an NIS was born out of an academic exchange between Freeman and Lundvall, all under the influence of List [30] (p. 1). Since then, as seen in Table 1, various researchers have come up with the concept of an NIS, based on the characteristics of the object they wish to explore [31] (p. 37). While the definitions may slightly differ in terms of what is emphasized, they all share the common idea that the role of the public sphere, such as governments and institutions, is critical when it comes to enhancing the innovative capacity of a country.

The definition of an NIS differs among researchers because they have come to define an NIS within the context of the system in which they are interested. There is no single principle that will work simultaneously in multiple systems; even within the national system of a country, operating mechanisms may differ by subsystem [5]. This is known in social science as context sensitivity [32–34]. According to Ahn [35] (pp. 133–134), when research on NISs first started, it attempted to classify the categories by country, and to understand the developmental process of innovation for each country according to their historical, political, and cultural context.

Meanwhile, there are ongoing criticisms of the limitations of an NIS because of its systemic approach. Regardless, the common features of NISs from the systemic aspect are organizations and institutions, and the focus is on the roles of actors and networking, centered around the government. As such, an approach focused on NISs serves as the theoretical background for innovation policies, by emphasizing the role of government in increasing innovation capacities across a country, through correcting systemic failures by facilitating the networks between actors who make up the innovation system [36].

Table 1. National Innovation Systems: Definitions and Characteristics.

Researcher	Definitions	Characteristics
Freeman (1987)	*"The network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies . . . "* [37] (p. 1)	Introduces the concept of National Innovation Systems and emphasizes institutional factors
Lundvall (1992)	*" . . . elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge and that a national system encompasses elements and relationships, either located within or rooted inside the borders of a nation state."* [2] (p. 2)	Defines national innovation systems in a narrow and broad sense, focusing on the institutes and organizations which make up the main elements of a national innovation system
Nelson and Rosenberg (1993)	*" . . . a set of institutions whose interactions determine the innovative performance, in the sense above, of national firms."* [3] (p. 4)	Develops the concept by applying an evolutionary perspective to analyze each country
Patel and Pavitt (1994)	*" . . . the national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change-generating activities) in a country."* [38] (p. 79)	Approaches from the perspective of the total capacity of institutions participating in technological innovation at a national level
Metcalfe (1995)	*" . . . set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provide the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artifacts which define new technologies."* [39] (pp. 462–463)	Focuses on those affected by the government's establishment and implementation of technological innovation policies

Source: OECD [40] (p. 10), Park [31] (pp. 35–39), Sharif [4] (pp. 746–748).

2.1.2. Elements and Framework

In general, the components of an innovation system comprise individuals and organizations, referred to as groups of individuals. Particularly within an NIS, actors (innovators) and interactions among actors, as well as policies and institutions supporting the interactions, can be considered the main components [5,36]. Here, actors include enterprises, universities, public research institutes, and governments, all of which can be categorized in different ways. For instance, if the purpose of innovation is to create economic value, then actors can be divided into two groups: corporate and non-corporate. Or, they could be classified into direct actors, such as enterprises, universities, and research institutes directly involved in innovative activities, and indirect actors, such as a government supporting the innovative activities of direct actors. Indirect actors are also known as supporting actors. What is interesting here is that in an NIS, the government plays a central role even though it is a supporting actor. This is because the government sets the stage for actors to conduct innovative activities.

Actors of innovation, and interactions among them, can be configured into a framework. As shown in Figure 1, this paper seeks to present an NIS framework based on the principal elements and achievements of the NIS approach. The most well-known model is from the OECD [41], and there are other frameworks presented by Korean researchers such as Lee and Song [42], Chung [43], and Hong [44]. However, the OECD model [41] (p. 23) and the framework by Lee and Song [42] (p. 10) seem to be rather complicated because of their detailed structuring of the innovation process and elements within an NIS. The frameworks by Chung [43] (p. 192) and Hong [44] (p. 97), on the other hand, seem to have simplified the frameworks by focusing on actors.

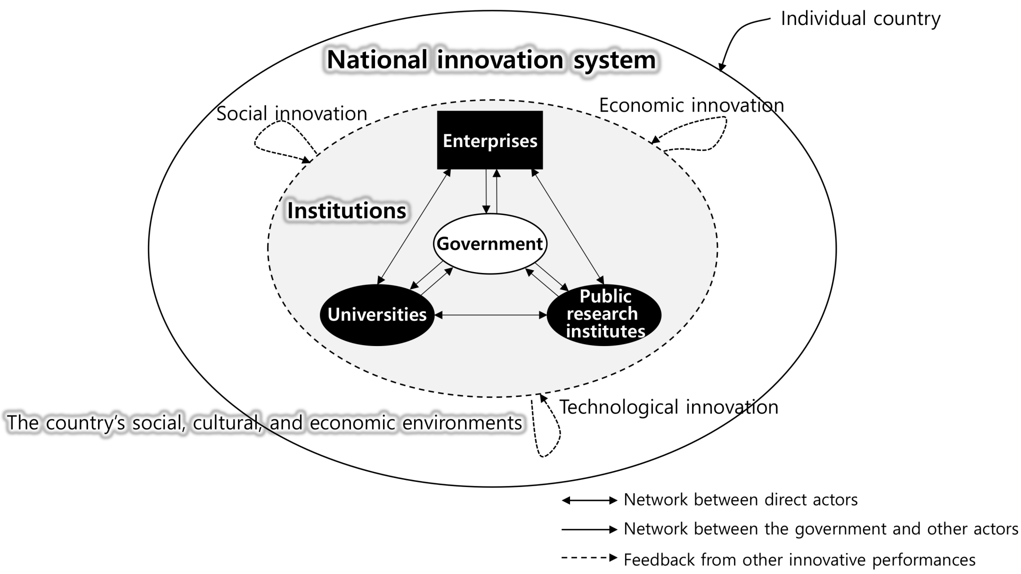


Figure 1. The framework of a national innovation system.

The framework proposed in this paper is based on the works of existing researchers, but has stressed the elements and performance of the NIS approach. To start, the framework has been designed to distinguish the roles of direct actors and supporting actors of innovation. Government has been placed in the center, because it usually has the supporting role of coordinating and encouraging the innovative activities of diverse actors at the national level, under a long-term national development plan. The direct actors of innovation are placed around government in order to emphasize their interactions, since they receive directions and support for innovative activities from the government. The interaction network among direct actors is expressed as double-headed arrows. On the other hand, the network between the government and other actors has been described using single-headed arrows to show reversible reactions. Here, the arrows pointing toward the government represent various demands by actors which are accepted by the government, and the arrows pointing away from government represent the government's support. In other words, if double-headed arrows represent interactions among actors during innovative activities, single-headed arrows in reversible reactions do not represent interactions, but the movement of information and resources.

Next, policies and institutions expressed as a circle in the middle represent the arena in which innovators are active, and surrounding the circle is a larger circle representing the country's social, cultural, and economic environments. Various innovative achievements generated through the innovative activities of an NIS diffuse to the national environment, then return to the national innovation system, causing innovation capital to develop continuously. In the past, the goal of the NIS approach was mostly toward economic feasibility, but today, the focus has shifted toward social cohesion. According to the co-evolution theory of innovation by Yi et al. [45], today the term innovation applies widely. It covers a wide range, and thus must include not just technological and economic innovation, but also social and policy innovation. For this reason, social innovation has been added in addition to technological innovation and economic innovation within the framework. Policy innovation, however, is not indicated in the framework because it is regarded as inherent in the system, based on the feedback from other innovative performances.

2.2. Innovation Studies

Although IS has a more extended academic history than NISs, there seems to be no clear consensus among scholars on the theoretical definition of the concept. According to Martin [16,46], who is a prominent scholar of IS still active in the field, IS "comprises economic, management, organizational and policy studies of science, technology and innovation, with a view to providing useful inputs for decision-makers concerned with policies for, and the management of, science, technology and innovation" [46] (p. 433). While his definition centers around the purpose of and academic approaches to IS, the background as to why his definition is not content-based but research-method-based can be found in the work of Fagerberg et al. [18] (p. 10), which states that innovation studies "may be approaching a Kuhnian juncture". Fagerberg et al. also claimed that innovation studies "may be defined as the scholarly study of how innovation takes place and what the important explanatory factors and economic and social consequences are", indicating that the definition came from a content-based aspect of academics [17] (p. 1132).

According to Martin [16], innovation today covers both science and technology. Since the concept of science policy was introduced in the 1960s, it has evolved into broader concepts such as research policy, science and technology policy, and science and technology innovation policy [47]. The reality is that there is no single unification of terms related to IS [16,45]. Among the terms mentioned so far, the only term that can cover science, technology, and research is innovation. Innovation policies are a crucial means for governments to support the innovative activities of other actors in an NIS project. Thus, the concept of an NIS is an essential topic for IS, and IS can be considered an academic field that studies the overall structure of an NIS, including its elements, actors, and the creation and diffusion of innovation achievements, in order to provide a knowledge base for governments to establish innovation policies to support an NIS.

As mentioned by Fagerberg et al. [18] (p. 10), innovation studies "may be approaching a Kuhnian juncture", and there needs to be an adequate definition of innovation studies for this research paper to move forward. To summarize what has been discussed so far, this research paper defines innovation studies as "an academic field that studies innovation in terms of its concept and type; process and characteristics; source; promotion and deterrence factors; and diffusion and transfer, all of which derive from the individual innovation activities of enterprises, universities, research institutes, the government, and interactions among actors". This definition includes an aspect of NISs and the main research scope of technological innovation theory, which can be understood as a narrower definition of IS.

The main research scope of the technological innovation theory mentioned here has been drawn from the existing research of Yi et al. [45].

Considering the content-based scope of IS, NISs can be regarded as one of the topics of IS. This research, however, focuses on the fact that the purpose of IS is to provide necessary information for an NIS to develop “policies and institutions”, which serve as the arena for actors. From the aspect of an NIS, this research seeks to suggest the direction for the development of IS by verifying that the elements of NISs are being thoroughly researched by IS, and the development of an NIS is actually in line with the current status of IS, etc.

2.3. Existing Literature

In Korea, there were few attempts to develop the theory of NISs from an academic stance. Instead, many studies focused on introducing the theories and principles of leading scholars in NISs, such as Freeman and Lundvall, drawing implications for their application in Korea. In order to check the current status of research papers on the topic of NIS, papers were searched with the keyword “national innovation system” in the paper titles and keyword category of the KCI (Korea Citation Index) Journal Database, which led to a total of 55 papers. If the text category was also included in the search scope, there would have been about 800 papers, but it would be inaccurate to include those papers in which the keyword appears only once or twice within the text. As such, the search has been limited to titles and keywords, and papers in search results were classified into three types: first, an analysis of the structure and characteristics of the NIS in Korea; two, a comparison of NISs between Korea and other countries; and three, a case study on the elements and subsystems of NISs.

Next, previous literature on the status of IS was reviewed. The works of Martin [16,46] and Fagerberg et al. [18] are considered representative studies on the analyses of the status of IS. Because their research scope was not limited to a particular region, a discussion on it is inevitable that European and American scholars who lead IS worldwide are at the center of the discussion.

In the 1990s, IS was introduced in Korea. After the 2000s, several studies attempted to elucidate the intellectual structure of Korea’s IS using bibliometrics, but no research analyzed IS from the perspective of NISs. Table 2 shows the findings from the analysis of research subjects of papers published in Korean academic journals related to IS. However, because the region is limited to Korea, it seemed challenging to identify influential researchers such as Martin or Fagerberg and their works in reference to citation indexes in order to analyze the status of IS. It is perhaps for the same reason that Lee [48] analyzed all the papers published in the chosen journal when he attempted to study the progress of IS in Asia, mainly focusing on Korea. Additionally, an existing study examined scientific innovation and NISs based more on web data than academic journals [49].

Table 2. Studies on the knowledge structure of innovation studies.

Researcher	Year	Journal	Subject
Namn et al. [50]	2005	JTI/ J-KOTIS/ KSBI	Analysis of the topics, goals, and methods of technological innovation research in Korea using keywords and citations
Namn and Seol [51]	2007	JTI/ J-KOTIS	Analysis of the characteristics of major research fields in innovation studies of Korea by journal
Lee, K. R. [48]	2014	AJTI	Analysis of the evolutionary characteristics of Asian innovation studies over the decade
Lee et al. [19]	2017	JTI	Exploration of the changes in research topics and methods in innovation studies in Korea

Table 2. *Cont.*

Researcher	Year	Journal	Subject
Kim and Lee [20]	2017	JTI	Analysis of the community structure of thesis topics using keywords
Kim and Yi [21]	2018	JTI/ J-KOTIS	Analysis of knowledge structure and knowledge flow through an analysis of a network of keywords
Oh and Yi [22]	2021	JTI/ J-KOTIS	Analysis of knowledge structure and knowledge production structure using author bibliography coupling analysis

Note: JTI = *Journal of Technology Innovation* published by the Korea Society for Innovation Management and Economics (KOSIME); J-KOTIS = *Journal of Korea Technology Innovation Society* published by the Korea Technology Innovation Society (KOTIS); KVMR = *The Korean Venture Management Review* published by the Korean Association of Small Business Studies; AJTI = *Asian Journal of Technology Innovation* (AJTI) published by the Korea Society for Innovation Management and Economics (KOSIME). Source: Oh and Yi [22] (p. 45), rearranged and partially modified.

3. Methodology

This section will discuss the systematic literature review method, selecting articles and conducting content analysis. Systematic reviews were conducted to appraise existing research in the area of interest at the initial stage of research, but they are also studies with essential findings in themselves [52].

We set the analysis period according to the status of the academic development of IS in Korea. The NIS in Korea was divided into three phases, referring to the discussions by Chung [43] and Hong [44], and *50 Years of Science and Technology in Korea* [53], published by the Ministry of Science and ICT (MSIT). The first phase spans from 1950 into the 1970s, when the foundation was laid. The second phase would be the "take-off" phase, from the 1980s to 1990 for about two decades, and the third phase is the developmental phase, from the 2000s to the present day.

During the foundational phase and the early take-off, science and technology developed institutionally under the leadership of the government. They, therefore, lacked the theoretical basis to support policy-making. It was not until the 1990s that academic societies and journals focused on IS came into existence. The analysis period for this research therefore was from 1993, when relevant communities began to publish scholarly journals, to 2020. Table 3 shows the analysis period and phases.

Table 3. The developmental process of NIS in Korea and the analysis period.

	1950s	1960s	1970s	1980s	1990s	2000s	2010s
NIS	Foundational			Take-off		Development	
Analysis period	-	-	-	-	Phase 1	Phase 2	Phase 3

3.1. Selecting Articles by the Review Protocol

We selected the articles to be reviewed according to the review protocol in Figure 2.

- Step 1. Journal selection

The objective of this research is to review IS studies that mainly discussed the NIS in Korea. Databases, such as Scopus and Web of Science, do not cover articles written or published in Korea. Therefore, this study selected two Korean academic journals, *The Journal of Technology Innovation* (JTI) and *The Journal of Korea Technology Innovation Society* (J-KOTIS). It may be a limitation of this study that it analyzes only two Korean journals. However, it is more appropriate to refer to journals published in Korea that reveal characteristics in that country. Those two journals are representative academic journals that mainly focus on IS. They were frequently chosen in prior studies analyzing the intellectual structure of IS in Korea.

Review protocol selecting articles to be reviewed

Step 1. Journal selection
- Two major academic journals mainly focus on IS in Korea
  - *The Journal of Technology Innovation* (JTI)
  - *The Journal of Korea Technology Innovation Society* (J-KOTIS)

Step 2. Papers and authors
- 598 in JTI from 1993 to May 2020
- 844 in J-KOTIS from 1998 to May 2020
- 1427 papers written by 1608 authors excluding non-Korean authors

Step 3. Publication scores calculation
- The publication scores for each author by first-and-corresponding-author-weighted fractional counting in consideration of multiple authors
- 0.7 credit to the first and corresponding authors and $1/n$ credit to the remaining co-authors, where n is the total number of authors

Step 4. Author selection
- 111 authors with the highest publication score

Step 5. Confirming papers to be reviewed
- 739 papers published by authors selected in Step 4

Figure 2. Review protocol for selecting articles.

- Step 2. Papers and authors

There were 1442 papers published, 595 in JTI from 1993 to May 2020, and 844 papers in J-KOTIS from 1998 to May 2020. The figures for publications by analysis period are shown in Table 4. Excluding non-Korean authors, there were 1427 papers written by 1608 authors in all.

Table 4. Research subjects [unit: no. of papers].

Journal Title	1993–2000	2001–2010	2011–May 2020	Total
JTI	109	227	262	598
J-KOTIS	94	340	410	844
Total	203	567	672	1442

- Step 3. Publication scores calculation

The publication score for 1608 authors, excluding non-Korean authors, was calculated by first-and-corresponding-author-weighted fractional counting in consideration of multiple authors. 0.7 credit was awarded to the first and corresponding authors and 1/n credit to the remaining co-authors, where n is the total number of authors.

- Step 4. Author selection

The top 111 researchers, 6.9% of all authors, had published 739 papers, 51.86% of all documents. This criterion is widely used in author-based bibliometric analyses [54,55]. It would be safe to say that Martin [16] also chose highly cited papers for his research on science and technology policy and innovation studies for the same reason.

- Step 5. Confirming papers to be reviewed

Before content analysis, the papers to be reviewed should be confirmed. As explained earlier, 111 authors were selected based on their publication scores among 1608 authors of 1427 papers. Table 5 summarizes their publication scores and the number of papers. The author with the highest publication score received 29.15 points for 40 articles.

Table 5. Publication scores and papers per selected author.

Publication Scores	No. of Authors	%	Publication Papers	No. of Authors	%
≥25	3	2.7	≥30	3	2.7
≥20	-	-	≥20	3	2.7
≥15	3	2.7	≥10	19	17.1
≥10	9	8.1	9	8	7.2
≥5	28	25.2	8	10	9.0
≥4	15	13.5	7	6	5.4
≥3	30	27.0	6	15	13.5
<3	23	20.7	<5	47	42.3
Total	111	100.0		111	100.0

Next, Table 6 shows 739 papers by year and journal. As in Table 4, there are significantly more papers from J-KOTIS than JTI among all the selected articles, even though the span of publication for J-KOTIS is much shorter than JTI.

Table 6. Papers of selected authors by year.

Year	JTI	J-KOTIS	Year	JTI	J-KOTIS	Year	JTI	J-KOTIS
			2001	6	13	2011	7	32
			2002	10	19	2012	13	22
1993	3		2003	12	18	2013	17	26
1994	4		2004	13	17	2014	19	20
1995	6		2005	13	35	2015	13	11
1996	2		2006	11	24	2016	21	17
1997	11		2007	7	17	2017	18	23
1998	7	17	2008	10	18	2018	11	30
1999	9	18	2009	7	20	2019	9	19
2000	14	16	2010	3	20	2010	2	9
Sub-total	56	51		92	201		130	209
Total								739

3.2. Framework for Content Analysis

The classification system to organize content analysis results is divided into two parts: process-based and content-based. According to Yi et al. [45], the content-based research would be about science and technology, as well as various sectors seeking innovation. On the other hand, process-based research would be about innovative activities. Table 7 shows the analytical framework, including the sub-categories.

Table 7. Analytical framework.

	Perspectives	Contents
Innovation studies	Process-based	Research scopes Innovation actors
	Content-based	Industry and technology sectors

Table 8 shows the categories for the procedural aspect, divided into research scopes and innovation actors. Research scopes were rearranged from the perspective of the NIS, categorizing the research scopes of science and technology policy research, as suggested by Yi et al. [45]. First of all, various research scopes of IS were categorized into NIS-related and not related to the NIS, which were further sub-categorized. Under the category of NIS-related, there could be two sub-categories at the national level, technological innovation and policies and institutions. Then technological innovation could be further broken down into concept/type, process/feature, source of innovation, promotion/deterrence, and diffusion/transfer. As for policies and institutions, they could be further sub-categorized into policy-making, policy implementation, policy evaluation, organization management, human resources management, and financial management. However, the management of innovative activities at the independent organization level seemed to have low relevance to the NIS.

Table 8. Categories under the process-based aspect of innovation.

Research scopes	NIS-related	Technological innovation	Concept/type Process/feature Source of innovation Promotion/deterrence Diffusion/transfer
		Policies and institutions	Policy-making Policy implementation Policy evaluation Organization management Human resources management Financial management
	Not related to NIS		
Actors of innovation	Enterprises Universities Public research institutes Individual Country		

Actors refer to individuals or organizations directly involved in innovation, such as enterprises, universities, and public research institutes. For this research, they were sub-categorized into individuals, enterprises, universities, public research institutes, and country, because actors are made up of individuals and a country exists as an actor comprising all of them. While the government is considered a non-direct actor in NISs, it was not necessarily separated because government activities are inherent to policies and institutions.

Next, as shown in Table 9, the sub-categories of the content-based aspect can be divided into regional innovation systems (RIS) and sectoral innovation systems (SIS) as well as the NIS. To further discuss at the sectoral level, SIS were further divided into sub-categories of industrial sectors and technological sectors. The categories were selected in reference to Korea's National Science and Technology Standard Classification System [56], but some sub-categories have been grouped together.

A systematic guideline was a tool for consistently analyzing IS. Several existing studies categorized and labeled a topic using judgment based on experience and a search of titles, abstracts, keywords, etc. This is likely because the academic status of IS is unstable, and lacking in a research scope agreed upon by all scholars. However, because their categorization did not distinguish between the area of research and the level of analysis, there could be difficulty when conducting contextual analysis. This research, however, was systematically conducted by utilizing the classification system.

Table 9. Categories under the content-based aspect of innovation.

NIS				
RIS				
SIS	Application	Industries	Industry as a whole	
			Manufacturing as a whole	
			Manufacturing (metal/non-metal)	
			Manufacturing (medical equipment)	
			Manufacturing (medicine)	
			Manufacturing (vehicle/transportation equipment)	
			Manufacturing (electrics/machinery)	
			Manufacturing (electronics/telecommunications)	
			Manufacturing (chemical)	
			Construction	
			Agriculture/forestry/fisheries	
			Arts/sports/leisure	
			Services	
		Public sector	Advancement of knowledge	
			Health	
			National defense	
			Earth exploration	
			Environment	
			Energy	
	Research fields	Science and technology	Nature (mathematics/physics/chemistry/earth science)	
			Life	Agriculture/fishery/food
				Health care
				Life science
			Artifacts	Construction/transportation
				Machinery
				Energy/resources
				Nuclear power
				Materials
				Electrics/electronics
				Information/communications
				Chemical engineering
		Humanities and social science		
		Interdisciplinary		
		Not focused		

4. Analysis of Selected Papers from JTI and J-KOTIS

This section discusses the results of the literature review, according to the analytical framework design based on the theoretical discussions.

4.1. Process-Based Aspect of Innovation

4.1.1. Research Scopes

It can be seen that there is a difference in research scopes between the take-off phase and the developmental phase (Table 10).

Table 10. Research scopes of selected papers [unit: no. of papers (%)].

Research Scopes	1993–2000	2001–2010	2011–2020	Total	Remarks
NIS	68 (63.6)	214 (73.0)	251 (74.0)	533 (72.1)	↗
Technological innovation	33 (30.8)	153 (52.2)	171 (50.4)	357 (48.3)	↗
Policies and institutions	35 (32.7)	61 (20.8)	80 (23.6)	176 (23.8)	↘
Non-NIS	39 (36.4)	79 (27.0)	88 (26.0)	206 (27.9)	↘
Total	107 (100)	293 (100)	339 (100)	739 (100)	

Note: ↗ = The increasing trend over time; ↘ = The decreasing trend over time.

The first phase tended to be more geared toward the policies and institutions of the NIS. In contrast, research on technological innovation increased significantly until 2020, although the difference is not dramatic (Figure 3). This finding was in accord with the argument that the government's role is crucial in enhancing the innovative capacity of the NIS at the national level. It could also be said that IS provided the knowledge required for the government to establish policies and develop institutions, supporting the establishment of the NIS. Increasing research related to technological innovation from 2001 to 2020 seemed to be affected by growing interest in the technological innovation activities of individuals and organizations after the NIS in Korea stabilized.

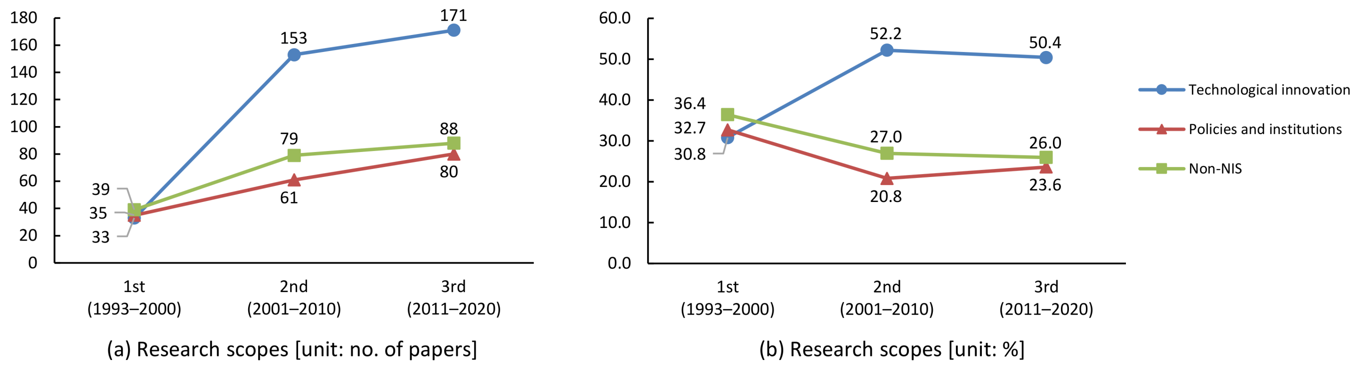


Figure 3. Research scopes of selected papers.

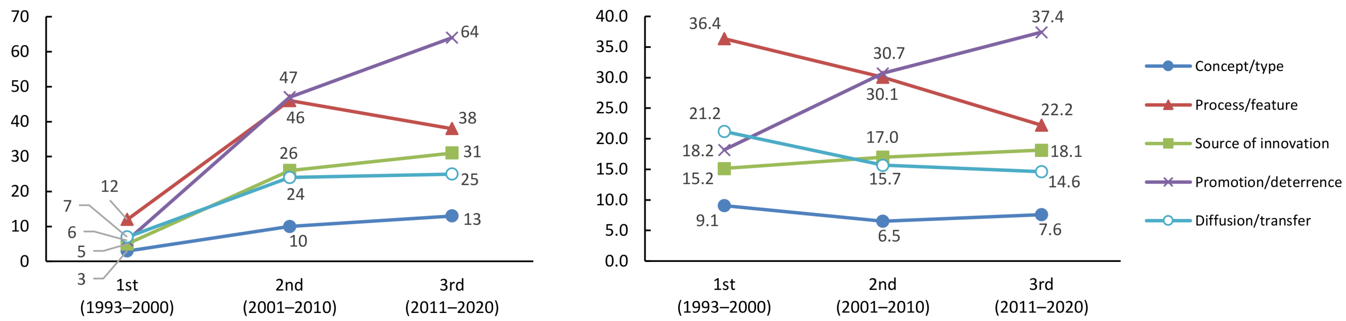
Table 11 indicates the sub-categories under technological innovation. Even though there was no distinct trend in the 1990s for technological innovation-related research due to the low number of studies, studies under process/feature were relatively high compared to other sub-categories. This can be interpreted as an attempt to understand innovative activities, because Korea acquired skills from abroad and established relative policies and institutions during this period. Since then, there has been a slight decline in the process/feature sub-category, but it still accounts for a large portion of technological innovation topics.

Table 11. Sub-categories of technological innovation [unit: no. of papers (%)].

Technological Innovation	1993–2000	2001–2010	2011–2020	Total	Remarks
Concept/type	3 (9.1)	10 (6.5)	13 (7.6)	26 (7.3)	↘
Process/feature	12 (36.4)	46 (30.1)	38 (22.2)	96 (26.9)	↘
Source of innovation	5 (15.2)	26 (17.0)	31 (18.1)	62 (17.4)	↗
Promotion/deterrence	6 (18.2)	47 (30.7)	64 (37.4)	117 (32.8)	↗
Diffusion/transfer	7 (21.2)	24 (15.7)	25 (14.6)	56 (15.7)	↘
Total	33 (100)	153 (100)	171 (100)	357 (100)	

Note: ↗ = The increasing trend over time; ↘ = The decreasing trend over time.

There was a change in the technological innovation sector, shifting gradually from the macroscopic to a microscopic perspective. Figure 4 clearly shows increasing promotion/deterrence and source of innovation topics. This is in contrast to the decline in research on processes and features. There was more research on enhancing innovative performance involving case studies of enterprises. There was also some research on concepts and types. In Korea, interest in IS was geared more toward its utilization than the development of theory. Diffusion and transfer were more studied in the earlier days, in order to introduce and adapt to the innovation system. In contrast, today, more research was on diffusing technological innovation among different organizations.



(a) Technological innovation [unit: no. of papers]

(b) Technological innovation [unit: %]

Figure 4. Sub-categories of technological innovation.

Table 12 shows the findings for the sub-categories of policies and institutions, which is the second scope of this research paper. According to the findings, there is a shift in interest from "how to turn a policy into an institution" to "how to successfully implement policies and institutions at the government level". Throughout the entire period, policy-making has the highest ratio of research, particularly in the early phase. This will be further discussed in Table 13.

Table 12. Sub-categories of policies and institutions [unit: no. of papers (%)].

Policy and Institutions	1993–2000	2001–2010	2011–2020	Total	Remarks
Policy-making	22 (62.9)	22 (36.1)	28 (35.0)	72 (40.9)	↘
Policy implementation	1 (2.9)	5 (8.2)	7 (8.8)	13 (7.4)	↗
Policy evaluation	5 (14.3)	12 (19.7)	12 (15.0)	29 (16.5)	↘
Organization management	1 (2.9)	3 (4.9)	7 (8.8)	11 (6.3)	↗
Human resources management	4 (11.4)	9 (14.8)	12 (15.0)	25 (14.2)	↗
Financial management	2 (5.7)	10 (16.4)	14 (17.5)	26 (14.8)	↗
Total	35 (100)	61 (100)	80 (100)	176 (100)	

Note: ↗ = The increasing trend over time; ↘ = The decreasing trend over time.

Table 13. Sub-categories of agenda-setting [unit: no. of papers (%)].

Policy Making	1993–2000	2001–2010	2011–2020	Total	Remarks
Agenda-setting	10 (45.5)	7 (31.8)	7 (25.0)	24 (33.3)	↘
Policy formation	12 (54.5)	13 (59.1)	15 (53.6)	40 (55.6)	⇝
Policy change	-	2 (9.1)	6 (21.4)	8 (11.1)	↗
Total	22 (100)	22 (100)	28 (100)	72 (100)	

Note: ↗ = The increasing trend over time; ↘ = The decreasing trend over time; ⇝ = The maintaining trend, although there are some changes over time.

Meanwhile, another sub-category showing a growth trend is policy implementation, whereas policy evaluation, which was growing in the 2000s, somewhat decreased in the 2010s and 2020s. Other trending sub-categories were organization management, human resources management, and financial management (Figure 5). This is in line with the increase seen in policy implementation. In other words, an increase in interest in the application of policies in institutions diffused to an increase in interest toward researching the field of public management. On the other hand, the fact that there was a decrease in research on evaluation could be an interpretation that rigorous assessments hinder innovation.

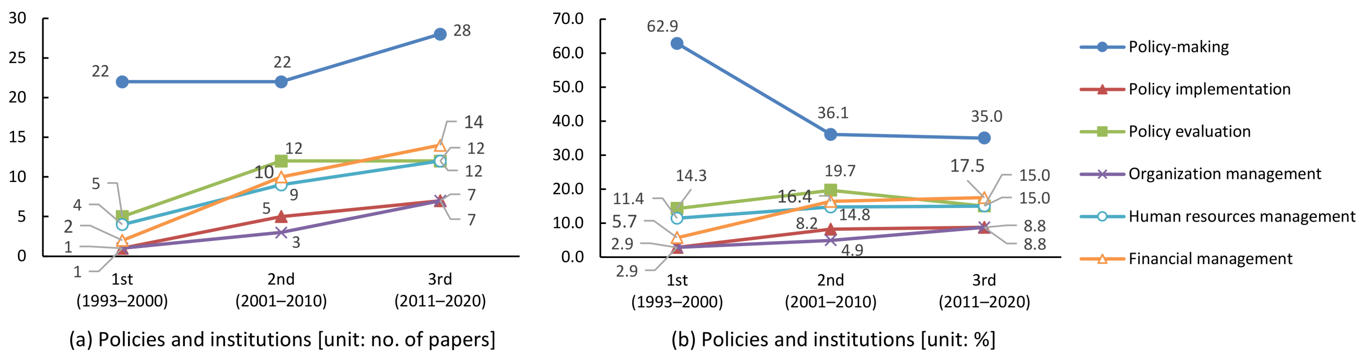


Figure 5. Sub-categories of policies and institutions.

Table 13 shows the findings for policy-making, which has the greatest representation under the policies and institutions sector. The sub-categories of policy-making were agenda-setting, policy formulation, and policy change. In general, policy-making includes agenda-setting and policy formulation, but not policy change [57–59]. For this paper, however, policy change is viewed to be in connection with policy processes in the past, and is part of the decision-making process for new agenda-setting and policy formulation [60]. All of the agenda-setting, policy formulation, and policy change topics have been included under policy-making.

It can be seen in the ratio of change in research related to policy-making that the NIS in Korea is shifting from the take-off phase to the developmental stage. In the 1990s, the ratio between agenda-setting and policy formulation was about 1:1, and there was no research on policy change. After that, there was a decrease in the proportion of research on agenda-setting, whereas the research ratio for policy formulation remained the same in general (Figure 6).

Meanwhile, research on policy change, which rarely existed in the 1990s, gradually increased toward 2020. Such a change signifies that there needs to be a shift in existing policies, as Korea's NIS is growing out of the foundational and take-off phases. In other words, IS was shown to be in sync with the development of the NIS. As such, it could be inferred that the 1990s focused on discovering new policy agendas to set the basis for the NIS and ensure internal stability. However, there should be a shift from agenda-setting to policy change for the sustainable development of the NIS.

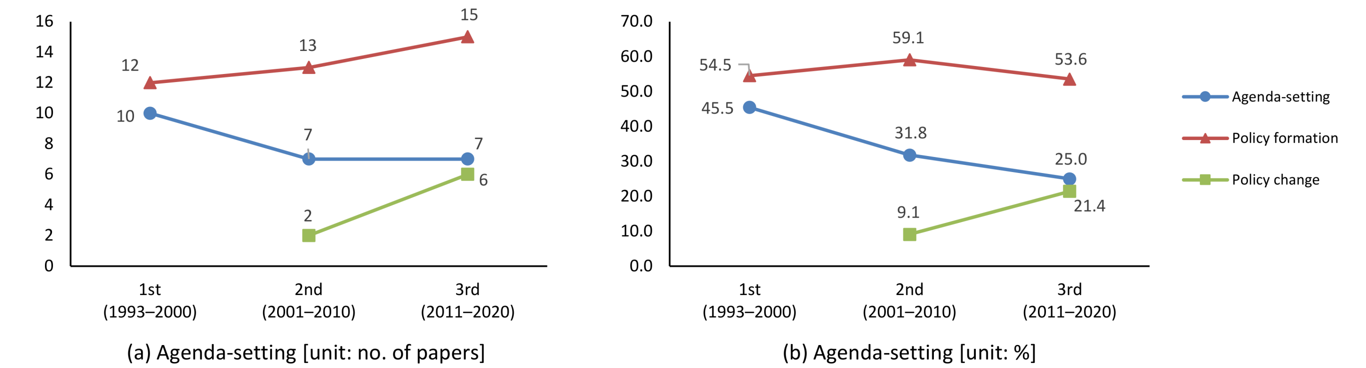


Figure 6. Sub-categories of agenda-setting.

4.1.2. Actors of Innovation

Another category with regard to research on the process-based aspect of innovation is actors. Similar to the findings under research scopes, the finding for actors showed a shift in the IS trend from macroscopic research to microscopic research. This is supported by the fact that research indicating the involvement of actors steadily increased. On the other hand, research that did not indicate actors of innovation, such as research on the maintenance of policies and institutions relating to NIS, decreased steadily (Table 14, Figure 7).

Table 14. Actors of the NIS [unit: no. of papers (%)].

Actors	1993–2000	2001–2010	2011–2020	Total
Individual	4 (5.9)	12 (5.6)	13 (5.2)	29 (5.4)
Enterprises	14 (20.6)	47 (22.0)	78 (31.1)	139 (26.1)
Universities	4 (5.9)	9 (4.2)	6 (2.4)	19 (3.6)
Public research institutes	6 (8.8)	24 (11.2)	36 (14.3)	66 (12.4)
Multiple actors	2 (2.9)	14 (6.5)	11 (4.4)	27 (5.1)
Multiple countries	-	5 (2.3)	3 (1.2)	8 (1.5)
Non-actors	38 (55.9)	103 (48.1)	104 (41.4)	245 (46.0)
Total	68 (100)	214 (100)	251 (100)	533 (100)

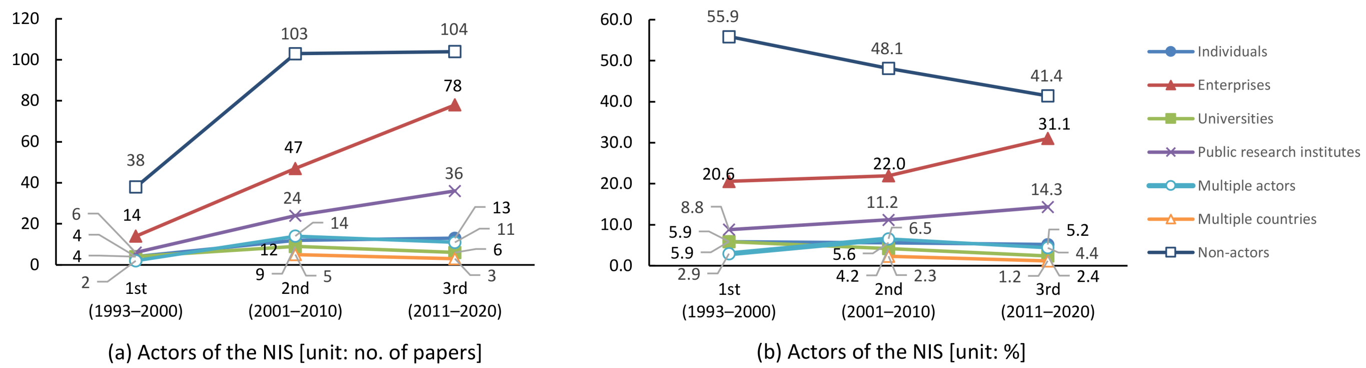


Figure 7. Actors of the NIS.

In Figure 7, research on enterprises continually increased. It suggests that innovation in the private sector is considered more significant than innovation in the public sector. Regardless, it can be interpreted that there is no decrease in research on public research institutes. Because of its long history, a role-change for public research led to ongoing discussions. Public research institutes were forced to change the role given to them when Korea was focused on innovation in order to catch up with developed countries [61]. Even though the change was subtle, it could also be confirmed that there was an increase in research that explicitly considered several actors at once. In order to study the connection between the public sector and the private sector, the research mainly addressed the network between enterprises and universities, and between enterprises and public research institutes.

However, the proportion of research on individuals and universities was meager, and it continued to decrease, suggesting that interest was biased against innovation actors. In particular, university-related research mainly focused on the establishment of universities for human resource training and on diffusion and transfer of innovative achievements generated in universities. As such, research was mainly on university establishment and education until the second phase, but most of the research was on technology transfer and commercialization in the third phase. Here, too, it can be seen that the research shifted according to the development of the NIS in Korea. In the sense that securing outstanding human resources in science and technology was essential for the NIS to advance, research on university systems would have been necessary from the take-off phase to the early stage of the developmental phase. Then, as the developmental phase of the NIS continued, the interest of research shifted to sharing the innovative achievements of universities with other actors, and diffusing the achievements to the national system.

4.2. Content-Based Aspect of Innovation

4.2.1. Subsystems of the NIS

In the next part, IS was addressed and for this, IS was classified into different levels of innovation systems: NIS, RIS, and SIS (Table 15).

Table 15. Subsystems of NIS [unit: no. of papers (%)].

Subsystems of NIS	1993–2000	2001–2010	2011–2020	Total	Remarks
National Innovation System (NIS)	48 (70.6)	133 (62.1)	152 (60.6)	333 (62.5)	↘
Regional Innovation Systems (RIS)	3 (4.4)	9 (4.2)	12 (4.8)	24 (4.5)	⇝
Sectoral Innovation Systems (SIS)	17 (25.0)	72 (33.6)	87 (34.7)	176 (33.0)	↗
Total	68 (100)	214 (100)	251 (100)	533 (100)	

Note: ↗ = The increasing trend over time; ↘ = The decreasing trend over time; ⇝ = The maintaining trend, although there are some changes over time.

Over the entire period, the proportion of research on the NIS was significantly more than the other two systems. It gradually decreased over time, whereas the percentage of research on SIS gradually increased, rapidly growing in terms of its absolute quantity (Figure 8). This can be seen as a result of recognizing that processes and characteristics of innovation vary across industrial and technological sectors [62]. During the early phase of the development of the NIS in Korea, the country's industrial base was weak, and the level of science and technology development was low. There was little research on SIS relative to the NIS because attention was given to policies and institutions at the national level to develop the NIS. However, it could be inferred that research on innovation systems in consideration of each industry or sector would increase when the NIS entered into the stable developmental phase. In particular, joint efforts among enterprises, academia, and research institutes to secure global competitiveness and maintain a stable position in the information and communications sector, in which Korea has the lead, could be viewed as contributing to increased research on SIS. This trend will be discussed further in the next section, by examining the industries in which SIS has mainly been studied.

On the other hand, research on RIS was visibly insignificant compared to SIS. The emergence of RIS can be understood as a policy to overcome severe economic inequality between regions when Western societies fell into an economic recession in the 1970s [63]. In Korea, local governments were first established in 1995, which led to the initiation of regional science and technology policies. As of 2021, The Fifth Comprehensive Plan for the Promotion of Regional R&D (2018–2022) is currently under implementation. It seems, however, that due to the centralized political culture and lack of autonomy for local governments in Korea, the demand for research on RIS itself has not been high. In fact, up to 2018, most local governments did not have their own institutions to establish and promote innovation policies that took into consideration the realities of each region. Instead, they had to rely on the organizations and projects of the central government [64]. It can be inferred that these circumstances acted as hindrances, interfering with the expansion of research related to RIS.

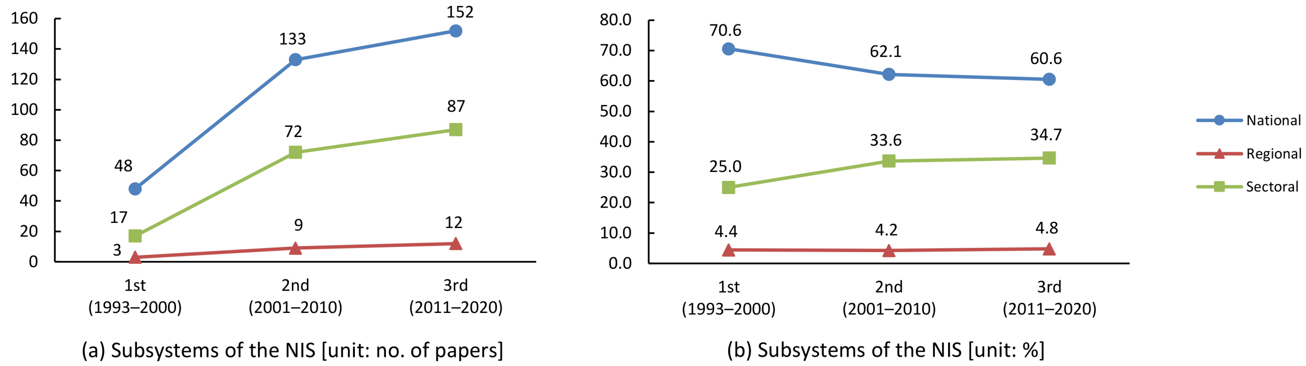


Figure 8. Subsystems of the NIS.

In addition, similar to countries such as the United States, Germany, Japan, the United Kingdom, and France, which treat regional science and technology policies as part of regional development policies, it can be deduced that RIS-related research in Korea is also being treated as part of regional development strategies [64,65]. However, various regions would ultimately want to take charge of their own innovation policies, and it is expected that interest in RIS will increase, with the goal of strengthening regional innovative capacities through comprehensive plans for the promotion of regional R&D.

4.2.2. Applications

According to Ahn [35] (pp. 162–164), the role of SIS is to explain, from the perspective of a system, differences in development among technologies or industries within a country. As such, it mainly discusses the characteristics of technological innovation in a relevant sector, and interactions among actors for the development of a particular industry. Therefore, implications can be drawn by classifying SIS-related research by industry or technology.

In Table 16, IS categories were classified based on the application sectors of SIS. First, under industries, it was noticed that most of the research was related to information and communications, reflecting the significant development of the information and communications industry in Korea. Next, even though electronics and telecommunications accounted for half of the entire SIS-related research for a while, its ratio dropped in the 2010s (Figure 9). This might reflect recent changes in Korea's electronics and telecommunications industries, in which attempts are being made to shift away from stagnant growth and bias toward the sector, turning to other industries such as biotechnology. Research on vehicles and transportation equipment increased significantly during this period. This resulted from an increase in research on technologies that graft information and communications to other technologies, as seen in autonomous vehicles. Moreover, there is also an increase in research on services and medicine.

In Figure 9, the research proportions of the industry as a whole and of manufacturing as a whole were also relatively high. Research in these fields provides implications to sub-sectors by understanding differences between industries or characteristics identified with industry groups. It also analyzes the factors of each sector, and reveals their impact on sectors. In the case of a developing country with a weak economic basis, it is common to focus on a particular industry in the starting stage of an NIS [66,67]. Then, when the industrial basis has become secure to some extent, the country seeks industrial diversification that leads to economic growth. As such, the need to understand the current status and characteristics of various industrial sectors can be seen as a reflection of the research focus of SIS.

Table 16. Application sectors of SIS [unit: no. of papers (%)].

Application	1993–2000	2001–2010	2011–2020	Total
Industries	16 (94.1)	69 (95.8)	74 (85.1)	159 (90.3)
Industry as a whole	1 (5.9)	8 (11.1)	9 (10.3)	18 (10.2)
Manufacturing as a whole	1 (5.9)	6 (8.3)	10 (11.5)	17 (9.7)
Manufacturing (metal/non-metal)	1 (5.9)	3 (4.2)	2 (2.3)	6 (3.4)
Manufacturing (medical equipment)	-	3 (4.2)	1 (1.1)	4 (2.3)
Manufacturing (medicine)	2 (11.8)	2 (2.8)	7 (8.0)	11 (6.3)
Manufacturing (vehicle/transportation equipment)	1 (5.9)	1 (1.4)	11 (12.6)	13 (7.4)
Manufacturing (electrics/machinery)	2 (11.8)	2 (2.8)	4 (4.6)	8 (4.5)
Manufacturing (electronics/telecommunications)	6 (35.3)	36 (50.0)	17 (19.5)	59 (33.5)
Manufacturing (chemical)	-	1 (1.4)	1 (1.1)	2 (1.1)
Construction	1 (5.9)	-	-	1 (0.6)
Agriculture/forestry/fisheries	1 (5.9)	3 (4.2)	2 (2.3)	6 (3.4)
Arts/sports/leisure	-	1 (1.4)	1 (1.1)	2 (1.1)
Services	-	3 (4.2)	9 (10.3)	12 (6.8)
Public sector	1 (5.9)	3 (4.2)	13 (14.9)	16 (9.1)
Advancement of knowledge	-	-	2 (2.3)	2 (1.1)
Health	-	-	1 (1.1)	1 (0.6)
National defense	-	1 (1.4)	1 (1.1)	2 (1.1)
Development of earth	-	1 (1.4)	-	1 (0.6)
Environment	-	-	1 (1.1)	1 (0.6)
Energy	1 (5.9)	1 (1.4)	8 (9.2)	10 (5.7)
Total (SIS)	17 (100)	72 (100)	87 (100)	176 (100)

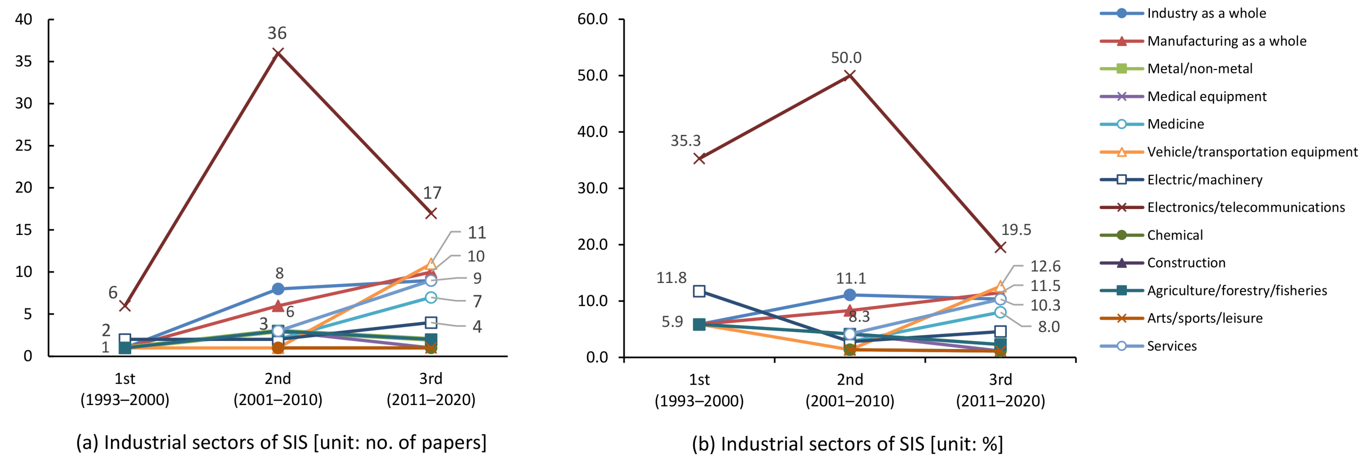


Figure 9. Industrial sectors of SIS.

Meanwhile, from the perspective of an NIS, SIS includes not only research on industrial sectors but also on public sectors, even though its proportion is very low. It seems only natural that SIS primarily focuses on industry-related research instead of public sectors. However, there has been a recent increase in research on public sectors. In particular, a significant increase in energy-related research is an indication that all around the world, energy issues are directly linked to national security, and have become one of the critical issues being addressed.

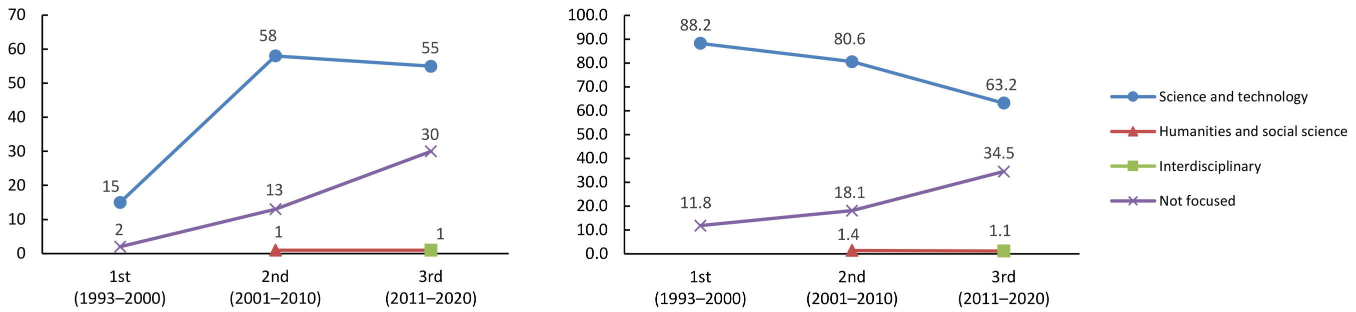
4.2.3. Research Fields

Table 17 shows the findings on research fields focused on SIS, particularly centered around science and technology. As explained earlier, research on IS covers both content-based and process-based aspects of innovation. SIS is what stemmed from the innovation system for the content-based aspect of innovation. However, according to the finding in Table 17, about a quarter (25.6%) of the research listed here is not relevant to the field of science and technology. This percentage includes industry as a whole and manufacturing as a whole, which together make up about 20% of the industrial sectors in Table 16. In addition, research related to actors, policies, and institutions of each industry has been included here.

Table 17. Research fields of SIS [unit: no. of papers (%)].

Research Fields	1993–2000	2001–2010	2011–2020	Total
Science and technology	15 (88.2)	58 (80.6)	55 (63.2)	127 (72.7)
Nature (mathematics/physics/chemistry/earth science)	-	3 (4.2)	2 (2.3)	4 (2.3)
Life	3 (17.6)	8 (11.1)	10 (11.5)	21 (11.9)
Agriculture/fishery/food	1 (5.9)	1 (1.4)	1 (1.1)	3 (1.7)
Health care	-	2 (2.8)	8 (9.2)	10 (5.7)
Life science	2 (11.8)	5 (6.9)	1 (1.1)	8 (4.5)
Artifacts	12 (70.6)	47 (65.3)	43 (59.4)	102 (58.0)
Construction/transportation	1 (5.9)	-	-	1 (0.6)
Machinery	3 (17.6)	3 (4.2)	14 (16.1)	20 (11.4)
Energy/resources	1 (5.9)	-	5 (5.7)	6 (3.4)
Nuclear power	-	1 (1.4)	3 (3.4)	4 (2.3)
Materials	1 (5.9)	5 (6.9)	2 (2.3)	8 (4.5)
Electrics/electronics	2 (11.8)	4 (5.6)	6 (6.9)	12 (6.8)
Information/communications	4 (23.5)	33 (45.8)	12 (13.8)	49 (27.8)
Chemical engineering	-	1 (1.4)	1 (1.1)	2 (1.1)
Humanities and social science	-	1 (1.4)	1 (1.1)	2 (1.1)
Interdisciplinary	-	-	1 (1.1)	1 (0.6)
Not focused	2 (11.8)	13 (18.1)	30 (34.5)	45 (25.6)
Total (SIS)	17 (100)	72 (100)	87 (100)	176 (100)

As seen in Figure 10, the proportion of research not focused on a particular science or technology gradually increases. This is because, in general, the operation of an innovation system is determined by various factors, such as the subject, source, system, and policy of innovation, even though the characteristics of science and technology undoubtedly play a critical factor in determining the characteristics of an innovation system in a particular industry [36]. In other words, it can be inferred that the stable development of the NIS in Korea led to a recognition that other factors, in addition to science and technology-related elements, are also important.



(a) Research fields of SIS [unit: no. of papers]

(b) Research fields of SIS [unit: %]

Figure 10. Research fields of SIS.

According to the findings, of all the sectors of science and technology which make up about 73% of research in SIS, information and communications were researched the most. This is likely because Korea is globally known for its competitiveness in electronics and telecommunications. Among the list of application sectors in SIS, electronics and telecommunications was the most researched sector, and information and communications, which can be considered the underlying technology of electronics and telecommunications, was explored the most. Even though the industrial sector and the science and technology sector were not precisely identical, when the percentages of information and communications

(27.8%) and electrics and electronics (6.8%) under Table 17 were added together, the total percentage was very close to that of electronics and telecommunications (33.5%) in Table 16. Changes in the research trend by period were not dissimilar (Figure 11).

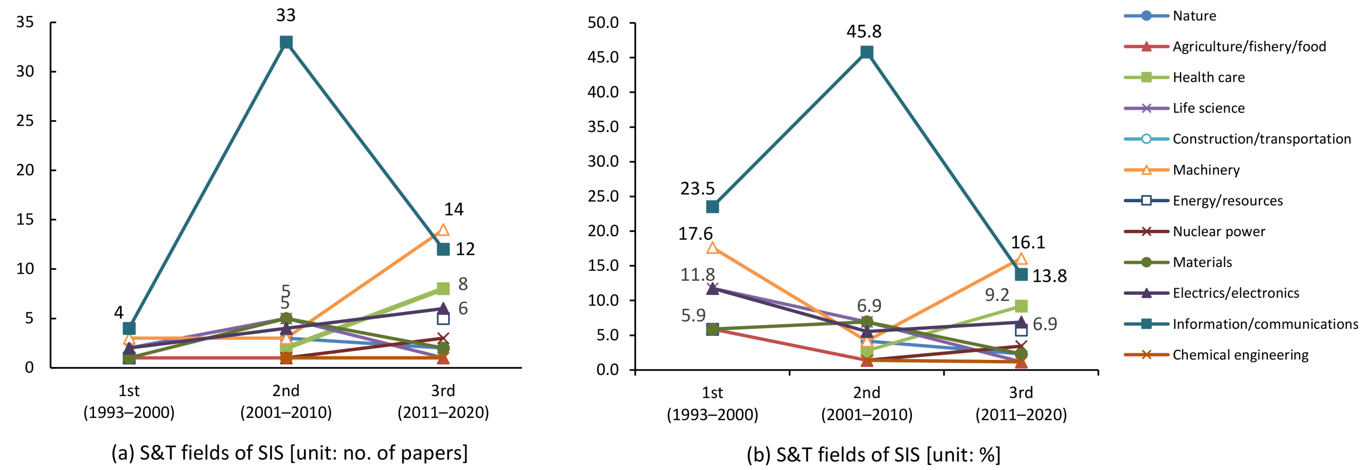


Figure 11. Science and technology fields of SIS.

Another field with increased research is machinery (under artifacts), and its related sectors of vehicles and transportation equipment and electrics and machinery show similar percentages. Health care (under life) was another field on the rise since the 2000s. As mentioned earlier, such trends appear to be consistent with the changes in industrial diversification, due to the development of the NIS in Korea.

5. Conclusions

The purpose of this study was to trace the past 30 years of IS in Korea from the perspective of the NIS. We utilized a systematic review method, and organized the analysis results in a classification system. In conclusion, IS has provided a knowledge base necessary for developing the NIS in Korea. The findings from this study can be summarized in three points as follows:

First, the research scope of IS shifted focus from building the NIS, the macroscopic perspective, to implementing it, the microscopic perspective. IS rapidly moved its research interest from research on policies and systems to research on technological innovation, and the amount of research increased significantly. It was confirmed that research on the promotion, deterrence, and source of innovation rose considerably, particularly in case studies. In addition, research is increasing, not only on the establishment of policies and institutions, but also on logical implementation and management of systems. Beginning in the 2010s through 2020, research on policy change has expanded, recognizing the need for a change in the existing NIS. Nevertheless, the attention on policy-making was still significant overall, indicating that the focus of IS did not wholly step away from the macroscopic perspective.

Second, there was an increased awareness of innovation actors in IS, particularly enterprises reflecting the maturity of the NIS in Korea. Apparently stemming from that, since the early 2000s there have been discussions that Korea should move from the era of catch-up development to a new period, to surpass the countries ahead of it [68]. In the 2020s, it is accepted that public research cannot lead the NIS, and that the public sector should transform into a role that supports other sectors.

Third, the industrial fields that SIS, as a subsystem of the NIS, was interested in also changed with the industrial sectors that supported Korea's economic growth over time. As innovation policies and institutions sufficiently grew and transitioned through the phases of foundation and take-off, their interest moved toward understanding and developing innovation characteristics for each industry. For example, the main focus of SIS shifted from the electronics and telecommunications industry, which is one of Korea's highly competitive industries, to other industries. It was noticeable that IS adequately reflected the changes in major industries and sectors.

Based on these three findings, we propose four challenges for IS to further contribute to improving the NIS in Korea. First, for the development of the NIS, it is necessary to study more microscopic subjects. Macroscopic research defines directions and goals, while microscopic research achieves a goal in line with guidance from the macroscopic research. The sustainability of the NIS will be guaranteed only when macroscopic and microscopic research are in balance, keeping pace with the development of the NIS.

Second, it is essential to study the interactions among various actors of the NIS, from individuals to the state. It cannot be denied that enterprises are key actors in economic growth. However, the role of each actor and the active interactions among them are more emphasized in an NIS, and as the NIS evolves, changes in the roles and capabilities of actors are essential factors [69]. As such, research should be further expanded to address the changing and enhancing of actors' roles and capabilities, as well as to address linking of different functions and capabilities among actors.

Third, there is a severe need for attention to RIS, one of the subsystems under an NIS. Korea's economy and industries are heavily concentrated in the metropolitan area, causing many issues. Those problems sometimes lead to calls for frugal innovation [70–72]. We should make an effort to resolve this concern through regional innovation. Considering that innovation capacity based on science and technology at the regional level is just as important as at the national level, IS should pay more attention to RIS. The Fifth Comprehensive Plan for the Promotion of Regional R&D (2018–2022) is soon coming to an end. Therefore, IS should be providing the knowledge base to build an effective RIS.

Lastly, IS in Korea tends to lean more toward practical research. We propose conducting more theoretical research. According to Dutrénit [69], the knowledge base needed for latecomer countries to implement a catch-up strategy is invalid for converting to a leading strategy. That implies that Korea, which has reached a turning point of economic development, needs to equip itself with an advanced innovation system and a rich knowledge base in order to move forward [73,74]. If IS cannot create and develop an independent theory reflecting Korea's distinct characteristics, it could hinder progress toward advanced innovation. In advanced innovation, the goal, in other words the target, of imitation embedded within the phrase "catch up" no longer exists. What this means is that the first task for Korea to transition from catching up to being in the lead is to equip itself with the ability to predict the future and set goals on its own. The first step to this would be the development of an innovation theory that reflects Korea's uniqueness and contextuality.

We can interpret from these findings, despite several limitations, that the fact that IS in Korea is in sync with the development of the NIS is a positive sign that it has performed its role relatively well over the years of its development. However, although innovation has moved on to the microscopic sphere, IS still focused on macroscopic research. In other words, IS did not entirely lead the development of the NIS in Korea.

This study has both methodological and analytical limitations. Our methodology used two academic journals published in Korea, which did not allow us to conduct a bibliometric analysis of the selected articles. It would be valuable for future research to utilize SCOPUS or Web of Science and review the literature on NISs. In addition, the findings do not show whether IS drove the development of the NIS or whether it simply followed suit. Future research should develop a more detailed research design that can directly evaluate the relationship between the developmental processes of the NIS and IS. Nonetheless, this research is meaningful in analyzing the research trend of IS in Korea from the perspective of the NIS, based on academic data.

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