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The Historical Change of Policies on Research Facilities and Equipment of South Korea

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Abstract This study analyzed changes in the national research facilities & equipment (RFE) policies historically promoted by the Rho administration (2003~2007), Lee administration (2008~2012), Park administration (2013~2016), and Moon administration (2017~2019) in South Korea. By adding new variables such as policy goals and policy means to a model suggested by Hogwood and Peters (1983), policy change types and their flow could be better classified. Korean RFE policies showed various flows in the policy change types instead of a general flow, which is the order of policy innovation -> policy innovation -> policy succession -> policy succession. This finding indicates that each administration could pursue a higher-level policy change purposively. It is highly required to prepare policy development that devotes to organizing and operating a national council, reflecting in the government's comprehensive plan after evaluating policy effectiveness, improving items needed for the RFE status survey, and unifying the research equipment registration.

Keywords Policy change, Policy change type, Research facilities & equipment, S&T infrastructure

I. Introduction

Korean government invested more than $20 billion in research and development (R&D) in 2019, where 5% of the R&D budget was spent on Research Facilities & Equipment (RFE). RFE refers to the overall research facilities and research equipment, which are directly used in research development activities to create functions and environments for research development. Research facilities refer to independent research space supporting

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research development activities (experiment, analysis, measurement, education, training, etc.) for one of the following purposes: 1. One huge research equipment, 2. One system combined with multiple research equipment, and 3. Measurement that combines all research equipment into one place to promote joint utilization. Research equipment refers to a non-consumed asset for scientific technology activities that cost more than $1,000 worth of establishment cost with more than a year of endurance (Ministry of Science and ICT, 2020a: 1, 11). As of late 2019, 751 research facilities including 'Pohang Accelerator Laboratory X-ray Free Electron laser,' and 59,425 research equipment including 'Bio High-Voltage Electron Microscope' are registered in the Zone for Equipment Utilization Service (ZEUS) in Korea.

Since the beginning of the Rho administration in 2003, South Korea (hereafter, Korea) has started to enact policies of RFE. Since then, subsequent policy changes have taken place along with the president changes in the central government. This study focuses on addressing how RFE policies have changed in their substantive policy contents. Also, this study analyzes what the type of policy change is and how the type has changed. It is highly expected to address what direction of future policies should be promoted considering the current and future contexts of Korea.

The Korean administration first started investigating the current status of RFE with the government budget in 1999. The government investigated the management status of high-end equipment of greater than $100,000 in 28 government-funded research institutes in which they found problems and suggested ways of improvement (Ministry of Planning and Budget 1999). Consequently, the government established the Science and Technology Basic Plan (STBP) (2002 ~ 2006) along with the Frame Act on Science and Technology (FAST) enacted in 2001. One of the core contents of the legislation was to promote growth in RFE under the science and technology (S&T) substructure section, but it merely ended in a planning stage without establishing specific enforcement approaches.

The Rho administration has been competitively enlarging the RFE-related infrastructure as the RFE could influence more extensively with the advent of large-scale and complex S&T; however, a strategic investment, efficient management structure, and efforts to collectively utilize them were lack. So in 2006, associated ministries collectively created a 'Pan-ministerial RFE for a joint utilization promotion method' (Science & Technology Related Ministerial Conference 2006; hereafter, Rho-P1). This is perceived as the first step towards RFE establishment in Korea.

The RFE policies are crucial for the Korean National Innovation System (NIS) development because RFE is a core component of the S&T substructure. NIS is commonly defined as 'the network of institutions in public and private sectors whose activities and interactions imitate, import, modify, and diffuse new

technologies' (Nelson 1993). The NIS Structure can largely be divided into four parts:

- Activities and interactions among innovative actors such as corporations, universities, joint institutes, etc.
- Government R&D investment and policies.
- S&T infrastructure that includes equipment and facilities, circulation of science & technology information, and link & support organization.
- Institutional conditions comprised of social infrastructure that includes financial support institution, patent institution, and culture and other conditions that include manufacture structure, market structure, and international environments (Hong and Lim 2000).

Due to the transformative innovation policy aspect that leads to a new policy paradigm, RFE constructs a new systematic base for research (Irvin et al., 1997; Schot and Steinmueller 2018; Dierecks et al. 2019).

Therefore, this study attempted to analyze policy changes from the Rho administration when the RFE policy was first established to the Moon administration for the next 16 years. This is the first trial to dynamically analyze Korea's RFE policy and its implications on Korea NIS. Since the Moon administration has just ended, and Yoon administration took his office in May 2022, it is important to deduce implications of policy direction useful for the currently needed policy adjustments and future policies for the next government. This study basically applied the policy change type introduced by Hogwood and Peters (1983) and analyzed the changes in RFE, attempting to provide the direction and implications on how the policy should change in the future. While they fundamentally viewed policy as a dynamic process and adopted four measurement variables that include basic characteristics, law, organization, and budget to distinguish policy change types, an adequate research framework that needed to discern the RFE policy types and analyze the direction of change in the policy types (Chung et al., 2003).

In this pluralistic society, there is a possibility that the adequacy of research results deteriorates if we distinguish policy change types and their direction only with past standards. Therefore, the analysis focuses more on a critical perspective instead of following the model of Hogwood and Peters (1983) passively for the policy change types in RFE where additional measurement variables applied for the examination of substantive changes in the RFE policy could be added. With literature research, this study conducted deep interviews individually and/or in a form of group discussion with 11 employees working in the National Research Facilities & Equipment Center (NFEC) from March to October of 2020. Additionally, by attending seven international workshops and forums, it was carefully modified based on discussions among participants. Finally, because an author has been working at NFEC, it was also possible to

collect sensitive information needed to understand the direction of policy change through participatory inspection.

II. Theoretical background and research framework

1. Policy change types

Research on policy change has advanced since the 1970s to reduce or abolish previous policies (Kang et al. 2016). However, numerous definitions of policy change have been made without consensus on the definition (Yang 2014) because it literally refers that a policy changes. Among them, we had insight into Kang et al. (2016) study where a policy needs to be appropriate in three dimensions: necessity, realization, and efficiency. If one of three dimensions is missing, policy goals or means established during the policy-making process should be amended, generating policy change. Policy change can be perceived as setting up an alternative policy in the policy content or needed for the implementation process and strategy. Hence, this study focused on the changes in the policy contents of RFE.

Various types of policy changes have also been studied. Hall et al. (1975) distinguished types of policy changes: innovation with which a government intervenes in a new policy area, a development that refers to change in the scale or subject of previous policy, and reform that adopts a new policy or method to a policy area intervened already. Hall (1993) analyzed the U.K.'s economic policy, proposing a first-order change that refers to routine adjustments to existing policies, a second-order change that changes in the policy instruments, and a third-order change that shifts to a goal itself. A crucial component needed for policy change by Rose (1976) includes a dynamic process of a policy, proposing four policy change types – static framework, cyclical framework, linear framework, and discontinuous framework – as a policy goal changes through time.

Following previous studies and more substantively digging into dynamic characteristics in the policy changes, Hogwood and Peters (1983) also proposed four policy change types referring to basic characteristics, law, organization, and budget: policy innovation, policy maintenance, policy succession, and policy termination. Ko (1997) divided them into innovative change, successive change, and managerial change according to policy changes in paradigm, goal, and means. Also, Howlett and Ramesh (1998) categorized policy change types into 'Gradual Incremental,' 'Gradual Paradigmatic,' 'Rapid Incremental,' and 'Rapid Paradigmatic' according to changes in speed and direction. Pollitt and Bouckaert (2009) categorized them into Tortoise(Classic incrementalism),

Stalactite (Gradual, but eventually fundamental change), Boomerang(Radical conservatism) and Earthquake (Sudden, radical change) according to the progress and results of changes. Kang et al. (2016) divided them into intentional and unintentional change according to the intentionality, further distinguishing them by policy dimensions (basic vs. enacting policy changes) and characteristics of policy change (integration, additional enhancement, division, and termination). Table 1 summarized the literature and compared policy change types and standards.

Table 1 Comparison of policy change types

Index	Standards	Policy change type
Hall et al. (1975)	Scope and content of change	Innovation Development Reform
Hall (1993)	Degree of change (means, content, etc.)	First-order change Second-order change Third-order change
Rose (1976)	Time, policy goal	Static framework Cyclical framework Linear framework Discontinuous framework
Hogwood and Peters (1983)	Basic characteristics, law, organization, budget	Policy innovation Policy maintenance Policy succession Policy termination
Ko (1997)	Policy paradigm, policy goal, policy means	Innovative change Successive change Managerial change
Howlett and Ramesh (1998)	Speed and direction of change	Gradual Incremental Gradual Paradigmatic Rapid Incremental Rapid Paradigmatic
Pollitt and Bouckaert (2009)	Result and process of change	Tortoise (Classic incrementalism) Stalactite (Gradual, but eventually fundamental change) Boomerang (Radical conservatism) Earthquake (Sudden, radical change)
Kang et al. (2016)	Intentionality of change	Intentional change Unintentional change
	Dimension of change	Basic policy change Enactment policy change
	Characteristics of change in content	Integration of policy Additional enlargement of policy Division of policy Termination of policy

Source: Based on Kim, Son and Lee (2018), authors modified.

Hogwood and Peters' (1983) classification has its relative benefits due to substantiality and clear measurement variables. As compared to Hogwood and Peters (1983), Hall et al. (1975) missed policy maintenance or termination. Also, policy termination was missed in Rose (1976), Hall (1993), and Ko (1997). Howlett and Ramesh (1998) and Pollitt and Bouckaert (2009) used the speed or process in the policy changes as the standard, but the RFE policies had a new general plan coming out every four to five years since 2009, according to FAST. Therefore, it is not suitable to look at changes in speed. The types categorized by Kang et al. (2016) are challenging to examine because of the involvement of minor standards. Therefore, the typology of policy changes suggested by Hogwood and Peters (1983) was relatively advantageous and adopted, which could categorize the changes from policy innovation to policy termination along with the degrees of change and hold measurement variables such as basic characteristics, law, budget, and organization.

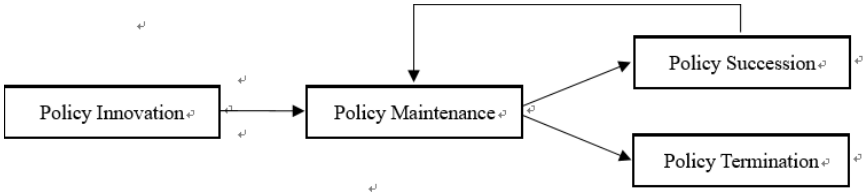
By elaborating the policy change types suggested by Hogwood and Peters (1983), policy innovation is defined as a government-led, new policy establishment with a purpose, which advances to a field that has not existed before in government organization, law, or spending. Policy succession means that a high level of policy change occurs purposely while maintaining the general structure of a policy goal. In this case, it can substitute the previous law, at least one change in the organization and some spendings. Policy maintenance has an adaptive characteristic, referring to a low level of policy change. There is no change in law or organization, and the previous level of budget is maintained. Policy termination refers to a purposive termination or halt of a particular policy. Previous law and government spending are terminated as well as organizational termination.

Finally, it is worthwhile to note that Hogwood and Peters' (1983) four measurement variables have the limitation to be applied for verifying actual policy content changes. While policy may appear in the form of law or budget, more concrete policy can be delivered via policy goal and policy means. For example, FAST requires establishing STBP every five years but only indicates the main items that should be included in it; more specific policy goals and policy means should be established via STBP. Therefore, policy goals and policy means should be added and examined to understand the pattern of policy change more accurately.

2. Research Framework on the flow of policy change types

Based on Hogwood and Peters (1983), Chung et al. (2003) proposed an organized form of the general flow of policy change types1. As shown in Figure 1, the first policy innovation occurs even if there are changes in the environment.

After that, policy content is adjusted to the change, as revised/altered to maintain the policy. With the changes accumulated, substantive changes to the policy will be introduced in the form of policy succession. The succession is maintained by adjusting to more changes. However, if the policy is perceived to be useless due to changes in the context, it terminates.



Source: Jung et al. (2003)

Figure 1 The general flow of policy change types

Several studies have focused on policy change types of Korea. Yang (2015) subsequently analyzed a four-river refurbishment project in Korea, where he concluded that policy change stream followed the pattern of policy innovation (as creation type) □ policy succession (as partial termination type) □ policy maintenance (as conformation type). Even if an important variable that affects policy change types is noncompliance of the policy subject group such as citizens, with regards to the RFE policy, there has been no instance of noncompliance by the policy subject group, so this study excluded it as well. On the other hand, Kim, Son and Lee (2018) added policy target group to the four measurement variables of Hogwood and Peters (1983) and analyzed policy for woman scientists and technicians in Korea and concluded that the trend followed the pattern of policy innovation □ policy maintenance □ policy succession □ policy maintenance as in Chung et al. (2003)'s research. However, Korea basically experienced policy changes along with a new administrative capital establishment project, where the policy change occurs in the order of policy innovation □ policy succession □ policy maintenance □ policy maintenance (Yang 2011). Further, the characteristics of the policy process differ as the dominant group changes, and detonation is the most important variable that affects policy change types. Changes in the dominant group mean changes in the government administration. Since policy contents have changed along with the administration change, this study focused on the aspect of the administration change for RFE. It should be noted that the Korean RFE policy is led by the government without any special detonation, so this study excluded detonation.

3. RFE policy in Korea

In terms of national innovation system theory, RFE policy can be understood as a sub-policy of S&T infrastructure policy[1]. Hwang (2005) has defined 'research equipment joint utilization policy' as a sub-policy for the RFE policy both narrowly and broadly. In a narrow sense, it is a policy that 'jointly utilizes research equipment of university-research institute-corporation and increases the efficiency of budget investment' while in a broader sense, it can be understood that it 'jointly utilizes research equipment and increase the efficiency of budget investment, and produces a new value that is university-research institute-corporation research collaboration and joint research.' However, a dearth of studies that defines what the RFE policy is have been conducted domestically or internationally.

According to Article 28 Clause 1 of Frame Act on Science and Technology, 'government must establish a policy to enlarge/develop RFE needed to promote research development, manage, run, jointly utilize and dispose of, and must promote them.' Further, the general government plan (Management Committee of National Science & Technology Council 2013; 2018) already stated some issues such as the development of RFE and the expert-level growth of human resources and projects related to RFE. Considering the Act and statement, this study defines the RFE policy as 'policy for R&D facilities and equipment enlargement, management, operation, joint utilization, development, and disposal as well as for those related to the fostering human resources and industries.'

The Rho administration established the 'Pan-ministerial RFE joint utilization promotion method' (hereafter, Rho-P1) in 2006 and subsequently established a specific plan in 2007. The Lee administration established 'National RFE enlargement and management advancement method' (hereafter, Lee-P1) in 2009, and established specific enforcement methods in 2010. The Park administration, then, made 'National RFE management/utilization promotion plan (2013~2017)' (hereafter, Park-P1) in 2013, '2013 National RFE status examination results and general plans on utilization efficiency' (hereafter, Park-P2) in 2013, and 'Promotion of national RFE investment efficiency and joint utilization' (hereafter, Park-P3) in 2015, establishing specific enforcement methods consecultively in 2013 and 2014. After the advent of the Moon administration, 'Research industry innovation growth strategy for improvement in R&D productivity and creation of quality jobs' (hereafter, Moon-P1) and the 'National RFE management/utilization promotion plan (2018~2022)' (hereafter,

1 OECD uses the term Research Infrastructure Policy. (http://www.innovationpolicyplatform.org).

Moon-P2) were established in 2018. The detailed RFE policies by administration are summarized in Table 2, where each policy was replaced with substituted words to present the policy easier and more consistent.

Table 2 Progress of South Korea's RFE policy

Index	Established time	Main policy content	Substitutes
Rho administration (2003~2007)	2006.11.	🖼 'Pan-ministerial RFE joint utilization promotion method'	Rho-P1
	2007.5.	♫ 'Pan-ministerial RFE joint utilization promotion specific promotion method'	Rho-P1-S1
Lee administration (2008~2012)	2009.3.	🖼 'National RFE enlargement and management advancement method'	Lee-P1
	2010.9.	♫ '2010 National RFE enlargement and management growth promotion method achievements and future plans'	Lee-P1-S1
Park administration (2013~2016)	2013.4.	🖼 'National RFE management/utilization promotion plan (2013~2017)'	Park-P1
	2013.7.	♫ '2013 National RFE management/utilization promotion enforcement plan'	Park-P1-S1
	2013.12.	🖼 '2013 National RFE status examination results and general plans on utilization efficiency'	Park-P2
	2014.4.	♫ '2014 National RFE management/utilization promotion enforcement plan'	ParK-P1-S2
	2015.10.	🖼 'Promotion of national RFE investment efficiency and joint utilization'	Park-P3
Moon administration (2017~2019)	2017.12	🖼 Research industry innovation growth strategy for improvement in R&D productivity and creation of quality jobs	Moon-P1
	2018.1.	🖼 'National RFE management/utilization promotion plan (2018~2022)'	Moon-P2

Notes: 1. 🖼 a general plan and ♫ a specific enforcement plan

2. Substitutes are developed by combining the order of established time and letters in a general plan (given to P) and a specific enforcement plan (given to S) with the last name of each administration. For example, 'National RFE management/utilization promotion plan (2013~2017)' in Park administration is substituted to Park-P1 because it is the first general plan of Park administration.

Most international studies focused on components comprising the policy. For example, Tassey (1991) argued that technology substructure policy should deal with every process of research development, production, marketing, and production cycle of the related products, while Justman and Teubal (1995) analyzed essential characteristics of technological infrastructure policy, defining

a catalytic role for government that emphasizes institutional innovation. However, innovation with high scientific importance needs to be suggested by research equipment users, and innovation with high commercial importance is by a producer of research equipment (Riggs and Hippel 1994). Similarly, Blind and Grupp (1999) underlined the most positive influence between the public science infrastructure and the industrial S&T output based on empirical research in German regions. About modernity, Caliari et al. (2020) analyzed the relative modernity of the research infrastructures through the case of Brazil as a less developed country, while Tomaskova et al. (2019) studied a Business Process Model representing the process of developing a medical instrument. In a different view, Yoon (2018) studied a policy conflict between governments and scientists on the efficient management of research equipment.

In South Korea, most studies have focused on research equipment and large research facilities. First, regarding research equipment, Kim et al. (2002) and Yi (2015) studied about management methods of research equipment; Hwang (2005) and Yi (2016) about joint utilization policy of research equipment; and Seol and Kim (2006) about establishment pattern of research equipment. More studies have extended them: efficient enlargement and joint utilization institutionalization methods of RFE (You et al. 2008), legalization of the RFE management (Cho et al. 2014), improvement of the management system of regional joint research equipment (Hong and Chung 2011), the innovation of user-centered service of research equipment infrastructure (Hong 2012), judging the similarity of research equipment(Kim and Kim 2018), the achievement of management system in joint utilization (You et al. 2015), and the promotion of Korea's research equipment industry (Kim et al. 2019). Furthermore, regarding large-scale research facilities, Lee et al. (2003) researched how to build and jointly utilize large-scale RFE. While Kwon et al. (2006) examined investment priorities of large-scale RFE, Kwon et al. (2007) and Noh et al. (2018) suggested an evaluation model of large-scale RFE. Yoon (2017) also suggested a third-generation synchrotron radiation accelerator policy.

However, these previous studies are all about specific issues. Indeed, they made limitations only by suggesting alternatives or improvement methods confined to a specific topic. Because they all fail to generalize RFE policies in Korea, the main contribution of this study is to provide a comprehensive and periodic analysis on Korea's RFE along with a policy change perspective as a generalized RFE policy study.

4. Research framework

This study suggested a research framework that explains that how policy change types could be connected to the RFE policy, investigating the flow of policy change types that have progressed and proposing a direction of policy

development. The timeframe of research is 17 years ranging from 2003 to 2019. Therefore, this study analyzed policy change in the Rho administration (2003~2007), Lee administration (2008~2012), Park administration (2013~2016) and Moon administration (2017~2019)[2]. This research framework is shown in Figure 2. Due to the limitation in Hogwood and Peters (1983), policy goals and policy means were added, categorizing into 6 variables. Policy goals and policy means are important to check if there is an actual substantive content change in the policy. Park (1990) categorized policy change evaluation indices into policy goal, policy alternative, and policy target group that is a core component of policy content; and implementation organization, budget, and ways that ensure conformity of policy target group as a core component of policy implementation method. Ko (1997) comprehensively organized various debates on policy components, suggesting that policy goals and policy means are the core components.

2 Note that Rho administration is from 2003.2.25~2008.2.24, Lee administration is from 2008.2.25~2013.2.24, Park administration was impeached in between, thus from 2013.2.25~2017.3.10, however policy is usually planned and implemented yearly, so this study analyzed the policy in a yearly manner. Moon administration has started in 2017.5.10 and is currently in the office, but due to the scope of this study, it only covers the policy changes until 2019.

Table 3 Policy change types and criteria

Index	Policy innovation	Policy succession	Policy maintenance	Policy termination
Basic characteristics	Purposive	Purposive	Adaptive	Purposive
Law	No existing law	Some law Superseded	No change in law	All relevant legislation repealed
Organization	No existing Organization	At least one organization subject to change	No Purposive (that is, policy-oriented) organizational change (changes consequential in workload, for managerial reasons, etc.)	An existing organization may be terminated
Budget	No previous Expenditure	Some existing Expenditure	Continuing budgetary item	All spending Ceases
Policy goal	No previous policy goals	Progressive changes in policy goals	Maintenance of policy goals	Termination of policy goals
Policy means	No previous policy means	Introduction of new policy means	Maintenance of policy means	Termination of policy means

Sources: Authors added policy goal and policy means to the four variables of Hogwood and Peters (1983: 27)

Also, policy means have been analyzed with regulation and incentive. The specific enforcing policy means are categorized into 1) conformity ensuring means and 2) implementation organization, implementation personnel, fund and public authority (Chung et al. 2003). Hwang (2013) categorized enforcing policy means into implementation organization, finance, regulation and incentive, and persuasion. Here, enforcement organization is analyzed under the organization category in this study, and finance is analyzed under the budget category. Thus, the analysis is to focus on regulation and incentive. Persuasion is an activity to increase conformity in the policy, and thus, an indirect means compared to regulation and incentive. Therefore, persuasion was excluded from this analysis. Table 3 provides specific criteria on the categorization to consider policy change types substantially, which was constructed with the 6 variables.

Further, verifying whether the flow of policy change types arranged by Chung et al. (2003) based on Hogwood and Peters (1983) or not was also made in this case. This is to grasp the policy flow that occurs in the long term, as seen in the RFE policy. This was examined whether the flow of policy change has occurred

generally in the sequence of policy innovation policy maintenance policy succession policy maintenance or in any other flow. Based on the result, this study brings important implications on examining S&T infrastructure policies and a new direction of policy development. To increase the feasibility as an alternative policy, the new direction is suggested by targeting the time frame of August of 2021. This research framework is shown in Figure 2.

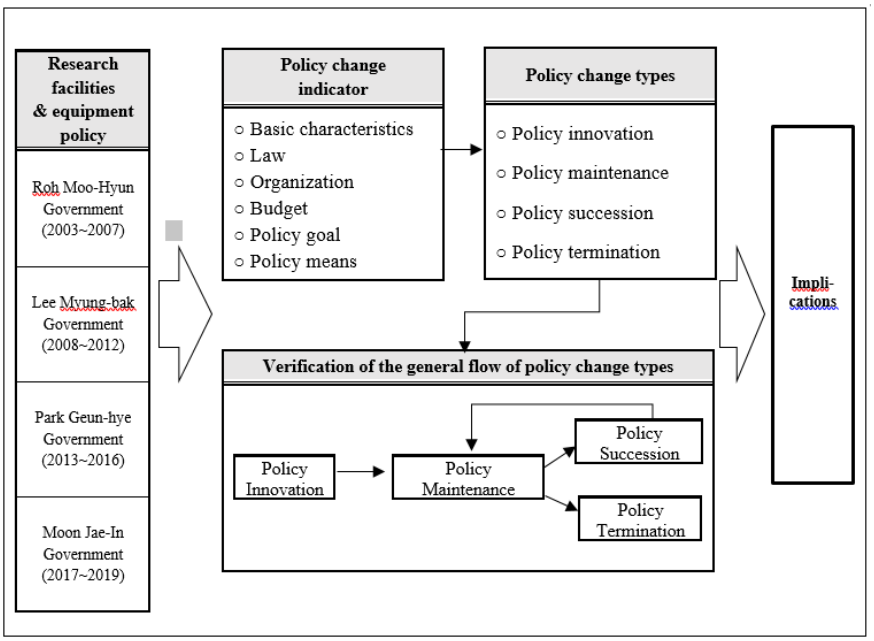


Figure 2 Research framework

III. Analysis of change in Korea's RFE policy

1. Rho administration (2003~2007): Policy innovation period

1.1 Basic characteristics

In May 2003, the government decided to promote 'sub-structure development for science technology productivity promotion' via a revised S&T basic plan[3], and stated 'research development facility and equipment development' in its

3 This is an overall revision of 'Science and Technology Basic Plan (2002~2005)' after the advent of Rho administration, which reflected the new science technology policy trend.

core promotion tasks. In November 2006, in S&T-related ministerial conference, the government enacted Rho-P1 to increase the utilization of and the efficiency of investment in RFE. Since then, in May 2007, it enacted Rho-P1-S1. The RFE policy in this period is thought to have basic characteristics that are 'purposive' towards policy change in which they created and implemented the methods jointly with the effort of 7 ministries.

1.2 Law, organization, and budget

Article 28 of FAST enacted in 2001 stated the development of RFE, but it was instead a statement than any action plans. However, in 2005, by amending 'National R&D Project Management Rules (NRPMR),' it stated a regulation that makes the registration of research equipment mandatory. In May 2007, through the S&T-related ministerial conference, the government agreed to appoint an institute as the main institution in charge of pan-ministerial equipment joint utilization, but the actual appointment did not happen. In terms of budget, except for the fact that $499.2 million in 2005, $598.2 million in 2006, and 1,154.8 million in 2007 have been used for the establishment of RFE, no other activities were made (National Science & Technology Committee 2011).

1.3 Policy goal and policy means

In Rho-P1-S1 that was enacted in May 2007, the goal is 'Pan-ministerial RFE joint utilization promotion,' where a promotion strategy was to (1) establish general life-cycle management structure according to a type, (2) establish pan-ministerial comprehensive planning/adjustment system, (3) promote investment efficiency of a research equipment project, and (4) improvement in openness and utilization of research equipment. While they lack specificity as a goal, they were conceived as a policy goal where a certain policy direction was introduced.

Among the aspects of policy means, some of the priorities of regulation means are as follows.

1) Adoption of research equipment registration system: in 2005, by amending NRPMR, equipment more than $30,000 acquired through national research & development projects or equipment that is eligible for joint usage even if they are less than $30,000 was required to be registered on Korea Equipment On-Line (KEOL) of KBSI within 30 days[4].

4 With these measures, research equipment joint utilization information network such as KEOL of KBSI, INFRANET of Ministry of Industry and Energy, Technical Resource Information Network (TRIN) of Small and Medium Business Administration that were separately ran became unified into KEOL, and KBSI began to start its role as pan-ministerial RFE general management.

2) Beta adoption of deliberation in the research equipment budget: in 2007, led by the Ministry of Economy and Finance, the government has adopted deliberation of research equipment of more than $300,000 when allocating budget for research & development projects, curtailing $19.95 million.

3) 2-level examination method to prevent redundant investment: each Ministry needs to write in advance to check if there are duplicated review results for equipment more than $30,000, and an equipment utilization plan for high-end equipment of more than $100,000, where the Science, Technology and Innovation Office should examine the redundancy for high-end equipment of more than $100,000.

4) Performance evaluation centered around utilization and linkage with budget deliberation: when submitting a project evaluation report, researchers must submit operation results centered around the utilization of RFE to reflect budget deliberation.

Next, some important incentive means are as follows.

(1) National Science & Technology Information Service (NTIS) linkage of each ministry equipment database (DB). The government promoted standardization for the equipment DB managed separately by 5 different ministries (Ministry of Science and Technology, Ministry of Industry and Energy, Ministry of Construction and Transportation, Ministry of Education & Human Resources Development, and Ministry of Information and Communication).

(2) Management of expert consultation among similar/same equipment: three had run since 2006, supporting seminars and so on (Science & Technology Related Ministerial Conference 2007).

1.4 Policy change type

This period formed policies after perceiving the necessity of the RFE policy; thus, the basic characteristic of the policy change is 'purposive' in this period. However, there had not occurred a meaningful change in law aspect. Even in the organizational aspect, it had not been able to appoint a main institution in charge of pan-ministerial equipment joint utilization, and in the budget aspect, it had no characteristic except for the fact that RFE establishment fees were continuously implemented.

However, it set 'Pan-ministerial RFE joint utilization promotion' as a policy goal, adopted a research equipment registration system and two-level deliberation system for prevention of redundant investment, and started NTIS linkage of each Ministry's equipment DB. Overall, this period can be understood as policy innovation because a dedicated organization has not appeared due to preparing law and budget. Especially, this administration established new policy goals and suggested some policy means that have not existed, leading policy

innovation.

2. Lee administration (2008~2012): Policy innovation period

2.1 Basic characteristics

Rho-P1-S1 was enacted in May 2007, but it lacked contents. Therefore, in August 2008, the government established 'Lee government's S&T basic plan towards developed first-class nation' ('2nd Basic Plan' onward) and appointed 'strategical enlargement and utilization of RFE' as a core promotion task as a part of S&T sub-structure improvement (Management Committee of National Science & Technology Committee 2009). Furthermore, in March 2009, the Management Committee of the National Science & Technology Committee deliberated and enacted Lee-P1. In September 2010, the Lee-P1-S1 was enacted. RFE policies in this period were 'purposive' along with the policy change in basic characteristics where 9 ministries jointly created and implemented the methods.

2.2 Law, organization, and budget

In February 2010, the government newly enacted Clause 2 of Article 28 in Frame Act on Science and Technology, and amended Article 42 of the same Act's enforcement ordinance in July 2010 and created rationales for support of fees needed for universities, research institutes, and corporations, the appointment of organizations to support the promotion of improvement in RFE and other core tasks. Further, in August 2010, the government amended a presidential decree, Article 25 of NRPMR, making the registration of NTIS for RFE information mandatory, deliberating the adoption of research equipment, and providing standard guidelines for the adoption and management of research equipment. Subsequently, the National Science & Technology Committee (NSTC) established 'Standard guidelines for the management of national RFE'('Standard Guidelines' hereafter) in December 2010 at the manual level and enforced it since July 2011, and NFEC established and distributed 'Registration manual for RFE information' and 'RFE sector' of research performance management manual. Moreover, NFEC established 'Standard categorization structure for national RFE' (hereafter, SCS) in December 2010 and categorized it into three categories: large (8), middle (48), and small (209).

In terms of organization, the supporting organization of RFE was appointed and managed. First, in May 2009, the government amended NRPMR and appointed KBSI as a management and circulation organization of research performance for RFE. In August 2008, through '2nd Basic Plan' and 28th NSTC, the government decided to establish and run NFEC in KBSI. It officially launched in August 2009, and its legal grounds were reflected in the amendment

of FAST in February 2010. As such, NFEC was appointed as an organization that supports the promotion of RFE.

Next, in terms of budget, budget-related RFE policy has been officialized since 2008. NFEC conducted organizational projects such as its management project and high-end research equipment management support project, conducting government-trusted projects such as a national RFE promotion support project and a research equipment engineer fostering project. The Ministry of Education, Science and Technology fostered expert human resources for research equipment via the Graduate School of Analytical Science and Technology (GRAST)[5]. Small and Medium Business Administration (SMBA) started a project that supports small and medium businesses to use RFE that universities or research institutes have owned since 2009. The Ministry of Knowledge Economy started a high technology research equipment competitiveness enhancement project that has supported the development of analysis and measurement equipment since 2010, and started an equipment competitiveness enhancement project for a new growth engine in 2011. Table 4 summarizes the budget status of the annual core budget. The budget total in 2008 was $772.7 million, and in 2012 it became $912.9 million.

Table 4 Lee administration's annual budget (regarding RFE policy)

(Unit: $ million)

Index		2008	2009	2010	2011	2012
RFE establishment fee		771.9	961.5	640.6	917.0	855.5
NFEC	Organization project	0.8 *	0.8	0.8	1.4	2.0
	Trusted project	-	-	0.8	2.9	3.8
GRAST project		-	2.0	3.0	3.0	3.0
Research equipment common use support project		-	7.6	12.6	15.0	16.8
High technology research equipment competence improvement project		-	-	5.0	4.7	4.8
Equipment competitiveness enhancement project for a new growth engine					24.0	27.0
Total		772.7	971.9	662.8	968.0	912.9

Source: NFEC 2011, 2012, 2013; Ministry of Science, ICT and Future Planning 2013

Note: KBSI established a research equipment promotion office in January 2008 and supported policy for the government's RFE policy until the establishment of NFEC in August 2009.

5 GRAST is a professional graduate school that opened in March 2009, jointly established by KBSI and Chungnam National University.

2.3 Policy goal and policy means

There is no specific policy goal in Lee-P1. However, setting 'science & technology sub-structure advancement for improvement in research productivity' as a basic direction, (1) strategic enlargement of RFE, (2) efficient management of RFE, (3) foster support of expert human resources and expert organization, and (4) development capacity reinforcement for high technology equipment and analytical technology as core tasks. While these lacked specificity as a goal, they suggested policy directions, indicating a policy goal.

Some important regulatory means among policy means are described as follows.

(1) Budget deliberation institution of RFE: when drafting R&D project budget, they established a research equipment budget deliberation committee and ran for pan-ministerial research equipment more than $100,000 (2007 through 2010, more than $300,000). As a result, for the 5 years from 2008 to 2012, it could reduce the budget by about $99.7 million in total.

(2) The RFE sector of pre-validity examination subject project: in 2012, by examining 10 industries, it could reduce $203.6 million worth of equipment establishment fee.

(3) Mandatory purchase status registration of research equipment: in 2009, with the amendment of the national R&D information standard, it is mandatory to register 6 criteria of research equipment purchases status in NTIS.

(4) Survey on the actual RFE condition. The operation management system, utilization and disposal performance, etc., have been investigated every year since 2011.

Next, some important incentive means are described as follows.

(1) Establishment of national large research facilities roadmap: in 2010, through the deliberation of related academic societies, universities and research institutes, the government deduced 69 national large research facilities. In 2012, it established '2nd National large research facilities roadmap' for the large facilities of over $5.5 million and appointed 13 core large research facilities.

(2) Support of the moving of low-use and idle equipment: in 2010, through movement support project of low-use and idle equipment, the government moved 5 in 2010, 7 in 2011, and 19 in 2012.

(3) Management of cyber mentoring support group of national research equipment: the government appointed 53 equipment mentors in 2010, 75 in 2011, and 115 in 2012, supporting expert consultation.

(4) Establishment and management of high-end research equipment committee: the government established 3 in 2008, 7 in 2009, 12 in 2012, and 7 in 2011 to exchange know-how and information via seminars (NFEC 2013;

Management Committee of National Science & Technology Committee 2010).

2.4 Policy change type

The basic characteristics of policy change in this period were 'purposive.' By amending laws and rules that were only announcements, actual institutional foundations regarding this policy were created. Further, actual rationales for organization and budget support were stated in the law. The advent of support or main organizations were designated to KBSI and NFEC, and the related budgets could individually be allocated and enforced according to each project. Furthermore, in Lee-P1, the government has installed basic directions and core tasks that can be seen as a policy goal. In terms of policy means, the government adequately combined regulatory means such as research equipment budget deliberation institution and incentive means such as national large research facilities roadmap, establishing the structure for the management of pan-ministerial life-cycle management (from planning to disposal).

Overall, this period clarified the legal basis, establishing an organization that the previous administration could not do so and executing six new budgets. While the previous administration rather focused on the joint use of RFE, this administration highlighted establishing a life cycle management system and setting policy goals and policy means, promoting innovative changes. Comprehensively to say, this period can be regarded as policy innovation.

3. Park administration (2013~2016): Policy succession period

3.1 Basic characteristics

In the National Assembly Inspection in 2011, two members of the National Assembly, EunHee Bae and YooJeong Kim, emphasized the need to set roles between Ministries and establish a consistent and structural RFE policy. Subsequently, the government established 'Pan-ministerial RFE committee,' and after four meetings, it established Park-P1 in April 2013, creating enforcement plans in the years 2013 and 2014. In addition, in July 2013, '3rd Science & Technology Basic Plan ('13~'17)' was established, where one of the tasks was 'opening of science & technology infrastructure and promotion of joint ownership.' In December 2013, the Park-P2 was established. In October 2015, Park-P3 was established for enforcement of 'Government R&D innovation plan.' The RFE policy in this period is 'purposive' in its basic characteristics, in which it established and enforced from Park-P1 to Park-P3 with a joint effort with 14 government ministries.

3.2 Law, organization, and budget

In this period, legal rationales for RFE policies were enlarged. In June 2015, Clauses 1 and 2 of Article 28 of FAST were amended, where government plans were specified to include enlargement and improvement of research development facilities and equipment, management/operation/joint utilization and disposal, thereby creating written laws related to life-cycle management. Further, by newly enacting Clauses 3 and 4, the Minister of Science, ICT and Future Planning was assigned the right to set rules necessary for the announcement, subject, establishment procedures of standard guidelines as presidential decrees. As such, in December 2015, Article 42 of FAST standard law was amended, where the tasks of an organization that supports research development facilities and equipment promotion in Article 8 was expanded to include support of policy formation/implementation, fostering human resources, developing RFE and supporting related industries.

Further, according to Park-P3, it needed to come up with legal grounds to promote pan-ministerial general adoption deliberation. So, the government amended NRPMR in December 2015 and deleted the previous evaluation committee for research equipment adoption by each Ministry. Instead, the national RFE deliberation committee was established. In July 2015, the government amended SCS for the advent of equipment that was missed in the scope of the previous structure: 8 large categories are the same, but middle and small categories increased to 54 and 410, respectively. In May 2016, the government officially enacted and announced 'Standard Guidelines for National RFE Management (SGNRM)' while they were partly amended in December of the year. In June 2016, the Ministry of Economy and Finance amended 'Total project budget management rules' in order to adequately adjust and manage R&D projects for the research base. Also, a management manual on national RFE was released in December 2016.

In terms of the organization, NFEC that was already appointed as an institution supporting the RFE growth continued its activities along with their enlarged tasks. In November 2014, the Ministry of Science, ICT and Future Planning has officially appointed and announced NFEC as a major institution for research performance management and circulation of RFE. Regarding budget, as all the projects that were in progress since the last administration continued, the budget increased. Among NFEC's entrusted industries, research equipment engineers fostering project fees increased from $1.08 million in 2012 to $3.0 million in 2013. The budget total increased from $741.1 million in 2013 to $991.1 million in 2016. Table 5 summarizes the major annual budget flow.

Table 5 Park administration's annual budget (regarding RFE policy)

(Unit: $ million)

Index		2013	2014	2015	2016
RFE establishment fee		677.9	786.2	971.1	950.1
NFEC	Organization project	2.1	2.1	2.1	2.1
	Trusted project	6.3	6.0	6.4	9.7
Graduate School of Analytical Science and Technology		3.0	-	-	-
Research equipment joint utilization support project*		18.4	16.5	16.5	18.7
High technology research equipment competence improvement project		5.0	4.6	5.7	6.0
Equipment competitiveness enhancement project for new growth engine		28.4	32.0	6.5	8.2
Total		741.1	847.4	1,008.3	994.8

Source: NFEC 2014, 2015, 2016, 2017; Management Committee of National Science & Technology Council 2014; Ministry of Science and ICT 2018.

Note: * The project name had changed from 'Research equipment common use support project' to 'Research equipment joint utilization support project' since 2013.

3.3 Policy goal and policy means

Park-P1 set its policy goal as 'Until 2017, creation of world-class RFE infrastructure environment,' pursuing specific goals as follows:

(1) reinforce investment efficiency of RFE
(2) reach 60% of joint utilization admission rate
(3) foster 2,700 equipment management experts in human resources
(4) create 8 regional specialized equipment clusters, thereby including quantitative goals.

However, among these goals, the creation of 8 clusters was not enforced. Also, in Park-P2, the basic direction was set as 'supporting high-technology research activities with science & technology sub-structure promotion,' and the core tasks as eliminating management blind spot, promoting establishment efficiency, structuring management system and promoting joint utilization. Park-P3 sets its policy goal as 'national RFE adoption efficiency and joint utilization promotion,' and stated tasks regarding life-cycle management from adoption to disposal.

Among policy means aspects, some of the important regulatory means are as follows.

(1) Budget deliberation of RFE. For 4 years, from 2013 to 2016, the government could save $177.7 million worth of excessively redundant equipment.

(2) RFE sector examination of pre-validity examination subject projects. From 2013 to 2016, the government could save $492.6 million worth of equipment set-up fees.

(3) Examination of rolling distribution project by Ministry of Economy and Finance. In 2015, by going through a beta deliberation of the total project fees for 18 research facilities construction projects, which were in the range between $5.0 million and $50.0 million, the government could save $114.3 million.

(4) Previous planning reinforcement of high-end research equipment. The government made it mandatory to write up a previous plan for research equipment over $5.0 million.

(5) Mandatory purchase status of registration for research equipment. With this, a total of 56,532 RFE information was registered by 2016.

(6) Census examination of RFE management status. Starting from 2013, the government initiated an institution-level examination that has more than two national RFE.

Some important incentive means are as follows.

(1) An establishment of an equipment utilization portal called Zone for Equipment Utilization Service (ZEUS). Equipment user service in 2013 started, and then, it could be expanded in 2015 as a form of portal.

(2) Improvement of RFE management of NTIS. It improved management structure by managing the quality of RFE information all the time and developing the registration function of large-scale research facilities and management services needed for human resources who are in charge of facilities and equipment.

(3) Enlargement of movement support for low-use and idle equipment. With this project, the government could increase 41 in 2013, 169 in 2014, 44 in 2015, and 182 in 2016.

(4) Enlargement of a cyber mentoring support group for national research equipment. 123 mentors in 2013, 140 in 2014, 239 in 2015, and 268 in 2016 carried out mentorship for technical experts.

(5) Presentation of RFE performance indicator. The National RFE manual released in 2016 provided 10 RFE performance indicators that ought to be managed by a research institute.

(6) World of Large Facilities for large-scale research facilities information service establishment. Since 2015, the government started building DB for domestic and international large-scale research facilities, providing information on 1322 facilities in 60 countries by 2016 (NFEC 2014, 2015, 2016, 2017).

3.4 Policy change type

In this period, the government established three general plans and two specific enforcement plans regarding RFE policy. There were major changes in law, organization, and budget. Legal ground enlarged and Frame Act on Science and Technology, enforcement ordinances, and NRPMR were amended. SGNRM was officially enacted, and SCS and 'Total project budget management rules' were amended. In terms of organization, NFEC enlarged by being appointed and playing a role as a major institution for research performance management and circulation of RFE. In terms of budget, new projects were initiated with the increase of budget fees. Further, the government established policy goals including quantitative goals such as 'achievement of 60% of joint utilization admission rate.' New regulatory means such as previous planning reinforcement of high-end research equipment and census examination of management status of RFE were adopted. The government also adequately mixed ZEUS equipment utilization portal and improved RFE management service of NTIS, completing a pan-ministerial life-cycle management system.

Therefore, the basic characteristics of policy change in this period are 'purposive' because there are high-level changes in law and organization, and the budget has increased continuously. Also, policy goals changed progressively while introducing some new policy means. Thus, it can be regarded as 'policy succession.'

4. Moon administration (2017~2019): Policy succession period

4.1 Basic characteristics

In December 2017, the Ministry of Science and ICT established Moon-P1 and included the research equipment industry. Subsequently, in January 2018, 17 Ministries jointly established Moon-P2, and especially included fostering of domestic research equipment industry and human resources fostering plans, intending that the scope of the government general plan widened compared to the previous administration.

In February 2018, 4th Science & Technology Basic Plan ('18~'22) was established with the joint effort of related ministries, and one of the core promotion tasks was 'scientific knowledge investigation and creative/ challenging research promotion,' stating to 'improve utilization of national RFE.' The RFE policy of this period is 'purposive' in that 17 Ministries jointly established and enforced Moon-P1 and Moon-P2.

4.2 Law, organization, budget

In the Moon administration, SGNRM was amended four times. In August 2017, the amendment occurred due to the renaming of government Ministries. The August 2018 amendment required general consideration of equipment management status when deliberating the adoption of research equipment of more than $100,000. In January 2019, the amendment clarified the scope of a broad deliberation subject, and then, the amendment reflected the mandate of upper laws that changed the registration/management information system of research development facilities and equipment from NTIS to ZEUS in May 2019. On the other hand, in March 2019, the government newly established Clause 4 of Article 12 of NRPMR and created legal grounds for 'Integration management system guidelines (IMSG) for RFE fee.'[6] and enforced them in September 2019.

In terms of organization, NFEC that was already appointed as an organization supporting the RFE improvement and 'Research performance management/ circulation institution for RFE sector' continued its activities.

On the other hand, in terms of budget, two new projects were initiated: first, NFEC created three beta core-facilities in 2018 using the government entrustment project and in 2019 entrusted $17.5 million for the basic science research capacity reinforcement project from the Ministry of Education, enforcing 20 core-facilities creation support and joint research utilization support fee. KBSI has initiated a research equipment development project regarding plural mode nano-bio optical microscope and so on since 2017. Research equipment development has existed in fragments in the past, but this was the first time that the project was implemented under the vision of research industry innovation growth. Since 2017, NFEC's organization project decreased, but this is because research equipment engineer fostering a project moved to KBSI according to the role allocation of the 1st vice-minister of science and ICT and science, technology and innovation office. Table 6 summarizes the major annual budget flow. The total budget decreased from $980.4 million in 2017 to $718.5 million in 2019.

6 IMSG refers to an institution allowing the use of fee for maintenance/repair, lend/borrow, movement/installment by previously reserving the finance needed for management of facilities and equipment during the period of research tasks. This helps stable management of RFE adopted with the budget of national R&D.

Table 6 Moon administration's annual budget (regarding RFE policy)

(Unit: $million)

Index		2017	2018	2019
RFE establishment fee		930.2	703.3	672.0*
NFEC	Organization project	1.5	1.5	1.3
	Trusted project	6.5	6.6	25.3
Research equipment joint utilization support project		14.7	10.6	12.5
High technology research equipment competence improvement project		5.6	3.6	-
Equipment competitiveness enhancement project for new growth engine		14.3	-	-
KBSI research equipment engineer fostering project		0.6	0.7	0.7
KBSI research equipment development project		7.0	7.0	6.7
Total		980.4	733.3	718.5

Source: Ministry of Science & ICT 2019; NFEC 2018, 2019, 2020.

* As of 2020.5.21., the RFE establishment fee is for RFE registered in 2019, and the fee could change depending on the material verification process.

4.3 Policy goal and policy means

In the Moon-P2, the vision was to 'lead science and technology-based innovation growth through improving national RFE utilization,' and stated examples such as 30% reduction of low-use and idle equipment rate and establishment of 30 research equipment core-facilities over the next 5 years. As strategies, it states improvement of research support-type of research equipment utilization, fostering of domestic research equipment industry and human resources. Further, 'Research Industry Innovation Growth Strategy' states four core tasks as a promotion strategy for enlarging research equipment domestication. These can safely be considered as policy goals.

Among policy means, some of the important regulatory means for 3 years from 2017 to 2019 are as follows.

(1) Budget deliberation of RFE. The government could save $61.6 million worth of excessive redundant equipment.

(2) Pre-validity examination subject projects for RFE sectors. The government could save $134.3 million worth of equipment set-up fees.

(3) Mandatory registration status for the purchased research equipment. A total of 67,946 RFE information could be registered.

Next, some of the important incentive mean during the same period are as follows.

(1) Establishing the unitary system centered around ZEUS, equipment utilization portal. Since 2017, the RFE registration system of NTIS was moved to ZEUS, where a deliberation information-based registration function was provided. In addition, ZEUS's mobile service environment was improved, and the linkage with other organization's information systems was expanded.

(2) Integrating management system for RFE fee. In 2019, the government appointed 36 enforcement organizations.

(3) Expanding movement support of low-use and idle equipment. With this project, the government moved 225 in 2017, 235 in 2018, and 426 in 2019.

(4) Keep managing cyber mentoring support the group for national research equipment. 106 mentors in 2017, 130 in 2018, and 132 in 2019 carried out technical expert mentoring work.

(5) Keep providing the WOLF large-scale research facilities information service. By eradicating redundant information and sharing information with MERIL-2, which is a research infrastructure information portal of ESF (European Science Foundation), the government could provide information on 1,324 facilities in 57 countries until 2019 (NFEC 2018, 2019, 2020).

4.4 Policy change type

In this period, related ministries jointly established general plans regarding RFE policy, and a separate government plan was established for the research equipment industry. In terms of law, the government amended SGNRM 4 times, and NRPMR 1 time, and enacted IMSG. In terms of organization, NFEC continued its role. Regarding budget, two new projects were pursued, including a basic science research capacity reinforcement project. Further, the government included quantitative goals such as '30% reduction in low-use and idle equipment rate' in Moon-P2, establishing policy goals such as the expansion of domestication of research equipment in Moon-P1. Among policy means, any special changes could not be found among regulatory means, but a 7 unitary system centered around ZEUS and IMSG could be newly adopted as incentive means.

Therefore, basic characteristics of policy change in this period can be thought to be 'purposive.' While there is no organizational change, legal change has been made. Also, there are two new projects in the budget, which made a progressive change. Further, establishing qualitative and quantitative policy goals made another progressive change and new policy means were introduced. Hence, this period can be understood as 'policy succession.'

IV. Conclusion and suggestions

1. Conclusion

Up to this point, this paper has classified changes in RFE policy and analyzed the flow of policy change types. Summarizing changes in RFE policy (as can be seen in Table 7), first, Rho administration(2003~2007) could not present a dedicated organization; rather, it focused on preparing law and budget, especially establishing new policy goals and suggesting some policy means that did not exist. This period led to policy innovation.

Lee administration (2008~2012) clarified the legal basis purposely. It established a new organization and executed six new budgets. This administration focused on establishing a life cycle management system and setting policy goals and policy means and promoted innovative changes. Overall, this period could lead to policy innovation.

Park administration (2013~2016) had a purposive direction in policy change basically. High-level policy changes could be achieved due to the expansion of law and organization as well as the increased budget. Also, quantitatively managed policy goals and some newly introduced policy means could establish a life cycle management system, and hence, it can be regarded as policy succession.

During Moon administration (2017~2019), basic characteristics of policy change were purposive, and the government amended SGNRM and enacted IMSG in terms of law aspects. Regarding organization, NFEC conducted roles it was appointed of, and regarding budget, two new projects were promoted. Even though no organizational change has been made, legal change and two new projects in the budget could make a progressive change. Establishing qualitative and quantitative policy goals as well as new policy means could make another progressive change, leading to 'policy succession.'

Therefore, each administration showed the order of policy innovation -> policy innovation -> policy succession -> policy succession, which is different from the general order of policy innovation -> policy maintenance -> policy succession -> policy maintenance. This indicates that each administration could understand RFE policy and pursue a higher-level policy change.

The history of science is a history of just how important resources and equipment is to discovery, and the importance of equipment in science is reported again and again in accounts of scientific discovery (Stephan and Levin 1992). Kruybosch (1997) argued that 81% of Nobel prize-winning research, 76% of 500 greatly cited research papers, and 63% of major progressive research in 1950 and 1970s were deduced from RFE. As such, RFE in modern science & technology research is a necessity, and the importance of RFE policy is

continuously increasing.

The main contributions that this study delivers include three points as a result of analyzing South Korea's RFE policy in terms of policy change, which are shown below. First, this study could expand a theoretical horizon in policy change research. By introducing policy goals and policy means to the four variables widely used in the policy change theory of Hogwood and Peters (1983), actual changes in policy content could be verified. Further, new classification criteria were introduced for these variables. In addition, by subdividing policy means into regulatory and incentive means, this study could enhance the specificity of the analysis on the policy means that other studies already distinguished.

Second, this study could make the policy change theory of Hogwood and Peters (1983) more flexible and comprehensive when applying to the actual policy change using the Korean case. This is because modern policy changes are very diverse by individual policy and shows a dynamic change. This study could include diverse stages of laws, from administration rules to laws passed by congress. Further, this study determined policy change type comprehensively. For example, even though Roh administration and Moon administration did not have an organizational change, policy goals and policy means were comprehensively considered in determining policy change type.

Third, Korean RFE policy turned out to display a unique flow different from the general flow of policy change types. In other words, looking at the flow of RFE policy change type, it was processed in the order of policy innovation -> policy innovation -> policy succession -> policy succession, which is different from Chung et al. (2003)'s summary of general flow they based on Hogwood and Peters (1983) (policy innovation -> policy maintenance -> policy succession -> policy maintenance). The fundamental reason why this happened is due to government change following a regime change. In other words, policy change occurred according to the ideology or national keynote after the government change, and we could examine it by analyzing policy changes in this study, contributing to the development strategy of the RFE policy introduced in August of 2021.

2. Policy suggestions and limitations

Based on the analysis applied in this study, the RFE development plan for Korea is suggested as follows:

First, in terms of law, the follow-up measures of the R&D Industry Promotion Act should proceed properly, which the National Assembly decided to enact on March 24, 2021. Since this Act includes the promotion of the R&D Equipment industry, the market expansion and ecosystem of RFE needs to be established

through the Act's enforcement ordinance and both general and specific enforcement plans. Further, SCS needs to be restructured because the current SCS is concentrated on research equipment while research facilities are limited to environment construction and production, leading to not being appropriate to comprehensively classify research facilities for each field. Second, in terms of organization, more diverse policy actors are required to participate in the policy process. For this purpose, it is desirable to form and utilize a national council where academia/research/industry/government members can participate broadly through policy establishment, implementation, and evaluation. Third, in terms of budget, it is necessary to efficiently use the budget of establishing RFE because the limited budget has been declined since 2016 after peaking at $1,008.3 million in 2015. Fourth, in terms of policy goal, after conducting the evaluation of policy effectiveness, the result needs to be added to the National RFE management/utilization promotion plan (2023~2027) to accurately measure the degree of achievement of the direct goal originally intended by the policy and determine in which direction of the policy and how to proceed it in the future.

Table 7 Summary of analysis

Index	Rho administration (2003~2007)	Lee administration (2008~2012)	Park administration (2013~2016)	Moon administration (2017~2019)
Basic characteristics	Purposive	Purposive	Purposive	Purposive
Law	-Clauses of Frame Act on Science and Technology is Proclamatory -Mandatory registration of research equipment in NRPMR	- Amendment of Frame Act on Science and Technology, etc. -Establishment of SCS	-Amendment of Frame Act on Science, Enactment of Standard, etc. -Amendment of NRPMR -Amendment of SGNRM	-Amendment of NRPMR -Amendament of SGNRM operational rate index -Amendment of SCS
Organization	Absence of Organization	Appointed KBSI as support organization, Established NFEC and appointed it as a support organization	NFEC played a role as a support organization and major institution	Continuation of NFEC's role

Budget		No special characteristics other than RFE establishment fee	6 Projects start of NFEC, SMBA and Ministry of Knowledge and Economy project	Budget continues to increase	Initiation of new entrusted project of NFEC and research equipment development project of KBSI
Policy goal		Pan-ministerial RFE joint utilization promotion, etc.	Promotion of science & technology sub-structure for improvement of research productivity	Reach 60% of joint utilization admission rate	30% reduction of low-use and idle equipment rate
Policy means	Regula -tory	-Research equipment registration system -2 stage reviewing system	-Budget deliberation system of RFE - Survey on the actual RFE condition, etc.	-Examination of rolling distribution projects by Ministry of Economy and Finance -Reinforcement of high-end equipment previous planning, etc,	Continuation of previous regulatory means
	Incent -ive	-NTIS linkage of each Ministry equipment DB -Operating experts council, etc.	-Establishment of large research facilities roadmap -Support of relocating idle and low-use equipment, etc.	-Establishment of ZEUS -Presenting RFE performance indicator, etc.	-Establishing an integrated system centered on ZEUS -Introducing IMSG, etc.
Policy change Type		**Policy innovation**	**Policy innovation**	**Policy succession**	**Policy succession**

Finally, there are two policy means. First, in terms of regulation among policy means, it is necessary to improve the survey items in the 'Survey on the Actual National RFE Condition' and prepare measures for the equipment utilization for

the joint use, which performs inefficiently. Note that the actual condition survey is being conducted on 12 items, among which only two items, the number of internal and external joint use and the number of days of failure, are investigated for RFE with joint utilization of $100,000 to less than $5 million. It is desirable to classify joint utilization institutions by nature so that the survey results can serve as basic data for future policies and investigate the outcomes such as thesis, patent, and prototype production support stemming from the joint utilization. In addition, it was found that 42.5% of the research equipment permitted and 20.5% of those served for joint utilization had no joint utilization record, which requires how to increase joint utilization. Second, in terms of incentives among policy means, it needs to unify the RFE registration window into ZEUS. The current RFE registration system is inconvenient for researchers and research institutes because ZEUS of the Ministry of Science and ICT and e-Tube (a common use system for industrial technology development equipment) of the Ministry of Trade, Industry and Energy exist in parallel. Since NFEC has been designated as an institute in charge of managing and distributing research results in the RFE field according to the Presidential Decree, it is reasonable in terms of efficiency to unify the registration window into ZEUS managed by NFEC while it can be allowed to automatically view the registration information and run some additional systems via e-Tube. In addition, it is necessary to establish the utilization and management system of RFE. In 2016, 10 items were suggested as RFE performance indicators and managed by each research institute; however, they could not reach active performance management such as setting performance goals and checking achievements.

While this study had its merits, the limitation of this study includes as follows. First, this study may have a lack of concreteness presented as a number due to a rather normative approach. Also, some of the policy development strategies suggested as a result of the research may simply stay at the level to suggest the development direction only. However, it is highly expected that a future study can lead to more specific and effective alternatives by tracking RFE policies continuously as well as various data analyses. Finally, introducing empirical research methods to this type of study may increase the objectivity of the findings currently suggested in this study.

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