An Empirical Study on the Dynamic Capabilities of Public Innovation Cluster

By

LEE, Jeongyun

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ABSTRACT

This study applies the dynamic capabilities concept introduced by Teece (2007) to examine the sustainable growth capability of the Daedeok Research Complex (DRC), a public innovation cluster in Korea. The thesis measures the three main components of dynamic capabilities - sensing, seizing, and transforming -as well as organizational cultural characteristics. This study conducted questionnaire surveys and semi-structured interviews with employees of public research institutions in DRC. The survey results were analyzed using a structural equation model (SEM), and the author conducted further interview about rejected hypothesis with three principal researchers and two directors who belong to the public IT institute.

The findings indicated that the information searching and benchmarking capabilities of sensing had a significant effect on the internalization of knowledge of seizing, while networking relationships did not it. In turn, the organization's internalization of knowledge had a significant effect on the resource adjustment or integration capability, but did not have a significant effect on the resource relocation or reconfiguration capability. In addition, organizational cultural characteristics had a positive mediating effect on the resource transformation capability. Through interviews with employees, the reason why networking relationship did not have significant effect on the organization's internalization of knowledge was the culture of competition among members due to PBS. The reason why the internalization of knowledge did not have a significant effect on the resource relocation or reconfiguration was the complicated research project reporting structure and weak authority of the head of the institution.

Overall, these findings suggest that the Korean government should focus on improving methods of evaluating public research and development (R&D) organizations, giving more authority to the heads of these institutions, and fostering an open organizational culture.

Keywords: Innovation cluster, Public R&D organization, Dynamic Capabilities

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1. Introduction

The Daedeok Research Complex (DRC) is a state-planned research and development (R&D) technology innovation cluster in Korea. DRC was built in 1973 by the Korean government to provide technological support for the modernization of the country's industry. During Korea's early industrialization, the government took the leading role in investing in R&D, while the private sector had a relatively weak R&D capability (MSICT, 2017). During this period, a number of major public R&D institutions such as the Electronics and Telecommunications Research Institute (ETRI), the Korea Atomic Energy Research Institute (KAERI), and the Agency for Defense Development (ADD) were created with extensive government support. These government-funded research institutions were guaranteed research autonomy under the 1973 "Specific Research Institution Promotion Act" (MSICT, 2017). In addition to establishing these institutions, the government specifically designated the Daedeok area near Daejeon to house these major public R&D institutions, along with Korea's most reputable national research university, the Korea Advanced Institute of Science and Technology (KAIST). The goal was to build a competitive research cluster, providing information exchange and joint research opportunities to academia and research centers (MSICT, 2017). Backed by strong government support, the public R&D institutions and KAIST successfully contributed to the rapid advancement of national industrialization throughout the 1980s and 1990s. As a result, DRC became known as Korea's leading science and technology research cluster (MSICT, 2017; Innopolis, 2021).

However, with the success of industrialization and economic development, Korean companies grew to become globally competitive. Large conglomerates, or chaebols, started to invest heavily in their own R&D (Cho et al., 2008). Furthermore, during the high-tech boom of the 2000s, not only chaebols, but also start-ups and small and medium-sized enterprises began to innovate. These firms gathered together, organically forming an innovative cluster in the city of Seoul known as "Teheran Valley". More recently, the Pangyo Techno Valley near Seoul has become known as "Korea's Silicon Valley," housing many successful high-tech start-up companies and others engaged in the so-called

"fourth industrial revolution". Furthermore, as more universities embark on national R&D projects, DRC appears to be losing its prestigious position as Korea's leading technology and R&D cluster.

One might argue that in today's changed circumstances, it is perhaps natural that an innovation cluster driven by big public R&D institutions should struggle to compete with those driven by active tech companies competing intensely in a fast-paced market. However, I believe that public R&D institutions do remain of value, since, unlike profit-driven companies, they can embody and create public value in their R&D activities (O'Flynn, 2007; Ju, 2018; Kim et al., 2014). This study examines DRC through a dynamic capabilities concept based on a primary survey and interview data, with a view to reviving DRC.

Dynamic Capabilities is a concept for organizational management and operations which focuses on the sustainable capacities and growth of an organization in an unpredictable industrial environment (Teece et al., 1997). In the fourth industrial revolution, where industry boundaries are breaking down and disruptive technologies are prevalent, a number of private firms are applying DC to maintain and improve their competitive advantage. While private companies are improving their capability to respond flexibly through dynamic capabilities, the government's R&D operational approach remains bureaucratic and inflexible. Moreover, although there is considerable interest in constructing a new cluster in Korea, there is insufficient interest in renewing the existing cluster (Chae, 2016). To overcome these limitations, this study applies a Dynamic Capabilities process to the DRC to determine its sustainable growth capabilities.

How can DRC be renewed to pursue more sustained growth? What factors hinder DRC's transformation capabilities? Dynamic capabilities can be categorized into three subfactors: sensing, seizing, and transforming, each of which has evolutionary characteristics. "Sensing" is a member's ability to acquire knowledge in response to environmental changes. "Seizing" is an organization's operational capability to internalize the knowledge acquired by its members. "Transforming" is the capability of an organization to convert internalized knowledge into performance by combining it with

existing resources. In order to accurately measure the DC subfactors in the case of DRC, I examined how each element affects the dynamic capabilities of DRC.

In addition to the three subfactors of DC, this study also examines the mediating effect of organizational cultural characteristics on the transforming capability of the DRC. Research has shown that the innovation-driven culture of public organizations, as well their members, has a positive effect on the organizations' performance. Based on the research—along with the assumption that higher job satisfaction and an open-minded company culture promotes the ability to transform resources—I also ask the following question in this thesis: what is the mediating effect of job satisfaction and organizational cultural characteristics on resource transformation capability?

In short, the main goals of this thesis are to examine the factors affecting DRC's sustainable growth through DC measurement, and to analyze how job satisfaction and open organizational culture impact DRC's resource-transforming capacity. The rest of this thesis is structured as follows. Chapter 2 reviews the literature on innovation clusters and dynamic capabilities. Chapter 3 describes research methods and hypotheses, creating the setting for empirical analysis. Chapter 4 describes the research subject, the data collection method, the structural equation modeling verification, and the results of the hypothesis verification. Chapter 5 concludes with the implications of the research, the limitations of the study, and suggestions for future study.

2. Literature Review

2.1 Innovation cluster

2.1.1 What is an innovation cluster

The innovation cluster concept was begun from Alfred Marshall's industry complex concept in 1890. The cause for the frequent came to use to the cluster concept is that Michael Porter was accounted for the nation's competitive advantage through the diamond model from his paper called the competitive advantage of nations in 1990. Porter (1990) explained the critical factor for improving the

nation's competitive advantages coming from the regional clusters (Chung, 2012). The discussion about the innovation clusters was conducted by OECD (1999) as researched the topic of the National Innovation System (NIS) and it was extended to the research of regional innovation system (RIS) and was increased through the relationship between industrial cluster gathered in the region and industrial competitiveness were investigated (Chung, 2012)

An innovation cluster is an industrial complex involving industries, universities, research institutes and companies in a particular region for the exchange of information and the creation of new innovative technologies and competitive advantages through networking interactions between organizations (Cooke et al., 1997, Cooke, 2002; Saxenian, 2002). "Many clusters include governmental and other institutions such as universities, standards-setting agencies, think tanks, vocational training providers, and trade associations that provide specialized training, education, information, research, and technical support." (Porter, 1998, p.78)

The innovation cluster's operational factors are composed of resources based on the interaction of institutional and supporting facilities. According to previous research on innovation clusters, based on Silicon Valley in the U.S. which is considered a successful cluster, an innovation cluster's success factors are based on the following resources: interaction between universities and companies; construction of a high-tech industrial complex containing many small-to-medium companies and start-ups; enterprise support services; venture capital; a high-quality public transportation system; a pleasant environment and facilities; and cultural distinctiveness, giving the cluster name value (Castells & Hall, 1994; Saxenian, 1994; Cook, 2008; Kearney, 2010; Gagne et al., 2010; Chung et al., 2016)

Institutional support from the government is an important growth factor for the cluster, in that it positively affects the sharing of knowledge and the spread of achievement through exchanges among the cluster's members (Uyarra & Ramlogan, 2017). Hence, the government should retain interest and support for the innovation cluster in pursuit of its continued development and the enhancement of its competitive advantage (Cook, 2008; Kearney, 2010; Gagne et al., 2010; Park et al., 2020).

For the same reasons, networking between members is an essential component of the innovation cluster (Castell & Hall, 1994; Saxenian; 1994). In her book, Saxenian (1994) emphasized that the cultural characteristics by which the network is formed among members are the factors that enable the innovation cluster's continued growth. In addition, such cultural characteristics should be developed to permit the flow of heterogeneous and fluid knowledge, so that the innovation cluster can build an environment favoring the open and interactive exchange of information and personnel (Saxenian, 1994; Cooke et al., 1997).

Previous studies on the success factors of innovation clusters measured these according to physical and institutional-centered resource components. These research results have limitations in explaining the dynamics of clusters, due to their lack of clarity, particularly concerning their evaluation methods (Martin & Sunley, 2006; Schmiedeberg, 2010).

Table 1. Preceding research on innovation clusters

Researcher	***Core factors for successful innovation cluster***
Saxanian (1994)	- Culture of organic network among members
Lee (2006)	- Highest interest on the part of government - Industrial-academic cooperation - Existence of pivot organizations
SERI (2002)	- Possession of inherent original technology - Brain-gain system - Supporting funding and information
Inzelt (2004)	- Knowledge exchange between universities and companies through human, institutional, and physical exchanges
Chung et al., (2017)	- Location of external environment

	- Institution for fostering cluster - Spread of knowledge and product - Creation of continuously outstanding performance
Gagner et al., (2010)	- Investment capital (government support, venture capital, management support) - Physical capital (education program, education infrastructure) - Human resources (talented labor pool, technology transfer) - Social capital (networking, promotion cluster, acquisition knowledge, name value)
Porter (1998)	- Innovation networking - Collective learning - Agglomeration of firms in a specific field - Fluid human capital - Active exchange of information and knowledge - Support for institutions by government
Eisingerich et al.(2010)	- Intensive exchange information network - Cultural openness - Physical, social and investment capital - Anchor organizations
Cooke (2008)	- Competence in knowledge and information acquisition - Agglomerated entrepreneurial spirit - Promotion by a support institution
Wolfgang (2004)	- Innovation system for local specialization

	- Good-quality housing and community facilities - Excellent traffic infrastructure - Talented labor pool - Promotion of innovation competence among personnel
Chung (2014)	- Innovation potential (innovation base, human resources, industry integration) - Infrastructure (amenities, production factors, traffic access)

Source: Yim (2013), Chung et al., (2016), Park et al., (2020); modified by author

No matter how good the resources are, if there is no clarity in the resource utilization method and no ability to organically transform resources within the industrial environment in response to change, the cluster's competitive advantage will decrease. From this perspective, the dynamic capabilities concept (Teece, 1997; 2007), which considers the ability to organically change resources in response to rapidly-changing industry conditions, has been seen as the correct one for enabling the continuous growth of the cluster.

2.1.2 Features of the innovation cluster life cycle

Innovation clusters display organic characteristics and evolutionary development patterns in four stages: emerging, growing, maturity/sustaining and regrowth/decline. The criteria for classifying the stages of the innovation cluster life cycle are included in a value chain: the strategic relationship between members, the dynamics of each stage, the influx of heterogeneous knowledge, and the number of entrants to the cluster (Klink & Langen, 2001). As the innovation cluster enters the maturity stage, the number of new entrants decreases while escapers increase. The diversity of internal knowledge, the internalization of external heterogeneous knowledge, and the dynamics, also decrease. This means that all indicators of the innovation cluster will diminish, which will lead to its decline. A decline in the entry of new knowledge and information exchange among members, and decreased interest from the government are leading factors in the decline of the cluster (Pouder & St John, 1996).

Table 2. Features of the innovation cluster life cycle

Stage of life cycle	Characteristic
Emerging	- Early difficulty in naming the cluster - Leading organizations present a vision for the cluster - Inducing inflow of external companies and start-ups through unconventional government policy - Start-ups actively entering the cluster - Apparent heterogeneity of various areas of knowledge
Growing	-Significant increase in employees due to growth of companies and increase in start-ups - Cluster support organization created by the government - Improved synergy between companies and research institutes - Strong connections among members through shared knowledge and network - Voluntary network formed between members and an environment that an environment that members wish to remain in - Various knowledge fields interact to create new innovations - Hardware and software infrastructure constructed
Maturity/Sustaining	- The number of workers is high, but companies per industry are decreasing. - High competency of members in the cluster - Creating synergy between industry, academia and research organizations - Influx period of knowledge diversity and cluster members approaches tipping point

	- Reduced interest in government support policies
Regrowth/Decline	- Increasing business churn and reduction of workforce - Attachment to specific market, knowledge in specific fields - Spin-off and starts-ups uncommon - Declining innovation due to fixation on previous successful methods - Reduced inflow of external knowledge, reduced dynamics - Creation of new clusters and adaptation to market changes

Source: Pouder & St.John, (1996); Eisingerich et al, (2008); Menzel & Fonahl, (2009); Gagner et al., (2010); Hwang, D. H., et al., (2018)

The operating method of the innovation cluster at each stage of the lifecycle is not a permanent growth component. This is because the operational factors that were advantages for each stage become causes of retrogression over time (Martin & Sunley, 2006). Therefore, in order for the innovation cluster to grow sustainably, it must change its operating method at each stage.

An innovation cluster can enter a stage of regrowth through adjustment and improvement. This must be achieved by an influx of heterogeneous knowledge. Moreover, if the diverse knowledge flow is not internalized, the innovation cluster will fail to grow again (Menzel & Fornahl, 2009). Hence, in order to converge heterogeneous factors and internal resources, the dynamics of the members, that is, their ability to acquire knowledge, are essential, because the member's dynamical behaviors are the core engines for practically operated innovation clusters (Menzel & Fornahl, 2009).

2.1.3 Features of the Daedeok Research Complex's life cycle

The Daedeok Research Complex (DRC) was established by the government in 1973 in the

Daedeok area near Daejeon, at the center of the country, as a justification for regional balanced development and the need for an integrated R&D research complex to enhance nation's technology industry development. In establishing the cluster, the government anticipated industrial-academic cooperation, joint research between institutes, increasing national industrial technology development, and the reduction of overcrowding in the city of Seoul's metropolitan area (MSICT, 2017).

Initial establishment of DRC, to invigorate the cluster and enhance national scientific and technological power, the government tried to attract researchers from overseas by offering high wages, travel expenses, subsidized residences and guaranteed research autonomy through provided extraordinary institutional benefits. To foster scientific talent, the government offered students special benefits such as free tuition, accommodation fees and exemption from military service (Moon, 2006; MSIT, 2017). As a result of the government's full support for DRC, the cluster took a core role in improving national science and technology with a series of innovative achievements, including top-ranking for U.S. patent evaluations, the world's first successful commercialization of the CDMA wireless standard for mobile phones by ETRI, the realization of independent defense capability by ADD, and advancement of nuclear power plant technology by KAERI. Thus, as prestigious the reputation, the DRC had led by the national science and technology competition development with various innovative achievements.

However, as time went by, the status of DRC changed. In the 1970s, the DRC led the nation in science and technology. In the 1980s, the DRC took a pivotal role in collaborative research with industry-academia research centers. However, from the 1990s, as university and private-sector research capabilities improved, the DRC's lead in national science and technology competitiveness began gradually to recede, and the DRC was criticized for low visible performance and low levels of research industrialization when gauged against the government's financial investment (Kim et al., 2005). Moreover, following the 1997 Asian monetary crisis, the government adopted an NPM (New Public Management) operational theory in an attempt to pursue productivity and efficiency through

competitive principles (Kwon, 2004; Jérôme, 2009). This approach was applied to the public R&D research organizations in the DRC.

The Star Project concept and the PBS (Project Based System) were introduced to promote efficiency in research (Kil et al., 2009; Jang et al., 2012; MSIT, 2017). PBS is the concept of supplying a research budget based on the total cost of the wages and research expenses required for R&D activities, and it is aimed at conducting research activities in response to customer demand (Lee, 2006). Its annual evaluations led to the restructuring of public R&D organizations. However, a case was made that this would lead to a bureaucratic and rigid culture, that it would hinder research autonomy through frequent government intervention (Jang et al., 2012; Lee & Park, 2018) and that it would undermine the public R&D innovation ecosystem (Kim, et al., 2005; Huh, et al., 2006; Lee & Choi, 2017)

Empirical studies suggest that the government's public R&D organizational evaluation system, which includes Star Project and PBS, does not have a quantitative effect on research results (Jang et al., 2012). On the other hand, other evaluations have indicated that the commercialization of research performance has been poorly handled (Huh et al., 2006; Kil et al., 2009; Kim & Lee, 2014). Currently, Korea's science and technology innovation capabilities rank second in the R&D investment activity sector, while the R&D performance sector, including the R&D support operation system and culture, was ranked 22nd, down eight places from the previous year (KISTEP, 2019).

The government's approach for pursuing productivity and efficiency among public R&D organizations has created issues such as unethical behavior on the part of institutions, lack of clarity about responsibilities, and no clear operational standards. As these issues hinder the public R&D research capability, a new operational paradigm should be developed and applied.

Unlike state-owned companies, which show clear results in the form of profit, public R&D organizations, which are semi state-owned, are less important to the government because of their low visibility and profitability. However, the public sector must ultimately pursue public value rather than profitability. To achieve this, the current government's operating method must be improved (Ju, 2018).,

The role of DRC is therefore considered very important in terms of creating public value through existing R&D capabilities.

For the DRC to revive, it will be necessary to create public profit value and monitor progress using the dynamic capabilities concept, which creates continuous performance and secures an organization's competitive advantage by responding dynamically to unpredictable and rapid changes in the industrial environment. This study will apply the concept to the DRC.

2.2 Dynamic capabilities

2.2.1. What is the dynamic capabilities concept?

Dynamic capabilities, the ability to pursue long-term business performance by reorganizing resources and capabilities to respond to the rapid changes in the market, was devised by Teece et al., (1997) and derived from the resource-based view (RBV) theory. The RBV explains that an an organization's sustained competitive advantage is determined by the value of the resources it possesses, their scarcity, inimitability and irreplaceability (Barney, 1991; 1997). However, RBV has certain limitations. First, the specialized resources held by an organization do not permanently guarantee its competitive advantage in a rapidly-changing market environment (Eisenhardt & Martin, 2000). Second, RBV fails to explain the difference in performances among companies with similar resources and assets in the same environment (Teece et al., 1997; Zott, 2003). Third, it provides no clear indication of how resources should be utilized to sustain competitive advantage (Teece et al., 1997; Eisenhardt & Martin, 2000; O'Reilly & Tushman, 2007). If unconverted, an organization's resources cannot guarantee the organization's continuous growth, and its existing core competence can become a form of core rigidity in the era of the fourth industrial revolution and digital transformation (Teece, 2017).

The reason for the contrast in performance between organizations that have similar resources in the same environment is that their dynamic capabilities for sensing environmental changes and internalizing external resources have been configured differently (Teece, 1997; Eisenhardt & Martin

2000). For an organization to generate performance, it not only needs to possess specific resources and excellent capabilities, but also needs organizational capabilities that can sense the changing market environment and exploit resources flexibly (Morgan, 2012). Hence, because dynamic capabilities are natural characteristics internalized within an organization's inherent operational capacity, they are defined as organization-specific capabilities (Teece, 1997, Eisenhardt & Martin, 2000).

As the market environment changes, for an organization to sustain its competitive advantage its resources must be reconfigured by combining external knowledge with its internal resources. Heuristic learning for reconfiguring resources through repetition is essential for achieving the dynamic capabilities to sustain a competitive edge (Teece et al., 1997; Blyler & Coff, 2003; O'Reilly & Tushamn, 2008).

That is, the organization's organically internalized knowledge and resource transforming capabilities is a critical success factor in point of sustainable growth view when considering the rapidly changing market environment

2.2.2 Sub-components of dynamic capabilities

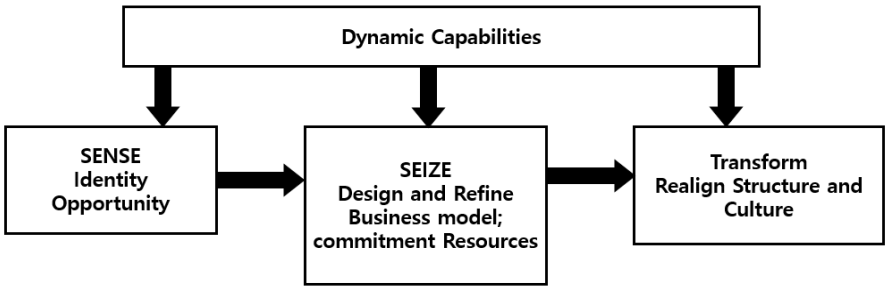
According to Teece (2007) dynamic capabilities have three main sub-components: sensing, seizing, and transforming. "Sensing" refers to the ability of members to identify, analyze, and evaluate environmental opportunities and threats. Sensing means exploring technological opportunities, closely observing and investigating new markets, and adapting previous technology as required by the member's sensing capability (Teece, 2007). According to Teece (2017), an organization needs its members to have the ability to sense market conditions quickly to address unmet needs that consumers have not experienced before, so that the organization may respond quickly to changing market conditions (Teece, 2017).

"Seizing" refers to the operational ability to determine the value of opportunities and to internalize them through the agile mobilization of resources. The main purpose of this feature is to

support timely resource mobilization and investment through rapid decision-making during environmental changes (Teece, 2007). The ability to acquire and utilize resources, to solve problems and seize new opportunities, is determined by the organization's ability to operate efficiently (Teece, 2017). An organization's operational competency is a special capability that cannot be imitated, because it is derived from the organizational culture, which no individual can clearly define. (Teece, 2014). Therefore, organizations must establish an organizational culture that routinely internalizes external knowledge in order to sustain competitive advantage (Zahra & George, 2002). To achieve this, flexible awareness and commitment are required from top executives (Aragon-Correa & Sharma, 2003, Teece, 2007).

"Transforming" means the ability to create performance by reconfiguring intrinsic resources during environmental change. This is the most important sub-component of dynamic capabilities (Teece, 2007). Transforming means the renewal of resources on their own in response to environmental changes. It requires the ability to reconfigure resources intermittently, although reconfiguring existing resources is not easy (Eisenhardt & Martin, 2000). Flexible operational management, work flexibility, resource coordination and redistribution, openness of possessed knowledge, and openness of top managers are necessary features of transforming capabilities from researchers (Eisenhardt & Martin, 2000; Zollo & Winter, 2002; Zahra and George; 2002; Teece, 2007). Organizations that have already secured a competitive advantage have fixed their growth strategies and organizational culture, and it is not easy to reconfigure their established organizational growth and management methods (Teece, 2017). In this regard, start-ups have superiority in creating new competitive advantages. Start-ups possess flexibility in resource conversion, in that they can quickly use and apply resources in a variety of ways, unconstrained by the fixity that comes with competitive advantage (Ries, 2011).

Figure 1. Business Models and Dynamic Capabilities



Source: Teece, 2017 p. 5

Dynamic competency has been studied from the following perspectives: emphasizing adaptation about environmental changes (Teece, 2007); the ability to respond quickly to opportunities (Jarvenpaa & Leidner, 1998); evolutionary suitability for adapting to the market environment (Helfat et al., 2007); organizational management practices that create new value by the combination of different forms of knowledge (Helfat & Raubitschek, 2000); the absorptive capability of creating performance by acquiring external knowledge and information and by having it assimilated by existing resources in the organization (Moreira, 2009; Lu et al., 2010); and resource reallocation capability through organizational learning (Zollo & Winter, 2002).

2.2.3 Dynamic capabilities and organizational cultural characteristics

As mentioned above, the awareness and commitment of top managers are important factors in improving an organization's dynamic capabilities. However, from the perspective of human resources, employee job satisfaction and openness to organizational culture are also important factors, as these factors increase employees' innovative behavior, which in turn positively affects the organization's performance (Mom et al., 2007; Yi et al., 2017).

A new strategy for private companies for sustaining an organization's competitive advantage in the rapidly changing market environment is for its members to quickly acquire information and convert it into performance (Rayport & Jaworski, 2004). From this perspective, the more innovative are

an organization's cultural characteristics, the higher are its dynamic capabilities (Zollo & Winter, 2002; O'Reilly & Tushman, 2004).

Won & Park (2018) argued that individual dynamic capability has an effect on organizational dynamic strategy. In order to effectively implement its strategy, the organization should foster innovative behavior by individuals, integrating the organizational business purpose with individual desires. Won & Park (2018) showed through their empirical analysis that higher job satisfaction and open organizational culture contribute to fostering individual dynamic capability.

The job satisfaction of members and flexible organizational culture both have a positive effect on the performance of public organizations. Kim & Oh (2018) showed through empirical analysis that innovation-oriented work culture has a positive effect on performance in private organizations. Woo et al. (2019) carried out an empirical study of nine public R&D organizations which showed that the high job satisfaction and autonomous organizational culture contribute to the organization's innovation culture by promoting innovation activity among employees.

2.2.4. Dynamic capabilities in the public sector

Dynamic capabilities have an effect on positive performance, not only in the private sector but also in the public sector. Kattell & Mazzucato (2018) emphasized that promoting private sector investment through creating and forming new markets focusing on future growth opportunities was the key factor. In order for the public sector to innovate, it should pursue qualitative objectives such as public value, not quantitative targets such as numbers of patents or employment levels. An innovation policy oriented towards a qualitative objective through dynamic capability can be provided through a policy framework which will overcome the government's policy adjustment failure. The core of this policy framework must be formulated in cooperation with the private sector, as problem-solving through external knowledge acquisition is a recognized method for bringing innovation to the public sector (Kattel & Mazzucato, 2018).

Cho (2019) proposed a policy for public R&D organization based on dynamic capabilities and innovation system theory. Following a mid- to long-term approach, the government should first stimulate innovation by taking part in an innovation platform and acting as an intermediary between the public and the private sectors. The public R&D organization should adopt an industry-academic cooperation role, acting as a knowledge broker, communicating with industry, and conducting problem-solving research. Second, human capital must play an important role in the development of the industry-academia research-innovation system. Therefore, to secure outstanding human resources, appropriate incentives, an open organization and research autonomy should be guaranteed.

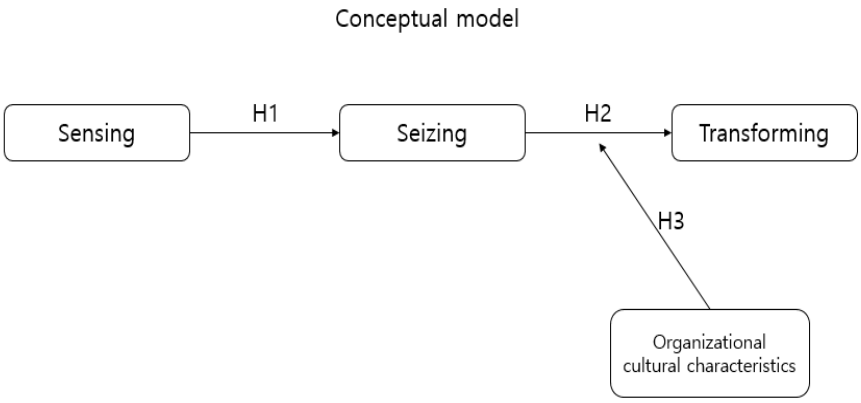
Some hold the view that it is difficult to expect dynamic capabilities to have meaningful effects in the public sector due to the limited access to resources, laws, and institutions for various stakeholders (Cha, 2014; Ferlie et al., 2016). However, when seen from the perspective of the need to avoid duplicated services, and for cooperation to improve the quality of public performance, dynamic capabilities are a necessary and essential component for a public organization (Frączkiewicz-Wronka, 2012). They should be introduced into public organizations as a means of predicting and eliminating future risks arising from unpredictable environments (Hawrysz, 2018).

3. Research method and hypothesis

3.1 Research design

This study aimed to measure the dynamic capabilities of the Daedeok Research Complex to analyze its capacity for sustainable growth. Sensing, Seizing, and Transforming, the dynamic capabilities' underlying components, were the main measured variables. Organizational cultural characteristics were measured as the moderating variables, because the innovation cluster is made up of employees whose innovative behaviors promote the cluster's sustainable growth (Saxenian, 1994).

Figure 2. Research Conceptual Model



3.2 Definition of measurement variables

3.2.1 Sensing capability

In this study, sensing capability was measured by dividing it into information search, network relationships and benchmarking. First, “sensing” means the ability of members of the organization to sense opportunities and threats in new markets. The organization’s assets are derived from human resources, and the first step for an organization in acquiring resources is the exploration for information by its members (Edvinsson & Malone, 1997). “Information searching capability” can be explained as the ability of members to recognize environmental changes, to gather information appropriate to the organizational strategy, and to reinterpret existing ideas within environmental changes (Teece, 2007; 2017, Rhee, 2020).

Second, the rich networking activities of members can gain insight through innovative thinking with the acquisition of new knowledge, information and opportunities, so reducing the risk of uncertainty and ultimately having a positive impact on the innovative performance of the organization (McAdam & MacAdam, 2008; Parida, et al., 2017; Rhee, 2020). In a rapidly-changing market environment, where it is difficult to maintain a competitive advantage only with internal knowledge, acquiring new and fluent knowledge through networking relationships is a necessary factor for an organization’s growth. Hence, the network relationships of members are an important factor in the

ability to sense the environment (Jeong & Yoon, 2013).

Third, the origins of Korea's R&D industrial technology lie in imitating and applying the advanced technologies of developed countries. The Korean government's strategy of imitating advanced technology succeeded in narrowing the technological gap with advanced countries (MSICT, 2017). In view of the fact that a benchmarking capability makes an organization's competitive advantage sustainable through the reinterpreting of existing ideas under changed market conditions, the members' reinterpreting capability can contribute to the company's growth in innovation (Cohen & Levinthal, 1990; Teece 1997; Rhee, 2020).

3.2.2 Seizing capability

"Seizing" is the operational capability for transforming acquired knowledge in the organization and mobilizing resources where they are needed. The flexibility of the organization's operational process, and its resource mobilization capabilities for acquiring external knowledge, will determine the organization's seizing capabilities (Teece, 2007; Garrido et al., 2020). Designing business model, mobilizing and investing resources according to new opportunity sensing are the main feature of this stage. When new opportunities are detected, organizations create profit results by offing new products and services that the market demands. In this process, in order to commercialize a product, investment resources should be supported for members can better sense the environment changed. Despite the rapid detection of environmental opportunities, it is difficult to convert them into performance unless investments are made in a timely manner (Teece, 2007).

3.2.3 Transforming capability

"Transforming" means to integrate and reconfigure the capabilities of internal resources with capabilities acquired from external resources to suit the market environment. Transforming is a core capability of dynamic capabilities, in that it maintains competitive advantage continuously (Teece, 2007; Eisenhardt & Martin, 2000; Zollo & Winter, 2002). In addition, through the reconfiguring of resources,

the process of transforming can remove the risk of rigidity in an organization's core competencies (Teece, 2017).

The transforming capability can be divided into two features (Huh, 2018). The first is the readjustment and integration of resources, which is carried out on a step-by-step basis, and enables continued growth and continuous performance innovation through human resource realignment, collaboration with outsiders, and devolving more authority in decision-making.

The second feature is the reconfiguration of resources according to market conditions. This is an organizational management method for responding flexibly in unpredictable market conditions. The transformation of IBM's business structure led by Gerstner, and Samsung's declaration of new business led by Lee Kun-Hee, are prime examples of this (Huh, 2018). The essence of this is that organizational structure and resources are organically rearranged and existing resources are reconfigured in response to changes in market conditions.

3.3 Research hypothesis

3.3.1 The hypothesis that sensing affects seizing

Because the R&D industry inhabits an inherently changing industrial environment, it is essential that the members are able to sense environmental changes and that the organization possesses the capacity for rapid decision-making and receptiveness to change (Bae & Kim, 2017). The members' ability to search for information with agility and accuracy, to sense new opportunities from networking relationships, and to benchmark to reinterpret existing ideas, all affect organizational performance improvement (Teece, 2007; Rhee, 2020). These competencies have a positive effect on the capability to internalize external knowledge, in that they can sustain the competitive advantage of the organization (McAdam & MacAdam, 2008; Parida et al., 2017). Nevertheless, the acquisition of information that is not standardized and not acquired through formal procedures may bring more harm than benefit (Schulz, 2003; Mom et al., 2007).

In composing the questionnaire items, the researchers referred to Teece's (2007) document and the questionnaire items of Rhee (2020) and Garrido et al., (2020). In this study, the hypothesis about the process from sensing to seizing was established as follows.

H1. Sensing will have a positive effect on seizing

H1-1. Information searching will have a positive effect on the organization's competence for internalization of knowledge

H1-2. Networking relationships will have a positive effect on the organization's competence for internalization of knowledge

H1-3. Benchmarking will have a positive effect on the organization's competence for internalization of knowledge

3.3.2 The hypothesis that seizing affects transforming

According to Kim (2019)'s research results on dynamic capabilities and operational capabilities for sustainable growth, if the seizing has positive effect on the transforming, the operational capabilities and innovation performance will be improved. Seizing its capabilities for acquiring knowledge and Transforming it into available resources transforming are more important than sensing in terms of sustainable organizational growth (Lee & Lim, 2017). However, if any one of the three capabilities are significantly degraded, the dynamic-capabilities effect decreases sharply (Kim, 2019). The knowledge-acquisition capability should not end with the mere acquisition of knowledge. If the acquired knowledge cannot be combined with internal resources, it is difficult to create a new competitive advantage for a company's innovative performance (Lee, 2018).

In composing the questionnaire items, the researchers referred to Teece's (2007) document and the questionnaire items of Rhee (2020) and Garrido et al., (2020). In this study, the hypothesis about

the process from seizing to transforming was established as follows.

H2. Seizing will have a positive effect on transforming

H2-1. An organization's* internalization of knowledge capability *will have a positive effect on resource adjustment/integration

H2-2. An organization's* internalization of knowledge capability *will have a positive effect on resource relocation/reconfiguration

3.3.3 The hypothesis that the mediating effect of organizational cultural characteristics in seizing affects transforming

For the continuous generation of performance, an innovative organization's operational capability should be supported in areas of corporate culture such as work satisfaction and openness, in ways that can be manifested through the members' innovative behavior (Dellana & Hauser, 2000). According to research by Kim & Oh (2018), high levels of job satisfaction and work autonomy, and an organization culture that fosters the organization's innovation culture will contribute to improving financial performance and lead to a higher quality of public service.

The questionnaire items of this study were formulated by referring to the questionnaire items of Woo et al. (2019), which empirically analyzed the organizational cultural characteristics of government-funded institutes. In this study, the hypothesis about the mediating effect of the organization's cultural characteristics in the process from seizing to transforming was established as follows.

H3. Organizational cultural characteristics will have a positive mediating effect in the process from seizing to transforming

H3.1.1 Job satisfaction will have a significant mediating effect in the process from internalization of

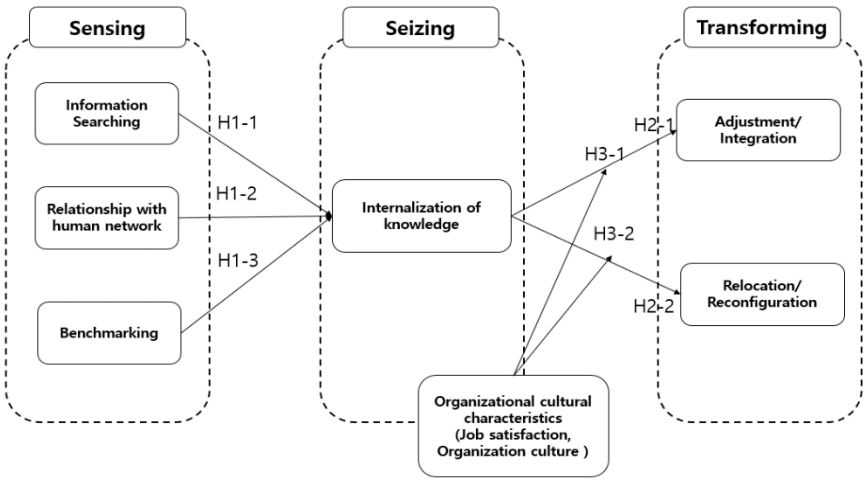
knowledge to resource adjustment and integration

H3.1.2 Organization culture will have a significant mediating effect in the process from internalization of knowledge to resource adjustment/integration

H3.2.1 Job satisfaction will have a significant mediating effect in the process from internalization of knowledge to resource relocation/reconfiguration

H3.2.2 Organization culture will have a significant mediating effect in the process from internalization of knowledge to resource relocation/reconfiguration

Figure 3. Measurement Research Model



4. Data analysis

4.1 How to perform data analysis

This study aims to measure the dynamic capabilities of the DRC for sustainable growth. The scope of the survey was limited to employees in government-funded institutes of the DRC because they follow the same management and administration, based on the laws and systems of the government. Questionnaire items were measured using Likert-5 point scales, and SPSS and AMOS were used for empirical analysis. After the first review of 15 employees of the DRC, the questionnaire was reset. The survey distribution and receiving responses were conducted through the internet with the Qualtrics

online surveys platform.

The data collection period ran from January 4 to January 18, 2021, a total of two weeks. The respondents belonged to 16 of the 17 government-funded research institutes in the DRC. After excluding questionnaire responses that were judged not to be sincere, 239 of 313 responses were used for statistical analysis. This study used the structural equation modeling (SEM) methodology, which uses the pathway approach for the structural equation.

SEM is an analysis method that recognize the causal relationship between latent (independent) variables through confirmatory factor analysis and path analysis. In addition, SEM has the advantage of being able to recognize at once not only a model of the continuous relationship among three or more independent variables but also, mediating variables' effect (Nachtigall et al., 2003). SEM is mainly used in multivariate analysis methods that combine factor analysis and regression analysis, pre-set model verification, and to identify the effects of multiple factors. For example, it can identify if A affects B and B affects C as well as can be recognized D's mediating effect between B to C. Each latent(independent) variables can be constructed from measurement(dependent) variables, which are questionnaire questions. In the analysis, independent variables must be independent of each other and measurement variables of latent variable should be required two or more to have statistical significance. The main purpose of using SEM is to verify whether the model set by the researcher that supported by the theory and preceding research. Hence, the theoretical and logical background for the established research model structure is important. The path analysis of SEM uses standardized coefficients, because it determines the influence of each variable.

Considering that the dynamic capabilities have a continuous form that sub-factors leading to Sensing, Seizing, Transforming, and measure the mediating effects of organizational cultural characteristics, SEM was judged to be a suitable analysis method for this study.

In addition, in order to find out the reasons for rejected hypotheses, this study interviewed three principal researchers and two directors from public IT institutions to determine the factors that

hindered the sustainable growth of the DRC. The composition of the total sample of survey respondents was as follows.

Table 3. Survey Respondents

Factor	Characteristic	Freq	Rates
Gender	Male	167	69.9
	Female	72	30.1
	Total	239	100
Age	21~30	29	12.1
	31~40	133	55.6
	41~50	44	18.4
	51~60	33	13.8
	Total	239	100
Employment conditions	Permanent	224	93.7
	Temporary	15	6.3
	Total	239	100
Organization sector	Nuclear	65	27.2
	IT	86	36
	Defense	41	17.2
	Others	47	19.7
	Total	239	100
Assigned task	Research	167	69.9
	Administration	72	30.1
	Total	239	100
Commission status	Commissioned	25	10.5
	Uncommissioned	214	89.5
	Total	239	100

4.2. Reliability and validity analysis

Research model fit, reliability and validity analysis of SEM is conducted through confirmatory factor analysis (CFA) procedure. Subsequently, Average Variance Extracted (AVE) and Construct Reliability (CR) are used to further determine the reliability and validity of each latent(independent) variables. The general factor analysis is divided into exploratory factor analysis and confirmatory factor analysis according to the research purpose. Exploratory factor analysis is mainly analyzed the relationship between the dependent variables and independent variable is not established theoretically and logically structured. On the other hand, CFA, the first step in the SEM analysis, is that verify the relationship between measurement variables (questionnaire items) and latent variables (the measured variables are clustered), as well as the relationship between the latent variables. Hence, in CFA, the measurement (dependent) variables must be created based on a strong theoretical background or preceding research and must be effected only by a latent (independent) variable, not related to other latent variables (Choi & You, 2017). Therefore, because of this study model applied the sub-factors (Sensing, Seizing, Transforming) of the dynamic capabilities concept, in which factors are independent and continuous form, to the DRC's characteristics, this study conducted to reliability and validity analysis through CFA.

The structural equation of reliability and validity was established through the confirmatory factor analysis (CFA) process. First, the goodness-of-fit index of the measurement model should be consistent to determine and validate factor analysis. If the goodness-of-fit index does not satisfy the required conditions, the reliability and validity analysis will have no meaning (Fornell & Larcker, 1981). In the event that this approach satisfies the goodness-of-fit index of the structural equation, the rudimentary reliability and validity are judged to be satisfied to some extent. After that, additional reliability and validity are judged through Average Variance Extracted (AVE) and Construct Reliability (CR). In CFA method, CR is used as the basis for determining independence, reliability, validity between latent variables, AVE represents the size of variance that an indicator can describe for a latent variable, and used as a basis for determining reliability and validity. This approach method was presented by Fornell & Larcker (1981). This method has the advantage that the application process is

very simple and the criteria for judgment are very clear.

In the criterion proposed by Fornell & Larcker (1981), the path-coefficient, lambda (λ) must have a statistically significant value. Lambda(λ) is a coefficient representing the causal relationship between the latent variable and the measured variable. The value of the standardized coefficients of a significant lambda must be at least 0.7. In addition, reliability and validity are secured when the CR value indicating reliability is 0.7 or more and the AVE value is 0.5 or more. As well as, if the CR and AVE values are satisfied, a standard lambda(λ) value of 0.7 or less is also allowed. Also, if the AVE value is larger than the square of the correlation coefficient, it is determined that single dimensionality and discriminant validity are secured.

In this study, a confirmatory factor analysis was conducted by applying the reliability and validity analysis method suggested by Fornell & Larcker (1981). This method proceeds in five steps, as shown in Table 5.

Table 4. Reliability and validity analysis process

Procedure	Criterion
1. CFA relevance of the goodness-of-fit index	Priority to satisfy the fit
2. Path-coefficient (λ)'s significant • Non-standardized λ secures statistical significance • Measurement items with a non-significant (λ) are removed, and CFA is conducted again.	Validity secured
3. Standardization $\lambda \geq 0.7$, Reliability ($\lambda^2 \geq 0.5$) • squares of path-coefficients (λ^2) is secure at least 0.4	Reliability and validity secured
4. Calculating AVE & C.R as standardized λ and error in measurement questions • C.R ≥ 0.7 or more (Above at least 0.632) • AVE ≥ 0.5 or more (Above at least 0.4)	Reliability secured
5. Compared with SMC (Squared Multiple Correlation) and AVE (Average Variance Extracted) • SMC < AVE	Discriminant validity secured

Source: Fornell & Larcker (1981)

Prior to this step, confirmatory factor analysis (CFA) was implemented to satisfy the goodness-

of-fit criterion to proceed with reliability and validity analysis. After the reliability for each measure had satisfied the goodness-of-fit criterion of the research model, reliability and validity analysis could be performed. Table 6 summarizes the simple meaning and criteria of each index as a representative goodness-of-fit index used in the structural equation.

Table 5. Goodness-of-fit index types

Kinds of Measurements	Goodness-of-fit index	Critical value	General model fit index
Absolute fit measures	X^2	p-value	The overall fit of the model
	CMIN/DF	between 1-3	
	RMSEA	less than 0.08	
	RMR	less than 0.08	
	GFI	more than 0.9	
	AGFI	more than 0.9	
Increment fit measure	NFI	more than 0.9	Independence vs. Research model
	TLI	more than 0.9	
	CFI	more than 0.9	
Parsimonious fit measure	PNFI	more than 0.5	Model complexity
	PCFI	more than 0.5	

Source: Fornell & Larcker (1981)

The Construct Reliability (CR) and the Average Variance Extracted (AVE), used for reliability analysis and validity analysis, were calculated using the following equation.

Figure 4. Construct Reliability (CR) Equation

$$Construct\ Reliability(CR) = \frac{\left(\sum_{i=1}^{p} \lambda_{yi}\right)^2}{\left(\sum_{i=1}^{p} \lambda_{yi}\right)^2 + \sum_{i=1}^{p} Var(\varepsilon_i)}$$

Sourced by Fornell & Larcker (1981) p.45

Figure 5. Average Variance Extracted (AVE) equation

$$Average\ Variance\ Extracted\ (AVE) = \frac{\sum_{i=1}^{p} \lambda^2{}_{yi}}{\sum_{i=1}^{p} \lambda^2{}_{yi} + \sum_{i=1}^{p} Var(\varepsilon_i)}$$

Sourced by Fornell & Larcker (1981) p.46

λ_{yi} stands for standard lambda and represents the factor loading value of the observed variable y for factor i. $Var(\varepsilon_i)$ stands for the variance of measurement errors. p is the number of observed dependent variables, y is the number of observed dependent variables and ε is a column vector of errors of measurement in y (Fornell & Larcker, 1981)

Following confirmatory factor analysis (CFA), the research model fit showed that χ^2=402.959(df = 269, p<0.001), CMIN/DF=1.498, GFI=0.886, AGFI=0.851, CFI=0.966, NFI=0.902, TLI=0.960, IFI=0.967, NFI=0.902, RMR=0.041, RMSEA=0.044, which appears stable for the calculated fit level.

Specifically, GFI (= 0.553) and AFFI (= 0.851) are shown to be lower than 0.9. However, the other fit indexes such as CMIN/DF and CFI, RMR for simplicity and RMSEA, the overall goodness-of-fit appears to be at an acceptable level. It is therefore judged that there is no problem for the research analysis progress.

The reliability criterion for each item is statistically significant when the non-standardized and standardized lambda (λ) should be at least 0.7($\lambda^2 \geq 0.5$). Based on these criteria, it can be decided whether to delete each item by checking whether the AVE (Average Variance Extracted) and the CR (Construct Reliability) are satisfied.

Table 6. Results of the confirmatory factor analysis (CFA)

Measurement Factors	Item	Non-std.λ	Std.λ	P	AVE	CR
Information Searching	IS.1	1	0.824		0.68	0.864
	IS.3	0.985	0.816	***		
	IS.4	0.833	0.715	***		
Networking Relationship	NR.2	1	0.89		0.74	0.895
	NR.3	0.919	0.781	***		
	NR.5	0.909	0.762	***		
Benchmarking	BM.1	0.99	0.869	***	0.801	0.89

	BM.2	1	0.859			
Internalization of knowledge	IK.2	0.723	0.725	***	0.611	0.862
	IK.5	0.682	0.691	***		
	IK.7	1	0.843			
	IK.8	0.941	0.83	***		
Adjustment / Integration	AI.2	0.743	0.675	***	0.581	0.804
	AI.3	0.713	0.676	***		
	AI.4	1	0.855			
Relocation / Reconfiguration	RR.2	0.868	0.733	***	0.588	0.851
	RR.3	0.903	0.73	***		
	RR.5	0.908	0.74	***		
	RR.6	1	0.754			
Job satisfaction	JS.1	0.778	0.765	***	0.659	0.885
	JS.4	0.797	0.722	***		
	JS.7	0.872	0.834	***		
	JS.8	1	0.85			
Organization culture	OC.2	0.966	0.755	***	0.599	0.818
	OC.3	1	0.774			
	OC.4	0.993	0.756	***		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The results of the CFA were that all non-standardized coefficients were shown as standard, and all standardized coefficients (λ^2) appeared above 0.5, indicating that there were no problems in item selection by factors. In addition, the AVE values were all 0.5 or more in all factors, and the CR values were all 0.7 or more, proving their reliability and validity.

In this study, discriminant validity was examined by calculating the standard error of the correlation coefficient with the bootstrap. At this time, it was considered that discriminant validity was satisfied if "1" is not included in the range of 'correlation coefficient ± (2 * standard error)' (Hair et al., 2011). Therefore, it was judged to have discriminant validity, because "1" was not included in the standard error estimation intervals for all correlation coefficients.

Table 7. Discriminant validity analysis

Correlation			Coefficient	S.E	2 standard error interval		p
					UL	LL	
Information searching	<-->	Networking relationships	0.501	0.045	0.591	0.411	***
Information searching	<-->	Benchmarking	0.638	0.051	0.74	0.536	***
Information searching	<-->	Internalization of knowledge	0.419	0.057	0.533	0.305	***
Information searching	<-->	Adjustment/Integration	0.351	0.053	0.457	0.245	***
Information searching	<-->	Relocation/ Reconfiguration	0.284	0.045	0.374	0.194	***
Information searching	<-->	Job satisfaction	0.518	0.056	0.63	0.406	***
Information searching	<-->	Organization culture	0.493	0.049	0.591	0.395	***
Networking relationship	<-->	Benchmarking	0.767	0.055	0.877	0.657	***
Networking relationship	<-->	Internalization of knowledge	0.33	0.052	0.434	0.226	***
Networking relationship	<-->	Adjustment/Integration	0.342	0.05	0.442	0.242	***
Networking relationship	<-->	Relocation/ Reconfiguration	0.301	0.043	0.387	0.215	***
Networking relationship	<-->	Job satisfaction	0.339	0.049	0.437	0.241	***
Networking relationship	<-->	Organization culture	0.343	0.044	0.431	0.255	***
Benchmarking	<-->	Internalization of knowledge	0.38	0.056	0.492	0.268	***

Benchmarking	<-->	Adjustment/Integration	0.333	0.052	0.437	0.229	***
Benchmarking	<-->	Relocation/ Reconfiguration	0.3	0.045	0.39	0.21	***
Benchmarking	<-->	Job satisfaction	0.426	0.053	0.532	0.32	***
Benchmarking	<-->	Organization Culture	0.392	0.047	0.486	0.298	***
Internalization of knowledge	<-->	Adjustment/Integration	0.701	0.083	0.867	0.535	***
Internalization of knowledge	<-->	Relocation/ Reconfiguration	0.696	0.072	0.84	0.552	***
Internalization of knowledge	<-->	Job satisfaction	0.733	0.077	0.887	0.579	***
Internalization of knowledge	<-->	Organization culture	0.689	0.071	0.831	0.547	***
Adjustment/ Integration	<-->	Relocation/ Reconfiguration	0.712	0.07	0.852	0.572	***
Adjustment/ Integration	<-->	Job satisfaction	0.7	0.07	0.84	0.56	***
Adjustment/ Integration	<-->	Organization culture	0.84	0.068	0.976	0.704	***
Relocation/ Reconfiguration	<-->	Job satisfaction	0.648	0.062	0.772	0.524	***
Relocation/ Reconfiguration	<-->	Organization culture	0.76	0.059	0.878	0.642	***
Job Satisfaction	<-->	Organization culture	0.709	0.064	0.837	0.581	***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The results of analysis of fit for all measurement research models is shown as χ^2=269.375(df =157, p<0.001), CMIN/DF=1.716, GFI=0.911, AGFI=0.869, CFI=0.964, NFI=0.920, TLI=0.952, IFI=0.965, NFI=0.920, RMSEA=0.055. so the calculated fit level was very high.

4.3 The results of hypothesis testing

This study is conducted path analysis between latent(independent) variables leading to the dynamic capabilities' sub-factors which are Sensing (Information Searching, Networking Relationship, Benchmarking), Seizing (Internalization of Knowledge), Transforming (resource Adjustment/Integration, Relocation/Reconfiguration) and measured the mediating effect of the organizational cultural characteristics (Job Satisfaction, Organization Culture) to the relationship between seizing to transforming. That is, H1 and H2 verified path analysis and H3 verified the mediating effect on H2.

Aforementioned, each latent(independent) variable was composed of several measured(dependent) variables made up of surveyed questionnaire items. As for the criteria of the questionnaire items that constitute the latent variable have at least of 0.7 ($\lambda 2 \fallingdotseq 0.5$) of non-standardized and standardized lambda values, and are composed of only statistically significant items.

The coefficient of hypothesis testing result stands for path analysis's influence intensity of latent(independent) variable A on B, and the p-value is used to determine whether the significance of hypothesis acceptation.

Table 8. Results of Hypothesis Testing

Hypothesis testing (path analysis)	***Coefficient***	***P-value***	***Results***
H1. Sensing will have a positive effect on seizing			
H1-1. Information searching will have a positive effect on the organization's internalization of knowledge capability	0.254	***	*Accepted*
H1-2. Networking relationships will have a positive effect on the organization's internalization of knowledge capability	-0.016	0.799	*Rejected*
H1-3. Benchmarking will have a positive effect on the organization's internalization of knowledge capability	0.199	0.001***	*Accepted*
H2. Seizing will have a positive effect on transforming			

H2-1. The organization's internalization of knowledge capability will have a positive effect on resource adjustment and integration	0.102	0.025*	*Accepted*
H2-2. The organization's internalization of knowledge capability will have a positive effect on resource relocation and reconfiguration	0.054	0.264	*Rejected*
H3. Organizational cultural characteristics will have a positive mediating effect on transforming			
H3-1-1. Job satisfaction will have a significant mediating effect on the seizing to resource adjustment and integration	0.242	0.021*	*Accepted*
H3-1-2. Organization culture will have a significant mediating effect on the seizing to resource adjustment and integration	0.332	0.003**	*Accepted*
H3-2-1. Job satisfaction will have a significant mediating effect on the seizing to resource relocation and reconfiguration.	0.481	***	*Accepted*
3-2-2. Organization culture will have a significant mediating effect on the seizing to resource relocation and reconfiguration.	0.344	0.002**	*Accepted*

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

4.3.1. The results of hypothesis testing that sensing affects seizing

Hypothesis 1 of this study verified that members' capability for information searching, network relationships, and benchmarking had a positive effect on the organization's internalization knowledge capability, as shown in Table 9. Information searching (H1-1) (Coefficient = 0.254, $p < 0.001$) and benchmarking (H1-3) (Coefficient = 0.199, $p < 0.001$) capabilities had a significant effect on the organization's internalization knowledge capability, but the networking relationship capability (H1-2) (Coefficient = -0.016, $p < 0.799$) was not significant effected. So H1-1 and H1-3was accepted but H1-2 was rejected.

In a dynamic capabilities study concerning the private sector, it was emphasized that

networking activities for communication, collaboration, and trust-building had a significant effect on improved dynamic capabilities (Parida et al., 2017; Rhee, 2020). However, in this study, only networking relationships capability did not appear to be a meaningful result for the organization's internalization of knowledge capability. This is due to the competitive culture of PBS in the public R&D organizations (Interview with three principal researchers in public IT institutes, January 2021). The PBS budget covers research needs and the wages of the researchers. Therefore, the project manager is responsible for providing wages to team members by winning the project through competition with other organizations. The project competition process places added stress on the project manager. In such an organizational environment, helping other team members does not have a positive effect on personnel evaluation, and it can create the perception that the project manager will be distracted from his/her duty.

The relationship between members within an organization is perceived to be a competitive relationship for winning a project rather than a relationship for sharing knowledge. For this reason, there is a community within the organization, but only for shared recreations, not for the sharing of knowledge.

4.3.2. The result of hypothesis testing that seizing affects transforming

Hypothesis 2 of this study verified that the organization's internalization of knowledge capability had a positive effect on the organization's resource adjustment/integration and relocation/reconfiguration capabilities. As shown in Table 9, the organization's internalization of knowledge capability had a significant effect on resource adjustment/integration capabilities (H2-1) (Coefficient = 0.102, $p < 0.025$), but the relocation/reconfiguration (H2-2) (Coefficient = 0.054, $p < 0.264$) was not significant. So H2.1 was accepted but H2.2 was rejected.

Looking at preceding research related with H2.1, in research on the effect of dynamic capabilities on innovation performance (Kim, 2019), the organization's seizing capability positively affected innovative performance. However, in order to lead to innovative performance through resource

transformation, the organization's rigidity of management can be a resistance factor, so an open culture should be supported. Therefore, this study supports Kim's (2019) research results for H2.1. The reason why hypothesis H-2 was rejected is also believed to derive from the operational characteristics of public R&D institutes. The operational characteristics of the DRC can be explained as follows (Interview with two directors belonging to a public IT institute, January 2021):

Public R&D organizations in the DRC are highly specialized in adjusting and integrating human and material resources among projects within the research center's manpower pool. However, it is almost impossible to reconfigure the resources of flexible research projects according to the external research environment.

The public R&D organizations' operational project evaluation method proceeds as follows: the project managers conduct research and report to the government department. The government department then establishes the purpose of the projects, the budget amounts to be invested, and the management of the research results. In addition, external experts evaluate the feasibility of the projects. Thus, it is impossible to expect the elaborated projects management, expertise and strong responsibility from a temporary organization for evaluation and management of a research project. Also, the method of evaluating projects participating various stakeholders gives easefulness for researchers that the just achieving the research goal of receiving a budget rather than endeavor to improved research quality.

Therefore, a whole–cycle project management should be administrated by the research institution through unifying the authority to the head of the institution. If the authority is unified with the head of the institution who understands the condition of the institution well, compared to the government departments, it can improve the flexibility of the resources use, prevent a comfortable researcher's attitude, and improving researcher's work engagement, as well as, can be expected to improve the higher quality research performance.

Unlike private organizations, the head of the public R&D organization has not only less official authority, but must also manage the organization according to the wishes of the superior authority (Kim,

2008). Even if the head of the R&D organization has a deep understanding of the organization's condition, it seems that it is almost impossible for them to organically transform the organizational resources in the light of internal and external conditions due to their lack of authority.

4.3.3 The result of hypothesis testing that the mediating effect of organizational cultural characteristics in seizing affects transforming

Hypothesis 3 of this study verified how much organizational culture characteristics positively affect transforming capacities (adjustment/integration and relocation/reconfiguration) as mediating variable. As shown in Table 9, job satisfaction had a significant mediating effect on resource adjustment/integration (H3-1-1) (Coefficient = 0.242, $p < 0.021$) and resource relocation/reconfiguration (H3-2-1) (Coefficient = 0.481, $p < 0.001$). Organization culture had a significant mediating effect on resource adjustment/integration (H3-1-2) (Coefficient = 0.332, $p < 0.003$) and resource relocation/reconfiguration (H3-2-2) (Coefficient = 0.344, $p < 0.002$). As a result of research showing that job satisfaction and organization culture competency have a strong positive mediating effect on resource transformation as a mediating effect. Because the meaning of coefficient value being high is evidence of a strong mediating effect.

As proved by Kim & Oh (2018), whose research showed that innovative organizational cultural characteristics positively affect an innovative public organization's performance, the higher the job satisfaction, the greater the sense of achievement and the opportunity for development. The provision of education programs for in-depth research, easy accessibility to external knowledge, and clear work responsibility are also increased. According to Dellana & Hauser (2000), an innovation-oriented and creative organizational culture has an impact on innovation performance, but a bureaucratic organizational culture does not contribute to performance improvement. The rigid culture can be shown to derive from competition between organizations and members due to PBS (Huh et al., 2006). This study's hypothesis test and its results for the organizational cultural characteristics have proved that the stronger the organizational cultural characteristics, the greater the positive capacity

provided for resource transformation.

5. Conclusion

5.1. Findings

This study empirically analyzed the dynamic capabilities of the public R&D cluster known as the Daedeok Research Complex to measure its sustainable growth capacity. In particular, this study analyzed the process of developing dynamic capabilities leading to sensing, seizing, and transforming through structural equation modeling (SEM). Sensing components were classified as information searching, networking relationships, and benchmarking. Seizing components were classified as internalization of knowledge, and transforming components were classified as resource adjustment/integration and relocation/reconfiguration. In addition, in examining the process from the stages of seizing to transforming, the mediating effect of organizational cultural characteristics were supported. This study included a statistical analysis of 239 survey responses.

The results included the following, broken down by step. The first step examined the transition from the capabilities of sensing to seizing. Of the three components of sensing, information searching and benchmarking had a significant effect on the organization’s internalization of knowledge (seizing), while networking relationships did not have a significant effect. These findings indicate that the organization easily internalizes knowledge from individuals’ information searching and benchmarking activities, while knowledge acquired through networking among members does not transfer well to the internal resources of the organization.

These results can be explained as the lack of motivation for cooperation and competition awareness among members due to PBS. Therefore, to improve the networking capabilities of public R&D organizations, both reforming the structure of PBS and providing incentives for organizational collaboration, can be solutions, and if members' collaboration is activated, the organization's capability to internalize knowledge will be expected to further improve.

Second, in the process of seizing to transforming, internalization of knowledge had a

significant effect on resource adjustment/integration, but did not have a significant effect on resource relocation/reconfiguration. These results indicate that the DRC's gradual resource transformation was specialized, while radical resource transformation was not. Consequently, it can be concluded that the DRC's operational characteristics, such as dualized authority between the head of the institute and the sponsoring government department and the complicated project evaluation structure, hinder the complex's ability to achieve flexible resource transformation.

Therefore, if the authority for a whole-cycle management of the research projects is unified to the head of the institution, it can be expected that the improvement of resource flexibility according to the external or internal condition, the simplicated project reporting structure increases the work engagement of members through rapid work response, and also can be expected to the high quality of research results.

Third, the process of seizing to transforming was examined. Organizational cultural characteristics appeared to have a positive moderating effect on this process. Results pertaining to the first hypothesis showed that the DRC had a very rigid culture. Accordingly, adopting a more open organizational culture may greatly improve the DRC's resource transformation capability.

This study measured the dynamic capabilities of the DRC in order to evaluate its sustainable growth capability through resource transformation in an unpredictable environment. Study results provided practical information to support and enhance the continuous growth of this public R&D cluster.

5.2 Implications

This study suggests several implications to support the sustainable growth of the DRC. First, the networking relationships between the members of the DRC appeared weak, which was due to the competitive consciousness created by the PBS. Generally, the members of public R&D organizations react sensitively to evaluation. Given that the PBS system is creating a competitive consciousness, reforming the PBS's structural problems and personnel evaluation methods may motivate members to increase collaboration.

Second, the internalization of knowledge capability significantly affected the DRC's resource

adjustment/integration capability, but did not have a significant effect on resource relocation/reconfiguration. Identified problems included the head of the institution's weak authority and a complicated project operation evaluation method that extended to the sponsoring government departments. In the DRC's unpredictable environment, rapid response decision-making is essential. Accordingly, the head of the institution should be given sole authority over research project design and the process of evaluating project operations should be simplified.

Third, this study suggests improving organizational cultural characteristics in order to increase the capability for flexible resource transformation. In the rapidly changing industry environment, dynamic behaviors are essential to maintain a long-term competitive advantage. Hence, it is necessary to build a flexible organizational culture that can lead to innovative practices.

5.3 Limitations and Future Research

One limitation of this study was its small sample size and data collection relative to the entire workforce of the DRC. In addition, face-to-face interviews could not be conducted with members of the various organizations due to COVID-19. Therefore, the study may gain more meaning if compared to future research on similar types of organizations that is not constrained by these limitations, such as larger sample sizes and increased data collection, including face-to-face interviews.

This study measured dynamic capabilities of the DRC. However, this study does not indicated relationship between dynamic capabilities and practical research outcomes (such as patents, research result transfer, and commercialization research results, etc.). Considering that the sustainable growth must be supported by practical performance, future research should compare these dynamic capabilities with numerical and practical research performance.

This study investigated the factors that the sustainable development of the public R&D cluster by measuring the DRC's dynamic capabilities. The results suggest that management methods should be improved in order to create a flexible and optimal organizational culture, particularly in order to facilitate resource transformation capability in an unpredictable environment. Based on the academic and practical results of this study, a follow-up study without the limitations of the current study indicated

by the researcher could produce additional and more in-depth research on these dynamics and processes.

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Appendix

1. What is your gender?

( )Male ( ) Female

2. What is your age?

( ) 21- 30 ( ) 31- 40 ( ) 41 - 50 ( ) 50 or more

3. How long is your working period?

( ) under 5yrs ( ) 5-10yrs ( ) 10-15yrs ( ) 15-20yrs ( ) 20yrs or more

4. What is your employment condition?

( ) permanent ( ) temporary

5. What kinds of public organizations are you with?
( )

6. What is your task?

( ) research ( ) administration

7. What is your position status?

( ) Commissioned ( ) Uncommissioned

Please indicate the degree to which you agree with each of the statements below using the following scale:
Completely Disagree = 1 Agree Completely = 5

Sensing: Measures capability of new opportunity search and explore (I am….)		
Information Searching	IS.1	I am searching research trend to related with my research
	IS.2	I am getting research ideas by various internal studies
	IS.3	I am getting research ideas by various external studies
	IS.4	I am getting exemplary study case to my research purpose
Networking Relationship	NR.1	I endeavor to establish trust relationships with external people related to research activities.
	NR.2	I endeavor to collaborate with external people related to research
	NR.3	I participate in community activities within the organization for research activities.
	NR.4	I engage in research related exchanges with people from other departments in the organization.
	NR.5	I endeavor to participate in external research projects
Benchmarking	BM. 1	I am trying to apply to exemplary study to my research
	BM. 2	I am studying and learning the exemplary studies

	BM. 3	I am trying to reinterpret and utilize exemplary research studies
Seizing: Measures administrative and administrative capability to capture and respond the environmental opportunities (Our, organizations...)		
Organization's Internalization of knowledge	IK.1	Our organization provides financial support for members of the organization to acquire external knowledge
	IK.2	Our organization is active in the internal application of acquired external knowledge
	IK.3	Our organization has operating an internal community related to acquiring and sharing research knowledge
	IK.4	It is easy for external stakeholders to access research results of our organization
	IK.5	In our organization, the know-how of its members is used to create organizational performance
	IK.6	Our organization provides learning opportunities, including educational program related to research
	IK.7	Our organization actively accepts the opinion of researchers when they have making decision
	IK.8	Our organization performs flexible decision-making depending on changes in the research internal/external environment
Transforming: Measures the capability to constantly change and renew itself and to implement change intermittently (Our organizations…)		
Resources adjustment and integration competence	AI.1	Our organization readjusts internal human resources as necessary to improve successful research results.
	AI.2	Our organization utilizes external personnel when necessary to improve successful research results.
	AI.3	Our organization promotes joint research with external researchers when necessary to improve successful research results.
	AI.4	Our organization grants research autonomy to its members to improve successful research results.
	AI.5	Our organization empowers the team to make decisions to improve successful research results.
	AI.6	Our organization readjusts its resources to develop new technologies
	AI.7	Our organization reduces costs by realigning its resources
	AI.8	Our organization readjusts its resources to expand the scale of technology commercialization
Resource relocation and reconfiguration competence	RR.1	Our organization reconfigures research processes as necessary to improve performance
	RR.2	Our organization relocates the organizational structure and resources when necessary depending on the research environment
	RR.3	Our organization flexibly changes its research promotion strategy depending on the research environment
	RR.4	Our organization specializes in research organizations to expand research performance
	RR.5	Our organization subdivides in research organizations to expand research performance

	RR.6	Our organization develops new technologies by reconfiguring internal and external knowledge
	RR.7	Our organization reduces costs by reconfiguring internal and external knowledge
	RR.8	Our organization creates technological commercialization results by reconfiguring internal and external knowledge
Organizational cultural characteristics		
Job satisfaction	JS.1	I am generally satisfied with my researchers life as a member
	JS.2	I am satisfied with the wage and welfare
	JS.3	I am satisfied with the organization's promotion system
	JS.4	I am satisfied with my position and work
	JS.5	I am satisfied with working environment (e.g. Office, research equipment, lab, etc.)
	JS.6	I have a friendly relationship with my with colleague
	JS.7	I have a positive working accomplishment
	JS.8	I am getting opportunities for self-improvement from work
Organizational culture	OC.1	Our organization is free to set up a plan for the individual's work procedures and method
	OC.2	Our organization has a culture that is open to acquiring new knowledge
	OC.3	Our organization can easily request knowledge from other researchers in the organization
	OC.4	Our organization is a culture in which individuals easily present their opinions on team decision making
	OC.5	Our organization has clear responsibilities within team work

Source: Teece (2007), Woo et al., (2019), Rhee (2020), Garrido et al., (2020)

The Interview Questionnaire

Version of principle researchers (un-commissioner)

1. What do you think about networking relationship among members in your institution?
2. Do many members try to collaborate with others?
3. Are researchers willing to participate in different research projects to interact with different members?
4. Does it have a community for knowledge exchange within your organization?
5. What are some components that hinder networking among members of the organization?

Version of director researchers (commissioner)

1. What do you think about the resource transforming capability in your institution? and what is the reason for that?

2. Does your organization flexibly reorganize its organizational structure and resources according to the changing research environment? and what is the reason for that?
3. What are the characteristics of the organization operation for the use of resources?
4. What difficulties does the organization have to expand its research results?