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Structural efficiency to manipulate public research institution networks

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ABSTRACT

With the rising use of network analysis in the public sector, researchers have recently begun paying more attention to the management of entities from a network perspective. However, guiding elements in a network is difficult because of their complex and dynamic states. In a bid to address the issues involved in achieving network-wide outcomes, our work here sheds new light on quantifying structural efficiency to control inter-organizational networks maintained by public research institutions. In doing so, we draw attention to the set of subordinates suitable as change initiators to influence the entire research profiles of subordinates from three major public research institutions: the Government-funded Research Institutes (GRIs) in Korea, the Max-Planck-Gesellschaft (MPG) in Germany, and the National Laboratories (NLs) in the United States. Building networks on research similarities in portfolios, we investigate these networks with respect to their structural efficiency and topological properties. According to our estimation, only less than 30% of nodes are sufficient to initiate a cascade of changes throughout the network across institutions. The subunits that drive the network exhibit an inclination neither toward retaining a large number of connections nor toward having a long academic history. Our findings suggest that this structural efficiency indicator helps assess structural development or improvement plans for networks inside a multiunit public research institution.

1. Introduction

Public research more inclines to distribute its findings than commercialize in contrast to industrial research (Geffen and Judd, 2004). In general, institutes conducting public research are largely government funded and target the public domain (Bozeman, 1987). Because of their national orientation and stable funding source, public research institutes do cutting-edge research at least one academic field through long-term plans (greater than three years) (Bozeman, 1987). A public research institution often develops as an association of research institutes rather than a single organization. Research entities with a public research institution enjoy institutional autonomy in choice of subjects notwithstanding the fact that they are under the same umbrella of governance. Naturally, research organizations have different characteristics depending on national circumstances. Some public research institutions, such as the Max Planck Gesellschaft (MPG) in Germany, are faithful to pure research (Philipps, 2013), while others have significance within a particular national context: part of the National Laboratories (NLs) in the United States (US) addresses defense-related technologies (Jaffe and Lerner, 2001), and the Government-funded Research Institutes (GRIs) in Korea attempt to assist in the country's economic development by promoting indigenous public research (Mazzoleni and Nelson, 2005; Arnold, 1988; Lee, 2013).

With recent advances in our understanding of network, it is possible to apply novel network knowledge to manage public research institutions in response to internal and external changes. For example, entities in national innovation systems (Freeman, 2004) or the Triple Helix models (Phillips, 2014; Leydesdorff, 2003) can be external factors affecting research of public research institutions. The notion of national innovation systems provides a framework to explain underlying incentive structures for technological development at a national level and international differences in competence from a network perspective of public and private organizations (Patel and Pavitt, 1994). The Triple Helix model considers coevolving academic, industry, and government which provokes techno-economic developments of a country (Leydesdorff et al., 2013). In these systems, public research institutes provide fiscal and technical assistance to other organizations. Kondo (Kondo, 2011) pointed out that public research institutes dedicated to transferring technologies to industry by means of consulting, licensing, and spinning off. By doing so, they contribute to promoting integration and coordination within the system (Provan and Milward, 1995). In order to formulate policies and procedures to steer the entire system, system organizers are able to guide public research institutes properly. In this context, control of those key agencies is important to achieving desirable outcomes.

Moreover, there is a growing need for an efficient implementation throughout public research institutions composed of multiple sub-

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organizations in order to deal with internal controls (Yang and Jung, 2014). For example, most public research institutions have undergone transformations in recent years due to modernization, imperatives for efficiency, and the promotion of collaboration with the industry (Buenstorf, 2009; Cohen et al., 2002; Simpson, 2004; Senker, 2001). In unfavorable economic conditions, declining government funding causes the restructuring of research areas (Malakoff, 2013; Izsak et al., 2013) or the government demands more practical outputs from them, such as conducting applied research and setting standards (OECD, 2011). In an attempt to harness technology for socio-economic development, governments often prioritize future research through foresight activities (Priedhorsky and Hill, 2006) and accordingly assign new academic missions to public research institutions. In particular, developing countries have lately been paying more attention to the technology-driven development model under government supervision (Arnold, 1988). At that time, controlling every entity enables the institution to fully guide those internal changes but entails great expense.

From 1935 to 1945, public research institutions engaged in national strategic areas, including exploration of mineral resources, industrial development, and military Research and Development (R&D) (OECD, 2011). After the termination of World War II, the establishment of public research institutions grew in an effort to advance military technology in many countries. Moreover, at that time, public research institutions extended almost all areas with which governments were associated, such as economic and social issues. They continued growing until the 1960s. In the 1970s and 1980s, many countries expressed doubts on their contributions to innovation. However, as deepening the understanding of national innovation systems or the Triple Helix models, public research institutions started to be seen in a new light. In these models, public research institutions have played an indispensable role in preventing systemic failures, which reduce the overall efficiency of R&D (Lundvall, 2007; Sharif, 2006) due to their relations with external collaborators (Klijn and Koppenjan, 2000; McGuire, 2002). Still, the importance of public research institutions are emphasized in particular for scientific innovation (Cabanelas et al., 2014).

In this regard, a network approach is necessary to efficiently implement transformations throughout sub-organizations, and the academic interest also grows for the effective operation of the network (Cabanelas et al., 2014; Jiang, 2014). There is, however, a lack of empirical research on managing public research institutions through a network system. Hence, in this paper, we conceptualize three major public research institutions — the MPG, NLs in the US, and GRIs in Korea — as networks, identify the sub-organizational network structure of each, and examine its structural efficiency. A collaborative research network is one of the most prevalent inter-organizational configurations (Shapiro, 2015). However, we deem that topical similarity between research institutes is suitable to represent a relation between them in research interests. Most transformations involve changes in research areas, and changes in organizational research topics frequently occur when governments prioritize specific research fields or delegate new roles to institute (Wang and Hicks, 2013). Prior studies emphasized the importance of similarity in knowledge content among entities to effectively manage inter-organizational networks as well (Tsai, 2001; Hansen, 2002). For these reasons, a network here is formed by pairs of subunits having the most similar research profiles. With the addition of temporal dynamics to inter-organizational relations, a chain of networks over time allows the description of the structural evolution of public research institutions.

Based on revealed networks, we determined the structural efficiency with which network-wide actions can influence entities for finite time periods. No matter the measure puts in place, all members of network need to adopt it to achieve collective actions. In the early stages of change implementation, network organizers select initiators to change among entities. As the change initiators propagate control actions to the remainder of entities, a public research network can be steered in the desired direction like a car. We can derive a minimum number of suitable initiators from a theory of "structural controllability" (Yuan et al., 2013). In the theory, change initiators refers to injection points of external energy used to steer the network, which are theoretically selected depending on network structure. In this process, structural efficiency is obtained by calculating the share of change initiators in the network: the lower the efficiency value, the smaller the number of entities the network manager is required to handle. Therefore, by comparing efficiencies with structural properties over time, we can estimate network characteristics specific to institutions.

In this study, we divided institutional research portfolios into six time periods based on scientific output over eighteen years (1995–2012), and estimated structural efficiencies of research similarity networks. Considering structural efficiency, we can observe that networks in all three research institutions can be managed with less than 30% of sub-organizations, and the values reflect the changes that have occurred in research institutions. Each research institution has some sub-organizations consistently selected as suitable change initiators over a period of time. Our results primarily highlighted young subordinates as appropriate change initiators, which means that information blockades in network might occur unless the selected units are properly managed. Moreover, the estimated changes initiators tend to have a lower connectivity in network than the rest of nodes. We expect that our work has implications for decision-making bodies and network managers seeking to an efficient way to influence their intention on a network of public research institutes.

The remainder of this paper is structured as follows: in Section 2, we briefly describe the impact of structure on network effectiveness associated with public research institutions based on past research. Section 3 is devoted to an explanation of data sources, network construction processes, and the calculation of structural controllability in a network. We discuss the results of our experiments in Sections 4 and 5, and offer our conclusions in Section 6.

2. Research networks around public research institutions

Methods for utilization and development of networks have grown in an attempt to address complex problems that require collective effort. When the purpose of the network is to deliver public services, independent organizations are generally involved in the process, and interdependency between participants facilitates the formation of links (Kickert et al., 1997). By exchanging knowledge through a network, public research organizations attain a higher level of performance, at the same time, create a greater ability to innovate (Morillo et al., 2013). Goldsmith and Eggers (2004) claimed that using a vehicle for networks is favorable to organizations that require flexibility, rapidly changing technology, and diverse skills because actors can exchange goals, information, and resources while interacting with each other. Resources usually refer to units of transposable value, such as money, materials, and customers, and information signifies exchangeable units between agencies, such as reports, discussions, and meetings. With regard to exchanged goods between organizations, van de Ven (van de Ven, 1976) underlined the importance of information and resources as "the basic elements of activity in organized forms of behavior." In research systems, organizations can take advantage of network participation to have a greater possibility of funding, to broaden their research spectrum, or to reduce the risk of failure (Beaver, 2001). Therefore, networks are beneficial because they can pool resources, permit the mutual exploration of opportunities, and create new knowledge (Priedhorsky and Hill, 2006).

However, strategies are needed to coordinate interactions while managing networks because different actors have different goals and preferences concerning a given problem (Kickert et al., 1997; O'Mahony and Ferraro, 2007). The capability of network management is also necessary to promote innovations (Pittaway et al., 2004), but there remain questions as to how to manage such organizational interactions as Beaver (Beaver, 2001) pointed out. Orchestrating activities