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Estimating the Impacts of Investment in a National Open Repository on Funded Research Output in South Korea

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ABSTRACT
Open access is a paradigm whereby the electronic versions of scholarly publications are made freely accessible without any restrictions. It is actively promoted globally and is also promoted domestically in accordance with this global trend. However, there is a growing need to evaluate existing activities and to seek policies for the steady spread of open access. This study examines the necessity of switching to a national repository from existing institutional repositories through policy direction analysis of open repositories. We examined domestic open access policies by analysing various overseas cases and the situation in South Korea. Finally, we determined the validity of investment in a national repository by analysing its social and economic impacts using the modified Solow-Swan model. The main parameters for applying the modified Solow-Swan model were estimated, and the domestic research and development expenditure was predicted via a regression method. Then, we applied a range of rate of returns to research and development (10% to 50%) to various scenarios and examined the effects of increasing accessibility and efficiency by 1% to 10%. We found that the implementation of a national open access repository in South Korea would have a substantial impact (to the tune of 147 billion won), without considering the potential costs of such a repository. Based on the estimates of the social and economic impact of a national repository, the implementation of a national open access repository in South Korea is economically viable. Besides having beneficial social and economic impacts, a national repository is expected to enhance awareness of open access among Korean researchers and institutions.

Keywords: open repository, open access, modified Solow-Swan model, national repository, economic analysis

Open Access

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1. INTRODUCTION

The scholarly communication ecosystem follows a clear cycle (Cox & Tam, 2018): It begins with research, followed by the production of an academic paper through organizing the research results, which is then distributed to others and used in other research (thereby producing new outcomes) following a process of evaluation, review, and publication in an academic journal. Traditionally, researchers have published their academic papers in academic journals created by an academic society or publishing company to disseminate their findings as well as to communicate and exchange opinions with other researchers. Many such academic journals have played a considerable role in the development of studies through the publication and distribution of academic papers. However, these types of journals have been criticized for a number of problems, such as the complex examination process, opacity of the publication process, high academic journal subscription fees, and publishers' abuse of copyright (Choi & Cho, 2005). Open access is one effort to resolve this situation. Open access is a new paradigm of academic information distribution, whereby anyone in the world can freely view academic research outcomes on the Internet. It represents an attempt to restore the essential characteristics of academic papers—opinion presentation, discussion, and idea sharing.

The full-scale implementation of open access is widely regarded as beginning with the 2002 Budapest Open Access Initiative (Budapest Open Access Initiative, 2002). Following this declaration, a push for open access began in earnest through the Bethesda Statement (2003) and Berlin Declaration (2003). Open access can be classified as gold open access and green open access, depending on the strategy (Schimmer, Geschuhn, & Vogler, 2015). Gold open access refers to the strategy of publishing an academic paper with open access in a journal that uses a peer review system. Gold open access papers are freely accessible at the time of publication online by anyone in the world. For an academic paper to be published as gold open access, it must be submitted to an open access journal (wherein all papers are published with open access) or a hybrid journal (wherein papers can be published under the subscription-based system or as open access, depending on the authors' choice). For a paper to be published as open access, either the authors themselves or a supportive organization must first pay an article processing charge (Lawson, 2016).

Green open access, on the other hand, is a strategy whereby authors self-archive their works in an open access repository or post them on their homepages, allowing anyone to freely access them online. There are various types of open access repositories, including institutional repositories (operated by the author's institution), subject repositories (operated by organizations for specific subject areas), and national repositories (operated by governmental bodies). When a paper is published using the green open access system, the paper becomes accessible in the repository only after a specific embargo period, which is set according to the license policy of the journal or publishing company. Green open access is a compromise between authors (who wish to publish their research papers in such a way that the papers will be widely read and quoted), users (who desire for papers to be freely available), and publishers (who want to profit from papers' sales) (Hwang, 2017).

Since the 2002 Budapest Open Access Initiative, numerous developed nations and prominent institutions have been actively pursuing open access policies. For example, the United States, the United Kingdom, and Spain have pushed for legal measures promoting the self-archiving style (i.e., green open access), while India, Denmark, Australia, and New Zealand have made efforts to promote open access via recommendations and encouragement systems. Major institutions in many of these countries have also shown tangible results in promoting open access through signing declarations and enacting policies (Kim, Kim, Choi, & Hwang, 2016). In the early 2010s, nearly a decade after the initial Budapest Open Access Initiative in 2002, there were several major reports conducting objective evaluations of and making suggestions on ensuring the sustainability of open access, which are widely regarded as a turning point for open access.

For instance, the Finch Report, published in 2012 by a working group composed of various interested parties (Finch, 2012), not only led to the development of the current UK open access policy base, but also had an influence on global open access policy, particularly that in Europe. This report examined ways of accelerating sustainable open access transition through cooperation with various interested parties involved in publishing and distributing research results, such as funding providers (research support institutions), universities, researchers, libraries, and publishers, while maintaining the basis of the scholarly communication ecosystem. The Finch report recommended a strategy of mixing gold and green open access to achieve a sustainable and orderly open access transition. Since the Finch report, there have been a number of important policy developments in the EU, the United States, and other major countries, and there have been several initiatives to actively support open access through forums such as Science Europe, the Global Research Council, and the G8. Particularly in the UK, there has been much greater progress in open access transition compared to other countries: About

19% of British publications are now published with gold open access, which is supported by various institutions that offer research funds (especially Wellcome Trust, Jisc, and the FP7 Pilot 'OpenAire' of the European Union) as well as a number of individual institutions. Most British universities have developed an institutional repository for green open access, which has resulted in rapid growth in repositories and the number of papers deposited therein (Tickell, 2016).

In 2015, a study by the Max Planck Digital Library (Schimmer et al., 2015) evaluating open access activities for over a decade argued that existing paid subscription journals should be converted into open access journals in order for open access to further proceed. For this to be achieved, the fund flow must be extensively restructured by converting from the existing subscription-based model to the gold open access model based on the article processing charge. This paper provided the theoretical base for the implementation of the OA2020. Led by the Max Planck Society in Germany, the OA2020 sought to covert at least 90% of existing subscription-based journals to gold open access journals by 2020. The OA2020 can be considered a cornerstone for the implementation of gold open access.

In South Korea, since the 2000s, universities and academic societies, particularly the Korea Institute of Science and Technology Information (KISTI) and National Library of Korea, have been taking steps to invigorate open access by pushing it in a limited number of fields and institutions. In addition, Open Access Korea (OAK) was formed in the early 2000s for managing public research results supported by the country's research and development (R&D) fund. OAK was composed of the OAK repository, Korea Journal Copyright Information, and OAK Central, which provides repository setup service to Korean academic journals. However, such open access papers written by Korean authors collected by OAK are mainly published in international journals. Therefore, open access remains largely at the level of collecting metadata and connecting these metadata to the original text because of the publisher's copyright on these papers (Hwang, 2017). Many researchers have emphasized the need for a national open access repository. For example, Seo, Heo, and Noh (2009) reported that there is a need for open access policies for public research results, starting with building field-specific open access repositories and providing greater cost support to manage a repository. In March 2009, the OAK project was implemented to promote open access and the common use and dissemination of knowledge. Furthermore, various policies, including the building of institutional repositories, have been pushed. Nevertheless, these efforts have largely failed in their intended purpose.

Given this situation—particularly that domestic public research results, especially in the fields of science and technology, are published mainly in overseas academic journals—it is necessary for South Korea to actively participate in international open access activities such as OA2020 and Sponsoring Consortium for Open Access Publishing in Particle Physics (SCOAP3), as well as to establish policies that focus on establishing open access repositories, in order to invigorate open access in Korea. SCOAP3 is an international collaboration in the high-energy physics community to convert traditional closed access physics journals to open access (SCOAP3 Consortium, 2019). Therefore, we examined the necessity of building a national open access repository via situational analysis and case studies to help invigorate adoption of green open access in South Korea. Furthermore, we executed a quantitative analysis on the potential economic and social effects of such a repository.

This paper is structured as follows: In the second section, we review the existing studies on open access repositories. In the third section, we describe the international and domestic situations of open access repositories, as well as the necessity of developing a national repository. We describe the quantitative analysis of the economic impact of implementing a national repository using Houghton's model in the following section. Finally, we describe the conclusions in the last section.

2. LITERATURE REVIEW

Previous research has explored the formation of open access repositories. Most of these studies examined how these repositories can support green open access, particularly in terms of user attitudes and behaviours (Kim, 2010), different disciplinary positions (Xia, 2007), and role changes for librarians (Walters, 2007).

There are also numerous practice-based case studies. Armbruster (2010) conducted a study on twelve repositories implemented in response to institutional or funder open access policies, while Davis and Connolly (2007) studied the reasons that end users accessed the Cornell University repository through faculty interviews and usage log files. Covey (2009) explained the attributes and behaviour of faculty who used the institutional repository at Carnegie-Mellon University. Koskinen et al. (2010) investigated the accommodation and usage of the institutional repository at the University of Helsinki. Roy, Biswas, & Mukhopadhyay (2012, 2013, 2016) investigated repositories in India.

To analyse the main characteristics of open access repositories and their global trends, most studies have employed

OpenDOAR data.[1] According to Morrison (2012), the number of repositories registered in OpenDOAR increased from 800 in 2006 to over 2,200 in 2012. Pinfield et al. (2014) analysed OpenDOAR data, focusing on global trends in open access repositories from 2005 to 2012. Wani, Gul, & Rah (2009) also analyzed OpenDOAR data between October 7 and 8, 2008, focusing on repository distribution by continent, country, core content type, operational status, software usage, repository type, subjects, and language. Abrizah, Noorhidawati, and Kiran (2017) analyzed state of repositories of Asian universities using OpenDOAR.

Green open access is considered relatively more accessible and cost-efficient than is gold open access. However, it is not as cheap as open access advocates initially claimed. Many education and research institutes, including universities, build and operate repositories using open source solutions such as DSpace and EPrints, but considerable construction and operational costs are incurred to ensure smooth utilization. Furthermore, there are other costs, such as verification costs for the copyrights of uploaded materials, costs related to correction of references, education costs for researchers, and operation costs, which differ according to the scale and the degree of utilization of the repository. For instance, Houghton et al. (2009) estimated that, assuming an author's uploading time is about 10 minutes, the cost for uploading papers to repositories in the UK is about 33 US dollars per paper. In the European Community-funded Publishing and the Ecology of European Research (2011), the cost of building an IT system for a full repository would be about 60,000 US dollars, while the personal cost per paper would vary substantially (2 to 53 US dollars, depending on the repository).

There have been various studies on the economic impacts of open access. The Research Information Network (2008) predicted that out of the total cost of journal publishing (25 billion pound), publishing costs and library costs account for 4.9 billion pound. Open access is estimated to be able to save 560 million pound. Houghton et al. (2009) estimated that open access would reduce the system cost of open access by about 212 million pound in the UK alone, with the greatest savings being for research performance (about 106 million pound). Houghton (2009), besides finding that open access would reduce system costs, found that the economic and social returns of open access to the UK's public-sector R&D would be about 170 million pound (based on the results of a modified version of the Solow-Swan model). He applied his model to Denmark and the Netherlands as well, and conducted a comparative analysis between these countries. He also estimated the economic and social impacts of the Federal Research Public Access Act in the US (Houghton, Rasmussen, & Sheehan, 2010).

3. INTERNATIONAL AND DOMESTIC OPEN ACCESS REPOSITORIES

3.1. Global Open Access Repositories

Since the development of DSpace and E-Prints in 2002, two major pieces of repository software, the construction of repositories has progressed in earnest. DSpace was jointly

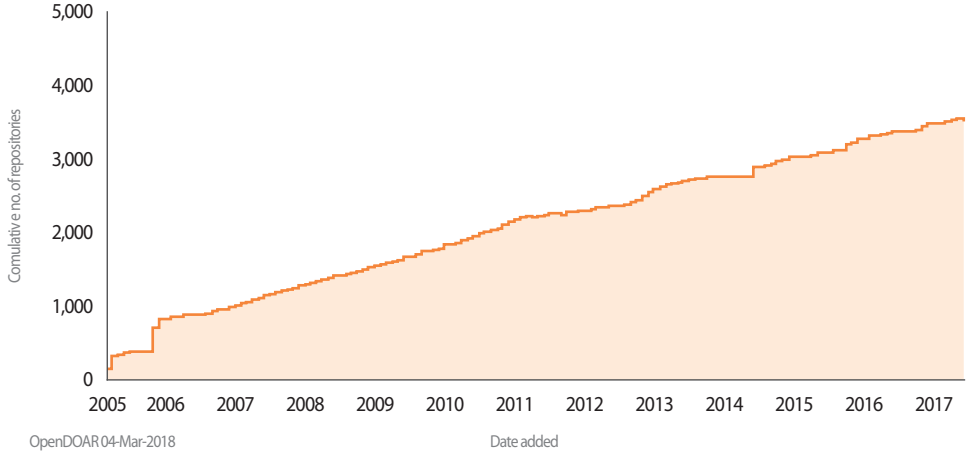

Fig. 1. Overall growth of repositories in OpenDOAR from December 2005 to March 2018.

[1] http://v2.sherpa.ac.uk/opendoar/

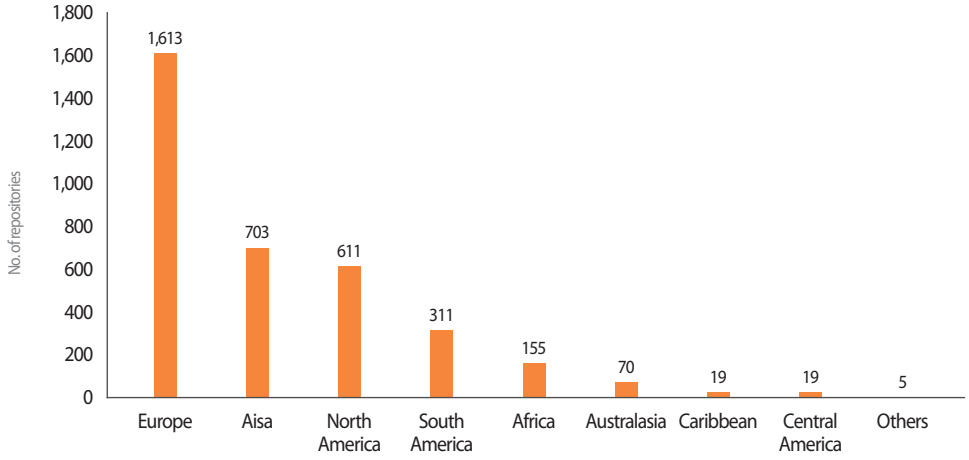

Fig. 2. Repository statistics by regions as of March 2018.

developed by the Massachusetts Institute of Technology and the HP Research Institute in the US and it quickly became known to the public because Cornell University utilized it to create its own repository. E-prints, developed by Southampton University in the UK, contributed substantially to the establishment and stabilization of the repository at Oxford University. Subsequently, the number of universities and research institutes worldwide that are developing repositories has steadily increased.

Fig. 1 shows the repository growth worldwide. The total number of repositories in OpenDOAR showed a steady increase (except in the first year) from 128 in December 2005 to 3,502 in March 2018. While there are slight differences in magnitude among regions, this increment was consistent across them. The increase can be attributed to growing awareness of open access.

Fig. 2 shows the repository statistics by regions as of March 2018. Europe had the highest number of repositories, at 1,162 (46% of the total), followed by Asia (702, 20%), North America (615, 18%), and South America (309, 9%). Asia—centred on Japan, India, Turkey, Indonesia, Taiwan, and China—is showing rapid growth in the number of repositories, to the point where the number recently surpassed that for North America. Therefore Asia, along with Europe, is becoming a centre of global open access repositories.

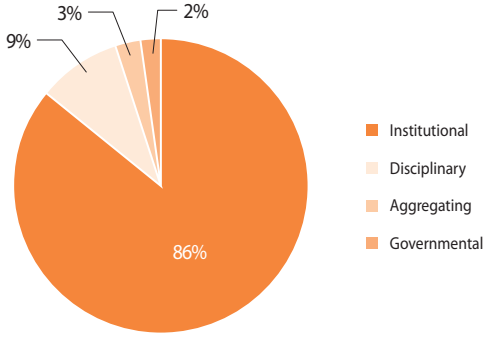

Fig. 3. Repository statistics by types as of March 2018.

When examining repository type (Fig. 3), most repositories were classified as institutional repositories (accounting for 86% of the total), followed by disciplinary repositories (at only 9% of the total). The proportion of institutional repositories is slowly increasing, indicating that recognition of open access is spreading and the number of requests for establishing institutional repositories is growing.

Table 1 compares the repositories of representative institutions and countries that are obliged to deposit public research results. The National Institutes of Health (NIH) in the United States (Organisation for Economic Co-Operation and Development, 2015) is in charge of depositing and utilizing research papers produced by the NIH fund in line with the national public deposit policy, while the Spanish Foundation for Science and Technology (Fundación Española para la Ciencia y la Tecnología, FECYT) operates a national repository called the 'Recolector de Ciencia Abierta' (RECOLECTA), based on a connection with the Network of Spanish University Libraries (Red de Biblioteca Universitarias Españolas). The Chinese Academy of Sciences (CAS, 2014) operates a repository called the 'CAS Institutional Repositories Grid' (CAS IR Grid) that comprehensively deposits and manages papers produced with CAS funds, linking them to the repositories of CAS-affiliated institutions.

Table 1. Comparison of repositories of representative institutions and countries that are obliged to deposit public research results

	PubMed Central	RECOLECTA	CAS IR Grid
Operator	NIH	FECYT, REBIUN	CAS
Object deposited	Research outcomes supported by NIH funds	Research outcomes supported by public funds	Research outcomes supported by CAS funds
Registration and depositor	Author or publisher	Author	Author
Connection system	NIH manuscript submission system	Institutional repositories	CAS-affiliated open access repositories
Form of materials	Final version accepted for journal publication	Edited version, preprint version	Final version of the paper, modified by author after peer review
Main service	Search, browsing	Search, browsing	Search, browsing
Main features	The provision of R&D statistical analysis data	Operates the National Open Access Repositories Community	Connection and integrated management at the original text level

RECOLECTA, Recolector de Ciencia Abierta; CAS IR Grid, Chinese Academy of Sciences Institutional Repositories Grid; NIH, National Institutes of Health; FECYT, Fundación Española para la Ciencia y la Tecnología [Spanish Foundation for Science and Technology]; REBIUN, Red de Biblioteca Universitarias Españolas [Network of Spanish University Libraries]; CAS, Chinese Academy of Sciences; R&D, research and development.

In February 2000, PubMed Central (PMC) built an open repository managed by the National Library of Medicine (NLM) which collects and stores papers published in biomedical and life science journals according to the NLM's legislative mandate for collecting and keeping biomedical papers. The academic journals fully participating in the PMC submit their papers to the PMC directly, and papers that are supported by NIH funds are directly deposited by the paper's author(s). In addition to its role as a repository, the PMC makes it possible to store and cross-reference data from various sources using a common format. Using the PMC, it is possible to find all related materials by quickly searching the entire collection of full-text documents. The PMC also integrates literatures from different fields in order to improve the research and knowledge of experts such as scientists and clinicians. As of March 2018, about 4.7 million articles from approximately 7,000 journals are retained in the PMC, and the number of fully participating journals is 2,098.

In 2007, the Spanish government encouraged the establishment of an open access repository, announcing the 'Draft of the National Law of Science.' This law included a regulation whereby researchers who received public funds had to make their research results open access within six months. Article 37 of Spanish Law 14/2011 on Science, Technology, and Innovation (named 'Open Access Dissemination') established a national standard stipulating that the outcomes of research activities supported by the state must be deposited in open repositories. Furthermore, since 2007, Spain's FECYT and Red de Biblioteca Universitarias Españolas have sought to build a national infrastructure for open repositories; accordingly, through steady collaboration, these two organizations conceived RECOLECTA, an open platform that links all institutional open repositories in Spain and provides services for repository managers, researchers, and decision makers. RECOLECTA has promoted and coordinated a national infrastructure for interoperable digital science repositories utilizing standards adopted by communities worldwide and was designed to promote research development and the adoption of open policy. Specifically, the RECOLECTA provides easy, free access to all scientific research outcomes stored in Spain's repositories, as well as seeking to build, maintain, support, and improve the national repository infrastructure. Specifically, it provides users with support services, enhances the national open community, and offers statistical data on repositories.

The CAS is a core pioneering organization in the field of Chinese technology and natural sciences, consisting of a comprehensive R&D network, higher education system, and outcome-based academic society. In China, open access began in 2003 through participation of Chinese scholars in open access and academic publishing seminars. Open access only became standardized the following year when the CAS and National Natural Science Foundation of China signed the Berlin Declaration. Since then, China has been constantly working on open-access-related activities, such as establishing a CAS institutional repository system (CAS IR Grid) on a trial basis in 2007 and opening access to China's information portal in 2008. The CAS IR Grid contains 114 institutional repositories as of March 2018. When a researcher deposits his or her paper into a CAS-affiliated institutional repository, the paper becomes available in the CAS IR Grid. If an institution does not yet have a repository, papers must be deposited in the repository operated by the National Science Library of the CAS. Since 2012, the annual number of papers registered in the CAS IR Grid has ranged from 40,000 to 1,500,000, of which more than 70% have the original text available. As of March 2018, there are about

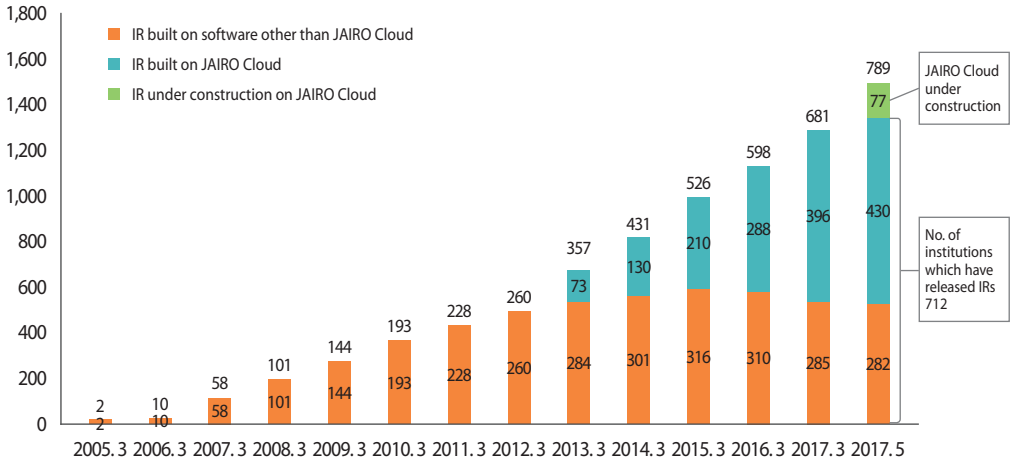

Fig. 4. Number of institutional repositories in Japan as of August 2017. IR, institutional repository.

820,000 registered papers, of which about 75% provide the original text.

Japan began its Cyber Science Infrastructure Program in 2005. Under this program, institutions (including universities) have begun devoting some effort to establishing their own repositories. In fact, by 2010 nearly 200 institutions across Japan had established an institutional repository. Research institutions, including universities, independently established these repositories using software such as DSpace. However, many institutions, while expressing a willingness to build a repository, found it difficult to afford or hesitated because of the expected burden of operating the repository after establishing it.

Based on past experiences of establishing a repository, the National Institute of Informatics of Japan promoted the introduction of the JAIRO Cloud in 2011 in order to promote wider development of repositories. The JAIRO Cloud, established in 2012, is a computing service based on an SaaS system that was created by the National Institute of Informatics to improve the operation of institutional repositories. Initially it targeted universities without an institutional repository, but since January 2014 it has begun accepting institutions with an existing repository. In May of that same year, starting with the transition of Tulips-R (the institutional repository of the University of Tsukuba), established institutional repositories throughout Japan began transferring to JAIRO Cloud. Fig. 4 shows the state of establishment of institutional repositories in Japan, and it is evident that rapid growth has been achieved as a result of introduction of the JAIRO Cloud, with many institutions transferring from their own repository to the JAIRO Cloud.

3.2. Korean Open Repositories

The establishment of institutional repositories in South Korea began with the Korea Advanced Institute of Science and Technology (KAIST) Open Access Self-Archiving System (KOASAS). In 2007, KAIST allocated some of its own budget to develop and operate a repository for managing, preserving, and distributing research outcomes obtained by the professors and researchers of the university. KOASAS utilizes the same model operated by the libraries. Later, in February 2012, KAIST made active use of its institutional repository by establishing the Researcher Information Management System, a performance evaluation system of researchers in KAIST, and connected it with KOASAS. As KOASAS holds more than 200,000 academic articles, including papers published in 2018, it is a valuable resource for researchers in South Korea and abroad.

The central library of Seoul National University officially launched its institutional repository S-Space in December 2008.[2] This repository was developed by benchmarking with DSpace and KOASAS, upgrading and customizing for the convenience of its members. More than 98,000 materials have been registered in S-Space as of March 2018, including research papers published in academic journals, papers presented at academic conferences, and dissertations issued by various academic societies and institutions affiliated with Seoul National University. In 2017 only, there were over 6 million downloads.

The full-scale implementation of a domestic open access

[2] http://s-space.snu.ac.kr/

repository was the OAK Project. The OAK Project, which was promoted by KISTI in March 2009, sought to build knowledge cooperation to promote open access for domestic academic information by adhering to the following steps: repository development and dissemination, open access journal publication support, open access portal (OAK Central) establishment, and open access governance system establishment. Following the replacement of the host organization by the National Library of Korea in 2014, the development and dissemination of the Korean OAK repository began.

The OAK repository was built using DSpace, and customized to the domestic environment. It was distributed through the help of an OAK repository operation consultative group, consisting of KISTI, repository system developers (KISTI's partners), and the OAK repository operation organization. This consultative group selects target institutions for new repository establishment through a public contest and shares the trends and know-how in operation through training and seminars with the selected institutions. About five institutions are selected annually based on their applications for establishing the repository; as of March 2018, a total of 38 OAK repositories have been established. KISTI's partners played a role in spreading OAK repositories to various institutions that wished to install it. Furthermore, the OAK repository is continually updated, in accordance with updates to DSpace.

In addition, institutions that installed the OAK repository identified new requirements through operation of the repository, thus helping the consultative group to improve the repository and its operation methods. The contents of all OAK repositories can be retrieved through integrated search services by both domestic and foreign users through the OAK portal, which is operated by the National Library of Korea. Interested users can access the original texts of content via the repository portal. This has helped increase web traffic to the OAK repository.

However, not all institutional repositories in South Korea are smoothly operated. While there are about 24 unique repositories that hold academic papers, only a few—such as KOASAS and S-Space—are actively operating. Considering the number of domestic universities and public institutions, this figure indicates exceedingly poor performance compared with Europe and Japan.

Open access is being pushed in various directions all over the world. For example, gold open access is being implemented through such policies as the OA2020 (led by the Max Planck Digital Library), SCOAP3 (centred on European Council for Nuclear Research), and the Big Deal models of various European countries, whereas green open access is being implemented through the establishment of open access repositories. Although South Korea is making a considerable effort to keep up with this trend, its achievements are comparatively limited because of problems such as peculiar characteristics in the domestic academic ecosystem, limited participating institutions, lack of government policy support, and low awareness among researchers of open access (Hwang, 2017).

As part of an effort to overcome this problem, the OAK Project is seeking to promote collaboration among institutions in the development of repositories through OAK Central. However, there is still a need to build a national repository such as Japan's JAIRO Cloud and Spain's RECOLECTA. The current situation in South Korea is similar to that in Japan before the introduction of JAIRO Cloud. In particular, while a number of institutions have established an institutional repository, some are in name only, as the institutions are incapable of maintaining their operation. It is therefore necessary to implement a nationally integrated repository, as well as to build up personalized institutional repositories for institutions which desire to build repositories, but lack the capability as well as the necessary technology to do so.

4. ESTIMATED IMPACT OF A NATIONAL REPOSITORY IN SOUTH KOREA

4.1. Model Outline

It is difficult to calculate the potential impact of implementing an open access repository, and doing so can cause a considerable degree of controversy. Nevertheless, to assess potential impacts and use them for future reference, Houghton developed a model using the Solow-Swan model (for further detail, refer to Houghton et al., 2009).

The basic Solow-Swan model (Solow, 1957) is represented in the following production function:

$$Y = A^{\eta} K^{\beta} L^{\alpha}$$

where A is an index of technology, K is the capital stock, and L is the supply of labour. Both K and L are taken to be fully employed by virtue of the competitive markets assumption. Solow further developed this model, proposing that once we exclude the impacts of capital and labour, what is left is the impact of technology. He subsequently studied the impact of technological development on overall production. He also applied the model to estimate the rate of return to R&D.

This model is based on several major assumptions. The first assumption is that all R&D creates useful knowledge in

economic or social terms (the efficiency of R&D). The second assumption is that all created knowledge is equally accessible to anyone who wants to use it for productive activities (accessibility of knowledge).

However, in the real world there are numerous barriers or limitations to accessing and utilizing knowledge. Based on this, Houghton (2009) demonstrated that it is possible to calculate the impact on return to R&D by improving the accessibility and efficiency of knowledge and reducing friction. In this modified Solow-Swan model, accessibility and efficiency are considered 'friction variables.' He proposed the following formula:

$$\frac{\partial y}{\partial R} = \Upsilon \frac{Y}{R}(1+\delta_{\phi})(1+\delta_{s})$$

Where δ_{ϕ} $(1+\delta_{s})$ is the percentage change in efficiency (accessibility), Υ represents the contribution ratio of the rate of growth of R&D knowledge stock to output growth as a factor of production (i.e., the elasticity), and R indicates the stock of R&D knowledge, which can be calculated as follows:

$$R_t = (1-\delta)R_{t-1} + R\&D_{t-1}$$

where δ is the rate of obsolescence of the knowledge stock.

4.2. Operationalizing the Model

The main parameters for applying the modified Solow-Swan model are rate of return to R&D, accessibility, and efficiency. Research on the economic impact of R&D at the firm, industry, and national levels has been increasing. However, the claimed variation in the rate of return to R&D differs widely among researchers. For example, Salter and Martin (2001) found that the rates ranged from 10% to 150%. Hall, Mairesse, and Mohnen (2010) found similar degrees of variation depending on the researcher and analysis level. When all results of these studies are combined, a conservative estimate puts the rate of return to R&D at between 10% and 20%.

Accessibility can be defined as the proportion of the stock of knowledge generated by R&D accessible to those who would use it productively. Houghton et al. (2010) suggested measuring the increment in accessibility by combining the degree of access to desired academic information (access gaps), the degree at which academic information was cited (citation), and the degree of variation at which academic information was downloaded. Although the degree differs according to the characteristics of the repository to be built, the results of existing studies suggest that accessibility can be increased by as much as 4.5% (as a conservative estimate).

Efficiency can be defined as the proportion of R&D spending that generates useful knowledge; it can have a number of dimensions relating to wasteful, inefficient, and/or poorly directed research expenditures. Houghton et al. (2010) suggested using scenario-based measurement tools for efficiency, such as wasteful expenditure, number of new opportunities, and time saving for research.

Various other parameters must also be defined. First, a project to establish a research repository can be considered a kind of 'information system business.' Considering the life-cycle of a system in South Korea, the analysis period of the main information system is generally four to seven years. Therefore, we conducted a study spanning five years, which falls in the middle of this range.

There is a time lag between research spending and the social and economic impact of research results. In some fields, this lag can range from 2 to 30 years or more, whereas in others, the lag is no more than 1 to 2 years. According to Mansfield (1991, 1998), the average lag in US firms between publication of academic research and the timing of a related commercial innovation was around 7 years (which fell to 6.2 in the later study). Adding the time for publication, the lag was about 10 years, but it can be assumed that the time was shortened when considering the difference from the time when the research results were announced. Accordingly, this study assumed a lag time of 7 years.

Since the cost and benefits of a business manifest over a long period of time, it is necessary to compare them by converting all the costs and benefits that will occur in the future to their present value. This conversion process means discounting the current value, and the interest rate applied at this time is called

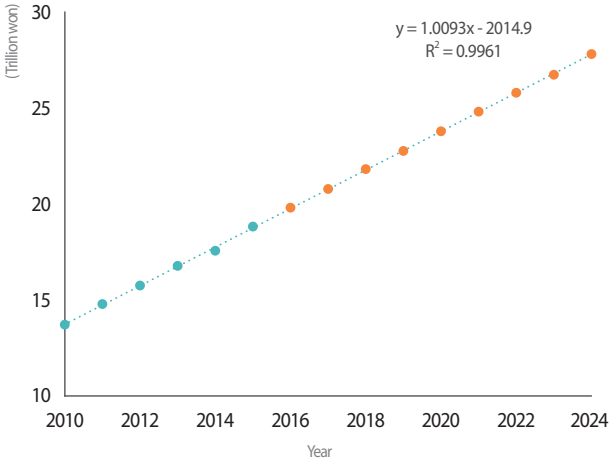

Fig. 5. Scale and prediction of research and development expenditure.

the discount rate. Since the task of estimating the appropriate social discount rate is exceedingly complicated, domestic studies in general use the 5.5% social discount rate presented by the Korea Development Institute.

Fig. 5 shows the results of estimating domestic R&D expenditure from 2016 to 2024 via a regression analysis, drawing on information of domestic R&D expenditure from 2010 to 2015. While the structure of the R&D expenditure is decided by policy, its coefficient of determination (adjusted R^2) was nevertheless very high; thus, it can be considered a valuable estimate. The results indicated the estimated R&D expenditure in 2019 and 2024 would be 22.9 trillion won and 28 trillion won, respectively, with an estimated annual growth rate of 4.4%.

Table 2 shows the estimates of the impacts of a national open access repository. For illustrative purposes, we expanded the range of rate of returns on R&D from 10% to 50% so that it could be applied to various scenarios. We also examined the increases in accessibility and efficiency by 1% to 10%.

With a 20% return to R&D expenditure on 22.9 trillion won in 2019, an increase of about 1% in accessibility and efficiency yields a return to R&D of about 63 billion won. This is a discounted amount based on 2019, taking into account the 7 years of time-lag between expenditure and impact. Overall, it is evident that the increase in R&D expenditure leads to an increase in impact. The increasing rate of return on R&D is beyond the rate of increase in R&D expenditure. The increase in accessibility and efficiency also appears to have a strong influence on the impact.

Table 2. Estimates of the impact of investment in a national open repository

		Rate of return on R&D (billion won)				
		10%	20%	30%	40%	50%
2019 (22,873 billion won)						
Percent change in accessibility & efficiency	1%	32	63	95	127	158
	2%	64	127	191	255	318
	5%	161	323	484	646	807
	10%	331	662	993	1,323	1,654
2020 (23,882 billion won)						
Percent change in accessibility & efficiency	1%	33	66	99	132	165
	2%	66	133	199	266	332
	5%	169	337	506	674	843
	10%	345	691	1,036	1,382	1,727
2021 (24,891 billion won)						
Percent change in accessibility & efficiency	1%	34	69	103	138	172
	2%	69	139	208	277	346
	5%	176	351	527	703	879
	10%	360	720	1,080	1,440	1,800
2022 (25,901 billion won)						
Percent change in accessibility & efficiency	1%	36	72	108	143	179
	2%	72	144	216	288	360
	5%	183	366	549	731	914
	10%	375	749	1,124	1,499	1,873
2023 (26,910 billion won)						
Percent change in accessibility & efficiency	1%	37	75	112	149	186
	2%	75	150	225	300	374
	5%	190	380	570	760	950
	10%	389	779	1,168	1,557	1,946

R&D, research and development.

Table 3. NPV of estimates of the impact of investment in a national open repository

NPV (base: 2018)		Rate of return on R&D (billion won)				
		10%	20%	30%	40%	50%
Percent change in accessibility & efficiency	1%	147	293	440	586	733
	2%	295	589	884	1,178	1,473
	5%	747	1,494	2,242	2,989	3,736
	10%	1,531	3,062	4,593	6,123	7,654

NPV, net present value; R&D, research and development.

Table 2 shows the increasing impacts over the years, as well as the result of converting them into the present value (2018) for basic economic analysis. As mentioned above, this refers to the value calculated for every 5 years based on the economic lifecycle; it could be much more effective if the lifecycle were longer than 5 years. Therefore, the values presented in Table 2 show the social and economic impacts of the establishment of a national open repository. This provides a guideline for investment in the establishment of a national open access repository. When focusing on the most conservative situation, if the rate of return on R&D is 10% and the rate of increase in accessibility and efficiency is 1%, there is still an impact of about 147 billion won. By contrast, in the moderate situation (30% rate of return to R&D, 5% increase in accessibility and efficiency), the impact is over 2.2 trillion won.

In this study, we exclude the costs of establishing and operating the national open repository. This is because these would differ considerably according to the architecture and scope of application of the to-be-established system, and estimating without reliable information on system design is foolhardy at best. Nevertheless, the information in Table 3 provides a rough guideline for national open repository investment.

5. CONCLUSION

There is plenty of research on the necessity of open access, so much so that it is often taken for granted by researchers and policymakers. Open access is being actively promoted around the world. The OA2020, SCOAP3, and various Big Deal models in European countries have demonstrated a new direction for gold open access and are producing important results with support by numerous researchers and institutions. However, presently gold open access has a somewhat limited scope in terms of the types of academic papers published. Therefore, implementing gold open access in earnest on a global scale requires more time. As an alternative to this, green open access, which involves the use of open access repositories, has received steadily increasing attention. Research on the establishment of such repositories was initially centred on Europe and North America, but is now actively being conducted in Asian countries, mainly Japan, China, India, and Indonesia.

Looking at the Korean situation, the establishment of institutional repositories under the OAK Project is continuing. However, the performance of this project is falling short of expectations because of limitations in managing already established repositories. To overcome this issue, it is now necessary to promote an alternative to these institutional repositories by implementing a national repository, as in the case of Japan and Spain. Our calculation of the social and economic impact of such a repository by applying Houghton's modified Solow-Swan model revealed that a national repository would have an impact of 147 billion won, even when using a conservative approach. Although we did not perform a comprehensive analysis of the potential costs, these findings are nevertheless encouraging for South Korea. Besides the social and economic impacts, a national repository is expected to enhance awareness of open access among Korean researchers and institutions.

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