The Development of Performance Indices for Basic Science Research

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Abstract

As an increasing amount of government support is given for scientific research and development (R&D) within key subject areas, it becomes essential to evaluate the academic and economic value of such support. In this paper, we develop performance indices for various basic research programs developed for scientists and engineers who are at the following different stages within their research career: postdoctorate and research fellows, junior professors, and outstanding scholars. The proposed indices are expected to provide feedback information necessary for continual improvement for the operation of government R&D funding programs

Introduction

The development of science and technology is recognized as an important aspect of international competition. It is especially imperative that the research of talented scientists and engineers is supported, both financially and otherwise, to promote these developments. A nation's ability to contribute to the academic community is directly correlated to how that nation is viewed by the rest of the world.

According to a report from the Committee for Economic Development (CED) of the United Stated (US), the original basic developments within science and engineering research brought economic stimulus, prosperity, and social development to the US (CED, 1998). The report also pointed out that the development of medicine, environmental science, society, and defense resulted from a steady, well-supported research system. At the time, this was possible due to the availability of research funding.

Currently, the execution of various programs are enhancing the financial support available for scientific research in Korea, for example, the support program of academic activities for postdoctorate studies, junior faculty, outstanding professors, as well as visiting international fellows, etcetera. The government research support program invests approximately 170 billion Korean won every year for scientific research. This program supports about six thousand researchers within Korean universities and research institutions.

However, much opportunity loss may incur, if the supported program is not managed to perform effectively. Ineffective management of funds also results in the missed opportunity for other promising research that could have been done in its place. Therefore, stringent performance evaluation is a necessary component of research support programs so that feedback information can be utilized for the next phase of support.

Thus far, the performance evaluation has been done based on published papers stemming from Korean research support programs. Unfortunately, these evaluations do not consider the diversity of support programs, or the long term performances of the researchers in consideration of different degree of research maturity over their research life-cycle.

In this study, we propose various individual performance index as well as composite index that can reflect different basic science programs over different point of the life-cycle of research. These indexes can be used to suggest the feedback for the future development direction of support programs. We expect that the results obtained from this study will enable the establishment of more efficient research support policies through performance evaluation.

This paper is organized as follows: Section 2 reviews related literature, section 3 suggests the performance indicators for evaluating the effect of programs supported by a life-cycle of scientists and engineers.

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Literature Review

The performance evaluation of government research support programs is generally based on quantitative indicators, including intellectual capital (Ernst, 2001). These R&D activities are directed towards producing valuable economic variables that relate to technological development, innovation and patents (Sohn et al., 2007). Griliches (1990) indicated that patents may be a positive sign of unobserved inventive output within production processes. In addition to patents, the publication of academic papers is the most common avenue for delivering research ideas and their outcomes (Wang and Huang, 2007).

However, the performance evaluation for scientific research is based on results, such as the number of publications, as well as their citations. Along with these indicators, Irivine and Martin (1985) evaluated the output of scientific research using peer evaluations. Averch (1987) examined the effectiveness of R&D funds when using publications and citations for economic and research support policy respect. Averch (1989) also considered the relationship between investment and performance in order to evaluate the efficiency of financial support for chemical research. The author considered the resource availability for each project, the characteristics of the researchers, the research environments, and also was conscious of the citation and the researcher evaluating the efficiency. Meyer (2000) evaluated the affect of scientific research on the industry, using paper citations and patents.

Crespi and Geuna (2006) suggested that the following three research variables would be useful for the evaluation of scientific and economic performance: new knowledge, human resource development, and new technology. Among these three variables, new knowledge and human resource development were considered to be the most important. The author used the publication of papers and frequency of citations to determine the value of new knowledge, and used the number of graduates with M.S or Ph. D. degrees to evaluate human resource development.

A fraction of the available literature related to the performance evaluation of scientific research supported by government funding considered the role of social effect. Salter and Martin (2001) discuss the many effects of government R&D funding such as the development of new companies, knowledge gain, the production of skilled graduates, technological development, the facilitation of social interaction, and the construction of new networks. Bozeman (2005) examined the social effect of science via government supported R&D funds by using benefit-cost analysis. The outputs of scientific research were evaluated through the numbers of patents and papers, the creation of jobs, and the contribution of technology to economic development.

We also examine approaches for evaluating the performance of basic science research on a national level. The Department for Education and Skills and the Department of UK proposed the “Science and Innovation Investment Framework 2004-2014” to promote scientific innovation in England in July 2004. The purpose of this framework was to demonstrate how productivity and employment growth could occur by investmenting in scientific research in order to further the innovation of companies and public services. Additionally, the Economic Impact Reporting Framework (EIRF) was developed in order to evaluate the investment effectiveness. The EIRF consists of four main factors used to measure economic effect, as well as additional factors that affect the main factors. The four main factors are ‘investment in the research base and innovation’, ‘knowledge generated by the research base’, ‘innovation outcomes and outputs of firms and government’, and ‘overall economic impacts’. The other factors affecting these are ‘framework conditions’, ‘knowledge exchange efficiency’, and ‘demand for innovation’.

Research Councils UK (RCUK) has invested in various areas, such as research, education, knowledge transfer, science and social activity, operation activity (RCUK, 2007). RCUK Performance Evaluation Group (PEG) has conducted the evaluation of science budget, and designed the strategic framework for RCUK. Especially, PEG has conducted the evaluation of best practice, performance management framework, and economic impact. For the performance management framework, PEG developed the output metrics divided into a healthy research base and better exploitation. A healthy UK research base is evaluated based on the UK contribution to the global knowledge pool, the UK supply of newly trained people, the UK pool of trained people, research facilities and infrastructure, and positioning and relationships. The better exploitation is evaluated based on the interaction with business and public services, collaborative research, commercialization of research, cooperative training, and people exchanges between the research base and users.

Godin (1996) reported that a useful indicators based framework for the evaluation of the effect of scientific research is necessary to demonstrate a coherent picture of science and technology in Canada.

Statistics Canada, Canada's national statistic agency, carried out the performance evaluation using Bibliometrics based on quantitative scientific achievements. The evaluation consisted of the following three steps: micro level or the performance appraisal of the researcher, meso level or the appraisal of the research program to determine its influence within academic, social, and economic spheres, and macro level or the appraisal of the national research system to measure the effectiveness of research operations (Gauthier, 1998).

Cozzarin (2006) grouped the eleven government R&D support programs within Canada into the following four categories: infrastructure or capital acquisition programs, academic programs, scholarships programs, and commercialization and/or development programs. Once grouped, Cozzarin then suggested the benefits derived from the new infrastructure, the number of graduate students trained and the difference in sales and/or profit before and after the grant or loan to evaluate the performance of each category.

To assess the economic effect of corporate and government R&D projects, the National Institute of Standards and Technology (NIST) of the US used Net Present Value (NPV), Benefit-Cost Rate (BCR), Social Rate of Return (SRR), and Adjusted Internal Rate of Return or Implied Rate of Return (AIRR) (Tassey, 1999). Tassey (2003) reported that the input, output, and outcome metrics were used to analyze the potential economic effect of government R&D programs. The input metrics contain the direct/indirect government research funds, the industry research funds, and the funds for industry commercialization. The output metrics contain the scientific contribution, the developed technology, and the convergence between the developed technology. The outcome metrics contain the decision for the R&D investment, the market entrance, R&D productivity, and the product quality (Tessey, 2003).

National Science Foundation (NSF) of US has been using the Program Assessment Rating Tool (PART), a government-wide assessment methodology, to evaluate program performance (NSF, 2004). NSF teams, led by program staff, have taken an active role in the current cycle of the process. PART evaluates program performance in the areas of program purpose and design, strategic planning, program management and results. NSF developed the PART evaluation schedule, consistent with the investment categories and priority areas in the NSF Strategic Plan (NSF, 2004).

Performance Measures

The Korea Research Foundation (KRF) is regarded as one of Korea's top academic research funding organizations. A considerable amount of expertise and knowledge and numerous innovations have been gained through the support of the KRF since its foundation in 1981. This organization has also provided financial support to the nation's academic research sector.

In this paper, we consider three research support programs of the KRF that affect different areas of a researcher's life cycle: the Postdoctorates and Research Fellows Program, the Junior Professor Program and the Outstanding Scholars Program. We propose performance indicators which reflect the purpose of each program, as shown in Table 1.

[Table 1] Support purpose and qualification of each program

Program	Support Purpose	Qualification
Postdoctorates and Research Fellows Program	• To maintain the stability of the academic research as well as to promote the improvement of qualitative research by providing an opportunity for research within domestic and foreign universities or research institutes. • To maximize the creativity of the research performance by promoting researcher specializations and activities of the university research institute	• Researcher has less than five years of experience since receiving a PhD
Junior Professor Program	• To maintain the research initiative of the professor, to maximize his research capability, and to offer opportunities for participation on an international level • To provide the stable research environment necessary to support the growth of a professor working towards the status of an outstanding scholar	• Professor has been a full-time instructor at a domestic university for less than five years
Outstanding Scholars Program	• To support the scientific accomplishments of an internationally recognized researcher • To improve the future of domestic research by promoting the participation of next-generation prospective researchers	• Professor has devoted ten years to scientific research as a university instructor or as part of a domestic, government-supported research organization

Within two years of the completion of each support program, a funded recipient must publish at least one paper in an international journal. In the case of a multi-year program, the published result should to be proportionally multiplied.

We develop a set of indicators to evaluate the particular characteristics of each of the following three programs: the Postdoctorates and Research Fellows Program, the Junior Professor Program, and the Outstanding Scholars Program. We then classify the factors and measurement variables into inputs and outcomes. The inputs are related to the amount of funding and duration of each research project, and the outcomes are evaluated in terms of the goals and characteristics of each support program.

The indicators for the Postdoctorates and Research Fellows Program are classified according to the defined goals, such as the durability of academic research, specialty of post-doctorates, and contribution of research result.

The outcomes of the Junior Professor Program are classified into the stability of research and the ability of research. The outcomes of the Outstanding Scholars Program are divided into three sections; international research level of research quality, strengthening of research competitiveness in university community, and training next generation and establishment of research infra.

In order to obtain the measurement variables for these outcomes, we utilized relevant literature (Sohn et al., 2007, Griliches, 1990, Wang and Huang, 2007, Crespi and Geuna, 2006, and Salter and Martin, 2001), and also consulted with researchers who are already experienced with the KRF programs and are considered to be evaluation experts (two Professors and three Researchers).

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