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Assessing R&D efficiency using a two-stage dynamic DEA model: A case study of research institutes in the Chinese Academy of Sciences

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ABSTRACT

Various studies have been devoted to the evaluation of the research and development (R&D) performances of universities and research institutes. However, existing studies tend to focus on static systems, that is, systems with no intertemporal effect. To tackle this issue, this study attempts to assess relative R&D efficiency of institutes from a dynamic perspective. The unified two-stage model proposed by Kao (2017) made a contribution to combining division efficiencies in the multiplier form with frontier projections in the envelopment form in a unified framework. We develop his model in a dynamic framework into which the effects of carry-over activities are embedded across the period. If the dynamic effects in the efficiency measures are not considered, the results will be biased. This is one of the few studies to examine dynamic effects within the framework of the R&D process. Our analysis is based on samples of 17 research institutes in the Chinese Academy of Sciences over the period of 2012–2015. When compared with the proposed data envelope analysis (DEA) model, results show that the static DEA model may underestimate the R&D efficiency scores. The institutes experienced significant improvements in system efficiency, mainly due to the improvements in transfer efficiency. However, there is still much room for improvement in transferring scientific and technological (S&T) achievements. We also find that the resource scale played an important role in influencing basic research. Finally, the projections of inefficient institutes indicate that most institutes had insufficient carry-over inputs (newly approved projects and management cost) based on the average four-year values, and existing slack resources for managers to improve the future performance.

1. Introduction

Research and development (R&D) activities play an important role in promoting and maintaining scientific and technological (S&T) development. In China, since the national strategy of innovation-driven development was implemented, many efforts have been made to pursue development that relies increasingly on innovation. As a result, Chinese research innovation activities have achieved rapid development, according to the following evidence: China is the fastest growing country in terms of global R&D expenditure, and the annual growth rate rose by 11.5% from 2011 to 2015. The number of published SCI papers in China accounted for 16.3% of the world share in 2015, and ranked second in the world for the 7th consecutive

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year.[1] The massive R&D expenditure contributed to this success. However, the growth of funding is limited. Managers should be concerned about finding ways to quickly improve production efficiency using limited resources. Performance evaluation can help policy-makers and administrators identify the best innovation practitioners for benchmarking, and benefit from improving areas of weakness (Guan & Chen, 2012). In other words, R&D performance evaluation is expected to result in better performance.

The Chinese Academy of Sciences (CAS) is a premier research organisation in China. It was established in 1949 and is affiliated with the central government. As a national research institute, it has made significant contributions in the past 60 years to the development of China's science and technology. It has undertaken major S&T projects for the promotion of domestic economic and social development, as well as enabling China to catch up in science, with leading national research institutes in developed countries. CAS undertakes multiple activities, such as pioneering scientific excellence, cultivating S&T talent, and acting as a think tank.

There are two ambitious goals for CAS. The first is to become a leading pioneer rather than to follow others in interdisciplinary frontier areas. Second, it aims to meet imperative economic and social needs. CAS has launched a series of development strategies, such as Knowledge Innovation Program (KIP) (since 1998), Innovation 2020 (since 2011), and the Pioneer Initiative (since 2013), which aim at breaking structural barriers in the existing organisation and to elevate innovative capability. The implementation of these strategies has turned knowledge creation products into technologies, while at the same time, successfully combining original basic research with high-tech research and commercialising industrialised technology for utilising social resources better. CAS has strengthened ties with industries and multiple spin-off companies, and therefore, technology transfer contracts and their associated income have made great contributions to economic growth.

In this context, R&D performance assessment for institutes in CAS is more highlighted now than ever, as it can determine whether research funding is used efficiently, and whether or not strategic adjustments are effective. Thus, this study aims at evaluating the R&D performances of institutes that are dedicated to basic research and innovative high-technology. They shoulder the responsibility of making further research progress and promoting high-technology applications and transfers.

Existing studies have utilised a non-parametric method, namely, data envelopment analysis (DEA), to measure the relative R&D performance with multiple inputs and outputs (Chapple, Lockett, Siegel, & Wright, 2005; Guan, Zuo, Chen, & Yam, 2016; Wolszczak-Derlacz & Parteka, 2011). This result-oriented evaluation treats the R&D process as a single-stage or 'black box', without considering the intervening process. For these institutes with multiple tasks, if we use a traditional DEA model to evaluate R&D performance, the results will be biased. Extensive empirical studies have been conducted on the evaluation of R&D performance within the network structure and indicate that basic research and technology transfer are generally connected in series (Guan & Chen, 2010, 2012; Lee & Worthington, 2016; Mei, Liu, Lu, & Huang, 2014), see the detailed literature review in Section 2. Recently, this process-oriented R&D performance evaluation has been widely used. However, these studies mainly focus on static DEA models. There are empirical studies that indicate that this traditional single-period framework may not be suitable from a long-term perspective. Some studies incorporate the time dimension to measure the efficiency changes across multiple periods (see the detailed literature review in Section 2), but these models neglect the intertemporal effect of carry-over activities between two consecutive terms. Carry-over activities are supposed to link different periods, in other words, certain inputs or outputs used by one decision-making units (DMU) in the current period may potentially influence the level of inputs or outputs in the future, for example, Fukuyama and Weber (2015) evaluated Japanese bank performance, in which some bank assets were defined as carry-overs. These can be treated as the outputs of the previous period and inputs of the current period. In this study, we consider newly approved projects as the carry-over input of research activities. In reality, institutes need the support of projects to produce S&T achievements, and then, based on that, they can apply for new projects in the next period. In order to promote the transformation of S&T achievements, many universities or institutes extract a proportion of the technology transfer revenue as management cost to support work in the next period (see details in Section 4). In this context, this dynamic framework allows resources to be reallocated over time and will have direct effects on efficiency measurement. Without incorporating these effects in the evaluation of R&D performance, there will be a bias in efficiency measurement (Chen, 2009; Chen, Kou, & Fu, 2017; Cui & Li, 2017; Fukuyama & Weber, 2015; Guo, Lu, Lee, & Chiu, 2017). Thus, our intention is to address the gap in the literature, which is that R&D performance of research institutes is evaluated without considering the influences of dynamic effects.

The efficiency measures of the two stages can be calculated in a multiplier model, while an envelopment model can identify the frontier facets determined by DMUs. If we use only one model, we will limit our discussion. Kao (2017) reformulated the envelopment model for the general two-stage system, so that both, the projection point and the division efficiencies, can be obtained simultaneously. While this approach conducted their analysis from a static perspective, instead of adopting a dynamic framework, we extend the unified two-stage model of Kao (2017) that allows intertemporal resource reallocation so as to maximise the R&D efficiency of research institutes.

This study uses samples of 17 research institutes that are dedicated to basic research and high-technology missions to evaluate R&D performance over the period of 2012–2015, in terms of efficiency in research and technology transfer. Our first concern is to evaluate R&D performance while considering the intertemporal effect, by adding carry-over activities to link each period. With such a unified dynamic model, more detailed information will be obtained, which will make it possible to

[1] http://www.most.gov.cn/kjtj/. Data were obtained from the scientific statistics of the Ministry of Science and Technology of the People's Republic of China.