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Exploring the operating efficiency of Technology Development Programs by an intellectual capital perspective—A case study of Taiwan

Wen-Min Lu [a,1], Shiu-Wan Hung [b,*]

[a] Department of Financial Management, National Defense University, No. 70, Sector 2, Zhongyang North Road, Beitou, Taipei 112, Taiwan
[b] Department of Business Administration, National Central University, No. 300, Jung-Da Road, Jung-Li City, Tao-Yuan 320, Taiwan

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ABSTRACT

Government supported technological research and development can help the private sector to compete globally. A more accurate evaluation system considering multi-factor performance is highly desired. This study offers an alternative perspective and characterization of the performance of Technology Development Programs (TDPs) via a two-stage process that emphasizes research and development (R&D) and technology diffusion. This study shall employ a sequential data envelopment analysis (DEA) with a non-parametric statistical analysis to analyze differences in intellectual capital variables among various TDPs. The results reveal that R&D performance is better than technology diffusion performance for the TDPs. In addition, the "Mechanical, Mechatronic, and Transportation field" is more efficient than the other fields in both R&D and technology diffusion performance models. The findings of this study point to the importance of intellectual capital in achieving high levels of TDP efficiency. The potential applications and strengths of DEA and intellectual capital in assessing the performance of TDP are also highlighted.

1. Introduction

Research and development (R&D) is a well-organized process of knowledge creation, production, diffusion, and application, and is widely recognized as an important input in strengthening a country's competitive advantages. It is also one of the most crucial elements in promoting scientific and technological progress of a country. R&D investment has also been considered a driving force for economic development. However, if R&D resources are not used effectively, additional investment may be of little help in stimulating progress. Understanding the nature of R&D efficiency/inefficiency is important for strategic planning and decision-making under an intense competitive environment.

Technology diffusion, on the other hand, is an important component in the broader innovation process. It is the dissemination of technical information and knowledge and the subsequent adoption of new technologies and techniques by users. The last two decades have experienced revolutionary innovation and rapid diffusion of various technologies (Anderson et al., 2008; Laranja, 2009; Toedtling et al., 2009). The contribution of technology to a country's economic performance has attracted renewed attention from scholars all over the world due to the quick pace of technology dissemination today.

To help the Taiwanese private sector to compete globally, the Ministry of Economic Affairs (MOEA) in Taiwan initiated a program called the Technology Development Program (TDP) in the early 2000s. Through this program, the government offers over 15 billion NT dollars/year to support technological research and development. The R&D capabilities of research institutes, industry, and academia are combined through the TDP to nurture industries' technological development. For the purposes of budget allocation and control, an annual performance evaluation of TDP is a needed, although difficult task. Despite the MOEA's establishment of a performance evaluation system that has been in place for years, there is no consensus on the fairness of this system among industries, research institutes and other interested parties competing for funds. A more accurate evaluation system considering multi-factor performance is thus highly desired. This study aims to establish such a performance measure system for the TDP.

To legitimize the programs' goals and expenditures, various evaluation methods, procedures, and measures have been employed (Ormala, 1989; Roessner, 1989; Tanaka, 1989; MeKeon and Ryan, 1989; Meyer-Krahmer and Montigny, 1989; Luukkonen and Stahle, 1990; Perelman, 1995; Zhu, 2000; Swink et al., 2006; Fu et al., 2007; Hung, 2006). Nevertheless, all these procedures and measures ignore the future value of the present R&D investment through technological diffusion. An important dynamic of R&D to consider is that most innovations borrow heavily from prior or related work (Ilori et al., 2003). This implies that enhancing the potential for such "spillovers" from one researcher's innovative efforts to another's can make R&D more productive. Therefore, R&D evaluation should consider both the

* Corresponding author. Tel.: +886 3 4269903; fax: +886 3 2118558.
E-mail addresses: wenmin.lu@gmail.com (W.-M. Lu), shiuwan@mgt.ncu.edu.tw (S.-W. Hung).
[1] Tel.: +886 2 2898 6600x604981; fax: +886 2 2898 5927.

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"current" R&D activity and the "future" value of R&D by technological diffusion.

Among numerous research proposals focused on obtaining sustainable competitive performance in the current dynamic and information-dependent business environment, firms are alike in their reliance upon their intellectual capital (Amir and Lev, 1996; Edvinsson and Sullivan, 1996; Edvinsson and Malone, 1997; Roos and Roos, 1997; Bontis, 1998; Ulrich, 1998; Juma and Payne, 2004; Kong, 2007; Smith, 2007). Unlike the traditional resources of financial capital, physical plants and machines, intellectual capital is considered key drivers of superior performance and value creation because it is idiosyncratic and hard to imitate by competitors (Marr et al., 2004; Nahapiet and Ghoshal, 1998; Pöyhönen and Smedlund, 2004; Solleiro and Castanon, 2005). The current report shall attempt to provide an alternative perspective and characterization of the performance of TDPs via a two-stage production process that considers both R&D and technology diffusion, stressing the importance of intellectual capital. The definition of R&D productivity is the quantity of output divided by the quantity of input, while technological diffusion is a measure of technological externality. While better R&D efficiency is essential for an enterprise, a higher level of efficiency in technological diffusion is also important in determining the real value of an enterprise. A data envelopment analysis (DEA) method which inherently recognizes tradeoffs among various measures is employed to determine the operating performance of TDPs in Taiwan.

DEA is a linear programming based technique that converts multiple output and input measures into a single comprehensive measure of performance. This is completed by the construction of an empirical-based production or resource conversion frontier and by the identification of peer groups. The philosophy behind DEA is predicated upon the fact that a frontier transformation function empirically captures the underlying process defining firms' production activities. The application of DEA is strongly supported in the multitude of empirical analysis methods in different fields of profit (Seiford, 1997; Linton et al., 2002; Gattoufi et al., 2004; Emrouznejada et al., 2008).

This paper is organized as follows: an overview of TDP performance and intellectual capital literature is given in Section 2; the design of the performance model and an introduction of the methodology are addressed in Sections 3 and 4, respectively; and empirical results and interpretations are provided in Section 5. Implications are given in Section 6 and Section 7 concludes with the findings of this study. The results of this study can provide policy makers with insights into resource allocation and competitive advantage as well as help with strategic decision-making, especially regarding operational styles under an intense competitive environment.

2. Literature review

2.1. Technology Development Program of Taiwan

The Technology Development Program (TDP) at the Ministry of Economic Affairs (MOEA) in Taiwan is designed to meet the needs of the national scientific and industrial policy, with strategic planning in different disciplines in support of key R&D goals set for Taiwan's industrial development. The funding directions for TDP focus on research institutes, the private sector and universities. The projects are composed of the following: research institutes funding, private sector funding, and university funding.

TDP strategies for research institutes funding, starting from 1979, focus on innovation and visionary research, development of pioneering and proprietary technologies as well as the promotion of international collaborations. Key focus areas include "Electronics, Information, Communications, and Optoelectronics field", "Biotechnology, Pharmaceutical, Material and Chemical field", and "Mechanical, Mechatronics, and Transportation field". The private sector funding, starting from 1999, are responsible for helping private-sector businesses to develop their own R&D capabilities. The main focus of this program is to implement the small business innovation research program to encourage domestic small and medium enterprises (SMEs) to carry out innovative research related to industrial technology and products. The program subsidizes up to 50% of the R&D cost spent by SMEs. The technology development program for academic utilizes a full-grant model to encourage the academic institutions to develop pioneering and innovative technologies. Since 2001, the academic TDP has focused on leveraging research specialties of different public and private universities in Taiwan to collaborate on applied level technology in R&D related programs.

2.2. Evaluation practice

Various studies have been done to investigate the effects of R&D investment on raising productivity and profit at the firm and industry levels (Mansfield, 1980, 1988; Griliches, 1986; Hartmann, 2003; Gonzalez and Gascon, 2004; Saiki et al., 2006; Walwyn, 2007). Lee et al. (2009) discussed the strategic importance of evaluating national R&D programs as resource allocation draws more attention in R&D policy agenda. Some studies applied the production framework to evaluate the relative efficiency of R&D activities across countries (Co and Chew, 1997; Rousseau and Rousseau, 1998; Sharma and Thomas, 2008; Lee et al., 2009; Garcia-Valderrama et al., 2009). Feller (1990) and Adams and Griliches (2000) emphasized the importance of the productivity of basic research in universities. Only in recent years have a few examples in the literature discussed R&D efficiency by using quantitative approaches with regard to R&D at the firm level. Zhang et al. (2003) applied the stochastic frontier analysis (SFA) approach to the R&D efforts of Chinese firms to examine the difference in efficiency among various types of ownership. As for academic research, Cherchye and Vanden Abeele (2005) applied the DEA technique to evaluate the efficiency of university R&D in Finland and the Netherlands, respectively. Verma and Sinha (2002) developed a theoretical framework for understanding the interdependencies between projects and their relationship to project performance in a multiple-concurrent R&D environment.

As can be seen in the brief literature review, a rich array of theories, determinants, and variables can impact the effects of R&D investment. Factors of the manpower, capital, and patents are commonly applied in the analysis. Despite the fact that various works have been completed to investigate the debate over R&D effects, no research has explored the R&D and technology diffusion performances of national Technology Development Programs.

2.3. Intellectual capital

Intellectual capital is not only the sum of individual knowledge and capabilities that bring forth value creation and wealth (Stewart, 1997), but also the organizational capital that involves organizational relationships (supply chain relationships and relationships with external stakeholders), infrastructure (physical assets and communication platform), culture (shared value and management philosophies), routine (business development processes that transmit information), and intellectual property (patents and trademarks) (Brooking, 1996; Marr et al., 2004; Roos and Roos, 1997). As Nahapiet and Ghoshal (1998) illustrated, intellectual capital is the knowledge and knowing capability of a