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Evaluating R & D investment efficiency in China's high-tech industry

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ABSTRACT

Research and development (R & D) investment activity plays a crucial role in developing high-tech industries. In recent decades, China has made sustained investments in its domestic high-tech industries, with the goal of increasing their productivity. This paper investigates the effect of this investment on relative R & D efficiency across China's high-tech sectors. Data Envelopment Analysis (DEA) was used to generate quantitative indices for sector comparisons. The analysis of this study indicates that overall R & D investment efficiency did not increase from 1998 to 2009, despite R & D expenditure increasing by 2188%. Over the same period, most sectors suffered from decreasing returns to scale (DRS), presumably also reflecting the inefficient R & D investment. Most of the sectors showed significant fluctuation on R & D investment efficiency. This research result indicates that the problem of China's high-tech industry may be from the inefficiency of its technology commercialization processes, and therefore represents a critical parameter for policy makers and managers.

1. Introduction

The importance of innovation has been widely acknowledged and the growth of high-tech industry has frequently been regarded as the one of most important indices for economic development (Cainelli, Evangelista, & Savona, 2006; Grossman & Helpman, 1991; Rosegger, 1996). This phenomenon is no longer confined to the developed countries; countries from emerging markets have been investing increasingly into the high-tech industry to enhance their capacity for innovation. Although the increasing level of investments would seem likely to promote innovation, it is not clear that this is occurring (see Zabala-Iturriagagoitia, Voigt, Gutierrez-Gracia, & Jimenez-Saez, 2007). In addition, because of the limitation of resources, investment should be prioritized strategically across the various high-tech industries in order to realize optimal levels of innovation and productivity.

Research and development (R & D) activities provide the basis for many corporate science and technology activities, and play a crucial role in enhancing the competitiveness of companies in achieving sustained and rapid growth (Zhong, Yuan, Li, & Huang, 2011). In order to improve R & D efficiency, it is first necessary to measure it, and so quantitative methods have been adapted to analyze the efficiency of R & D investment as an index of innovation. R & D investment efficiency is improved when for the same

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amount of R & D input more innovation output is generated, or when less R & D input is needed for generating the same amount of innovation output. Simply, innovation efficiency can be defined as the ratio of outputs over inputs (Hollanders & Celikel-Esser, 2007). Inputs include R & D expenditure, R & D personnel and knowledge capital stock, and outputs indicate the technical improvement and economic benefit from the R & D activities.

Measuring the R & D investment efficiency from the quantitative perspective is needed to provide practical indices for measuring and managing it, especially in the developing countries. Most of the relevant research is based on advanced markets in which the innovation production systems are more mature (for example, Mansfield, 1998; Timmer, 2003). Although the experiences from these countries are very useful, the particular characteristics of emerging markets decide the necessity and importance of measuring and understanding the R & D investment efficiency in developing countries.

As one of the main developing countries in the world, China has been making great efforts to develop its R & D capacity for high-tech industry. Firstly, China's government figures indicate that spending on R & D has increased dramatically in recent years. R & D spending has increased by 2794.044% from 1991 to 2008. Its R & D intensity, namely the R & D spending as a percentage of GDP, climbed from 0.76% in 1999 to 1.54% in 2008. On the global landscape, although China's global share in terms of gross R & D expenditure remains lower, it is currently the second to third highest investor in R & D, following the US and Japan. Secondly, from 1995 to 2004, the number of researchers in China increased by 77%. In 2006, China ranked second worldwide with 926,000 researchers, just behind the US and ahead of Japan. Thirdly, China's patent applications and authorizations showed a double-digit increase, with an average increase of 16.7% and 25%, respectively, from 1986 to 2007. China's world-ranking in terms of patent application rose from the 22nd place in 1997 to the 7th place in 2007 (Ministry of Science and Technology of the People's Republic of China, 2001; The Royal Society, 2011).

With these growing investments aimed at increasing innovation and productivity, China has emerged as the largest high-tech exporting country with 16.9% of global market share in high-tech products in 2006 (Meri, 2009). However, China is still far away from the developed countries in independent innovation capability and commercialization capability. For example, In terms of trade forms, 82% of high-tech exports belong to processing trade in 2009, i.e., “processed high-tech” exports. Under the category of high-tech products, what China actually exported is low skilled labour rather than technology (Xing, 2011).

A significant literature about the study of China's R & D capability has developed over the last decade. Zhang, Zhang, and Zhao (2003) made a contribution about the relationship between ownership and R & D efficiency based on a sample of 8341 Chinese firms. Guan, Yam, Mok, and Ma (2006) studied the relationship between competiveness and technological innovation capability based on the analysis of 182 industrial innovative firms in China. Liu and Buck (2007) investigated the impact of different channels for international technology spill-over on the innovation performance of Chinese high-tech industries. Guan and Chen (2010) developed the measurement of the innovation production process and applied it to a cross-region study of China's high-tech innovation. Zhong et al. (2011) evaluated the relative efficiencies of 30 regional R & D investments in 2004. Boeing, Mueller, and Sandner (2016) analysed whether different R & D activities show a positive influence on total factor productivity (TFP) for firms of different ownership types in China. Ruiqi, Wang, Xu, and Yuan (2017) examined the relationship between R & D expenditures and future performance, as well as the moderating effects of ultimate ownership on the relationship, using a sample of 772 Chinese listed firms from 2007 to 2012.

Research on the R & D productivity in China began with the studies of elements affecting the performance of China's innovation capability. Later on, researchers switched their attention to the measurement of performance on China's R & D productivity. However, the relative studies in the literature only focused on the cross-region comparison on R & D investment efficiency. So the research to systematically measure the performance of R & D efficiency performance in China's high-tech industry based on industry level and the comparison across sectors and sub-sectors is still needed to help understand the innovation capability of China's high-tech industry.

The main econometric methodologies for efficiency and productivity analysis are Data Envelopment Analysis (DEA) and stochastic frontier analysis (SFA). SFA has been adapted to develop the studies about the R & D productivity. For example, Zhang et al. (2003) applied SFA approach to examine the effects of various types of ownership on R & D efficiency of Chinese firms. Wang and Huang (2007) applied SFA approach to evaluate the relative efficiency of aggregate R & D activities cross 30 countries and observed a positive correlation between R & D performance and income level. However, there are two disadvantages for SFA technique which make it unsuitable for this research: it only can be used when the production function model is known, and more importantly it cannot accommodate many inputs and many outputs (Avkiran & Rowlands, 2008; Iglesias, Castellanos, & Seijas, 2010; Reinhard, Lovell, & Thijssen, 2000). DEA, in contrast, has several advantages in terms of evaluating the relative efficiency of R & D activities: firstly, DEA is especially valuable where the relative importance of the various inputs employed and outputs produced by a DMU (decision making units) cannot be defined; secondly, DEA allows for efficiency evaluation without necessitating the specification of a functional representation of the R & D/knowledge production technology; thirdly, R & D activities typically involves multiple inputs and multiple outputs (Wang & Huang, 2007).

Therefore, Data Envelopment Analysis (DEA) was employed to evaluate the R & D investment efficiency in this research. DEA has been widely used to evaluate the efficiency and productivity of many different kinds of entities ranging from manufacturing industry to service industry, and activities including cost efficiency measurement and operating efficiency measurement, as well as in contexts from emerging market to advanced market (Cooper, Seiford, & Zhu, 2004).

Specifically, in this study the following three questions were addressed: Firstly, What change did the entire R & D investment efficiency of China's high-tech industry undergo during 1998 to 2009? Secondly, what was the relative performance of China's five major high-tech sectors in terms of R & D investment efficiency? Finally, what factors triggered this performance and what are their implications for the future performance landscape?