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R&D growth and efficiency of scientific research development institutes in China

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ABSTRACT

With China tops global patent filings, Chinese innovation capability is coming into the picture. However, is this real innovation capability of China? This paper calculates and analyzes the Annual Growth Rate of R&D inputs and outputs from Scientific Research and Development Institute (SRDI) in PR. China, covering the time period of 1999-2010. pointing out the existing questions and reasons. And then assesses the R&D efficiency of SRDI by using Data Envelopment Analysis (DEA) method. The main contribution of this paper is that the activities of SRDI are analyzed from different perspectives and concludes that the total innovation capability of SRDI in China is exciting but the quality of outputs needs to be improved further in the future.

Keywords: R&D growth; SRDI; Inputs; Outputs; Data Envelopment Analysis (DEA)

INTRODUCTION

By the end of 2012, three important reports related to Chinese innovation had been published in the world. The first was secretary-general *Hu's report at the 18th National Congress of the Communist Party of China*, which put forwards implementing the new stratagem of innovation-driven development [1]. In fact, China's economy and society have undergone the rapid development of 30 years since 1978, and the Chinese government has effectively used the sustainable public-sector research potential to boost the knowledge-based economy of the country, which had laid a good foundation for the development of science and technology [2-3] and expected the continuation of this growth pattern in the near future [3-4]. The second report was *WIPO's World Intellectual Property Indicators 2012*, which showed that patent filings worldwide grew by 7.8% in 2011, and found that China's patent office became the largest in the world, as measured by the number of patent applications received [5]. Science technology innovation has already developed and improved the growth of invention patents, providing strategic support for raising the productive forces and boosting the overall national strength in China [1-3; 6]. The third report was *the 2012 Top 100 Global Innovators* according to a series of patent-related metrics that got to the essence of what it means to be truly innovative, but Chinese institutions were not on the list as a result of patent quality and influence was insufficient [7].These reports, on the one hand, illustrated that China had given great importance to the innovation. As innovation entities, R&D institutions have played an important role in the process of build the "innovation-oriented country" in China. On the other hand, although the number of Chinese patent application was leading the world, but there are some questions about innovation ability being insufficient and innovation efficiency to be enhanced. Therefore, the aim of this research is to analyze the change of input and output on R&D institutions and to improve their innovation ability.

The remainder of the paper is organized as follows. Section 1introduces the Sources of data and research method. Section 2 analyzes the inputs and outputs of R&D institutions and reports the annual growth rate (AGR) of R&D

institutions' inputs and outputs. Section 3 assesses the R&D efficiency of Scientific Research and Development Institute (SRDI). Section 4 gets conclusion and discusses the further issues.

DATA AND METHODS

The more research and development spent, the more patent applications had [2]. From the perspective of inputs in SRDI, personnel and expenditure, which are assigned to the basic, applied and experimental development field, may be two important input indicators. From the perspective of outputs in SRDI, R&D outputs mainly include two indicators of patent and paper for their widespread availability of data all over the world [4, 6]. Patents have generally been accepted as indicators of the innovation and R&D process in the absence of more robust indicators [2-3, 6; 8]. Patents are divided into Patent application and Patent granted according to the sequence of innovation activities. Patens include three types of invent patent, utility models patent and designs patent according to the difficulty of innovation. However, patents were used through different patent types by different researchers. The patent application was used for some researches because of the data availability [2]. The invent patents granted was used for other researches duo to reflecting the original innovation capability and the commercialization potential [3, 6]. To reflect the total innovation process more completely, this research not only uses the Patent application and Patent granted, but also focuses on the invent patent. Paper, as an important publication form, is the other indicator of science and research outputs [4, 6]. So this research regards paper as an important indicator of R&D outputs.

There are some researches on R&D change and efficiency from different perspectives [2-3, 6, 8-14]. There are the brief introductions as followed. Informetrics has been used to analyze the Pa numbers, patent intensity, technical fields, main IPC and the applicants [2]. For the spatial distribution of invention patents reflecting the distribution of innovation activities, patent grants and its growth rate between U.S. and China have been compared [3]. Patent statistics, Patent granted, publication and expenditures have been regarded as important indicators to assess R&D change and efficiency [7-8]. R&D capital, rate of return on R&D investment and its spillover have been analyzed in Japanese manufacturing industries [9]. The outputs of science and technology have been decided by the leading institutions [10]. But government funding R&D of SRDI has played key role in promoting innovation activities [11-12]. After Charnes, Cooper and Rhodes developed data envelopment analysis (DEA) approach to measure the relative effectiveness of making decision units in 1978, DEA has been used to assess the R&D efficiency and inefficiency [13-16]. We can deduce that there is no known research on the whole analysis of R&D in SRDI in China to the best of our knowledge. Therefore, first of all, this paper is to calculate and analyze the Annual Growth Rate (AGR) of R&D inputs and outputs in SRDI. And then measures the relative R&D efficiency of SRDI by use of the DEA approach.

According to Basic Statistics on Scientific Research and Development Institute from CHINA STATISTICAL YEARBOOK, data of personnel and expenditure is relatively complete, but patents and papers are lack of data before 2002 [17]. Therefore, when we only analyze the inputs trend, the data on total personnel and total R&D expenditure are taken for the years from 1999 to 2010. When we only analyze the outputs trend, the data on patent application, patent granted and papers are taken for the years from 2002 to 2010. Due to the time lag between the provision of inputs and the expectation of outputs in SRDI, analyzing their change of R&D inputs and outputs must consider the inconsistent issue. According to research experience previously [7, 9], we take a three year time lag between the inputs and the outputs data by using DEA approach. That is to say, when we assess the R&D change in SRDI, the inputs data on total personnel and total R&D expenditure are taken for the years from 1999 to 2007, the outputs data on patents and papers are taken for the years from 2002 to 2010 correspondingly.

3. The Annual Growth Rate of R&D inputs and outputs in SRDI in China

3.1 Inputs

R&D personnel are one indicator of main R&D inputs to the R&D process in SRDI. The input of Chinese R&D personnel in SRDI has changed greatly since 1999.The AGR of the total R&D personnel, basic research personnel, applied research personnel and experiment development personnel was 2.25%, 4.76%, 2.20% and 7.18% respectively during 1999-2010. These changes had three reasons. The first reason was the outcomes of Chinese SRDI' new round reform in 1999 which caused some researchers left R&D work. The second was related with Chinese development stage, especially putting forward becoming an "innovation-oriented country" in 2006 by the year 2020, which attracted a large young men graduating from high education institutions to the R&D procession since the latter of "the tenth five year". The third was national talent programs like The Chang Jiang Scholar Program started in 1998 and Thousand-Talent Program initiated in 2008, which aim is to attract some 2000 top scientists and talents to work in China over the next five to ten years. Therefore, the trend of the AGR of R&D personnel input is increasing since 21 century, which is laid sustainable foundation for the SRDI in China. Therefore, Chinese R&D personnel growth laid the sound foundation for the SRDI's development and the order of Chinese SRDI emphasizing R&D was experiment development, basic research and applied research.

R&D expenditure is the other indicator of main R&D inputs to the R&D process in SRDI. The input of Chinese R&D expenditure in SRDI has changed greatly since 1999. The AGR of the total expenditure, basic research expenditure, applied research expenditure and experiment development expenditure was 14.67%, 13.81%, 14.24% and 16.66% respectively during 1999-2010. The high speed growth of Chinese economy and government attaching importance to innovation were the main reasons of the expenditure growth of SRDI. Therefore, the sustainable growth of R&D expenditure during 1999-2010 provided the powerful support for SRDI's innovative activities and the order of Chinese SRDI emphasizing R&D was experiment development, applied research and basic research.

However, taking into regard of the time lag, the AGR of R&D personnel was decreasing sharply from 2.35% in 1999 to negative 9.77% in 2001, increasing sharply 4.88% in 2002, decreasing slowly to negative 0.97%, and then increasing to 10.39% in 2007. The AGR of R&D expenditure had great lumpy increasing from 11.08% in 1999 to 21.26% in 2007. The reasons for lumpy change lie in Chinese science and technology system reform lag, leading role of government and funding way of market-oriented R&D, which caused the unsteady expenditure input due to the decreasing of the number of SRDI, affecting deeply the outputs of in SRDI in China now and in the future.

3.2 Outputs

Papers' average annual growth rate (AAGR) in Chinese SRDI was 5.5% during 2002-2010. Patents application and patents granted both are increasing steadily in Chinese SRDI, their AAGR was 22.45% and 24.13% respectively during 2002-2010. The reasons of patents growth lies the growth of R&D personnel and expenditure, center governments' leading role through science and technology programs like 973 program, 863 program and the Key Technology R&D Program, and the policies of encouraging innovation [11-12]. Based on the data of the R&D outputs, we calculate the AGR of papers, patents application, patents granted, invent patents application and invent patents granted respectively. First of all, the AGR of papers was decreasing slowly from 6.18% in 2003 to1.95 % in 2010. This shows the number of papers has grown rapidly since the beginning of 21 century, got more high level now, and then has been getting increasing slowly. Secondly, the AGR of patents application decreased sharply from 26.6 % in 2003 to 12.99% in 2004, increasing to 24.71% in 2005 rapidly, decreasing to17.79 % in 2006, increasing to 27.89% in 2008 and then increasing to 21.68 % in 2010. Thirdly, the AGR of patents granted had the sharp decreasing from 40.47% in 2003 to 7.48% in 2005 and then increasing to 36.10% in 2010, which displays the improving the quality of innovation in SRDI for the past several years and keeping the growth tread. Fourthly, the AGR of invent patents application decreased from 30.29% in 2003 to 18.15% in 2004, increased to 26.75% in 2008 step by step, and began to decrease to 21.18% in 2010 in the end. Finally, the AGR of invent patents granted decreased sharply from 69.05 % in 2003 to 4.93% in 2006, increasing to 31.43% in 2009 and beginning to decrease to 28.75% in 2010. Therefore, we can conclude that the invent activities and their outcomes are decreasing from the perspective of the inventive change trend above. Improving the innovation outputs of SRDI in China will face great challenges in the future, including deepening science and technology system reform, building up the sound incentive mechanism from R&D, demonstration, deploy to industrialization, encouraging the cooperation among government, enterprises, universities and institutions, strengthening the scientific research institutions at home and abroad cooperation, and so on.

4. R&D efficiency of SRDI in China

4.1 DEA models

To assess the R&D efficiency of SRDI in China, we regard every year as a Decision Making Unit (DMU), so there are inputs of nine DMUs from 1999 to 2007, their inputs include Basic research personnel, Applied research personnel, Experiment development personnel, Basic research expenditure, Applied research expenditure, Experiment development expenditure or Total R&D personnel, Total R&D expenditure According to three year time lag between the inputs and the outputs data, which of nine DMUs from 2002 to 2010, their outputs data include either three indicators of Paper, Patents application, Patents granted; Paper, Invent patents application, Invent patents granted or two indicators of paper, Invent patents granted. For reflecting the outputs quality, we choose four key cases from different combinations followed as table 1.

Table 1 the R&D efficiency of four models about SRDI in China

Model	Inputs	Outputs
Model 1	Basic research personnel, Applied research personnel, Experiment development personnel, Basic research expenditure, Applied research expenditure, Experiment development expenditure	Paper, Patents application, Patents granted
Model 2	Basic research personnel, Applied research personnel, Experiment development personnel, Basic research expenditure, Applied research expenditure, Experiment development expenditure	Paper, Invent patents application, Invent patents granted
Model 3	Total R&D personnel, Total R&D expenditure	Paper, Invent patents application, Invent patents granted
Model 4	Total R&D personnel, Total R&D expenditure	Paper, Invent patents granted

4.2 The outcomes of DEA models

We apply input orientated DEA to assess the R&D efficiency of SRDI in China as followed. Here, the scale assumption is the Variable Returns to Scale Model (VRS), while slacks are calculated by using multi-stage method. The calculation process is through the computer program DEAP Version 2.1 which was written by Tim Coelli [18]. The outcomes of four DEA models are calculated by DEAP followed as table 2.We can deduce from table 2 that most of DMUs of the R&D efficiency about SRDI in China from 1999 to 2007 were not only technical efficiency, but also scale efficiency. That is to say, as for Model 1, all years except 2003 were technological efficiency and scale efficiency, for the year of 2003, its crste was 0.973, vrste was 0.975, scale was 0.998 and showing decreasing returns to scale. As for Model 2, the outcome was similar to Model 1, the R&D efficiency in 2003 was inefficient, its crste was 0.976, vrste was 0.976, scale was 0.999, but manifesting increasing returns to scale. As for Model 3, the R&D efficiency in 2000, 2001, 2004, 2006 and 2007 were all efficient, but the R&D efficiency in 1999; 2002 and 2003 were inefficient, their crste, vrste and scale respectively were 0.932, 0.990, 0.942; 0.985, 0.991, 0.967 and 0.971, 0.997, 0.974, but their returns to scale were all increasing, which meant increasing the inputs and getting the more outputs. As to Model 4, the R&D efficiency in1999, 2000, 2001, 2004, 2006 and 2007 were all efficient, but the R&D efficiency in 2002; 2003 and 2005 were inefficient, their crste, vrste and scale were 0.953, 0.955, 0.999; 0.974, 0.961, 0.961 and 0.995, 1, 0.995 respectively, but their returns to scale were increasing, constant and decreasing respectively. As a whole, SRDI had been in a good state and now undergoing the transferring process from quantity to quality, the quality of the outputs from SRDI in China needed to be improved.

Table 2 the outcomes of four DEA models about SRDI in China

DMU	Model 1			Model 2			Model 3			Model 4		
	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale
1999	1	1	1 -	1	1	1 -	0.932	0.990	0.942 irs	1	1	1 -
2000	1	1	1 -	1	1	1 -	1	1	1 -	1	1	1 -
2001	1	1	1 -	1	1	1 -	1	1	1 -	1	1	1 -
2002	1	1	1 -	1	1	1 -	0.958	0.991	0.967 irs	0.953	0.955	0.999 irs
2003	0.973	0.975	0.998 drs	0.976	0.977	0.999 irs	0.971	0.997	0.974 irs	0.961	0.961	1 -
2004	1	1	1 -	1	1	1 -	1	1	1 -	1	1	1 -
2005	1	1	1 -	1	1	1 -	1	1	1 -	0.995	1	0.995 drs
2006	1	1	1 -	1	1	1 -	1	1	1 -	1	1	1 -
2007	1	1	1 -	1	1	1 -	1	1	1 -	1	1	1 -

Note: crste = technical efficiency from CRS DEA; vrste = technical efficiency from VRS DEA; scale = scale efficiency = crste/vrste; '-' = constant returns to scale; drs = decreasing returns to scale; irs = increasing returns to scale.

4.3 The projection of the inefficient DMUs in four DEA models

Further DMU's input and output changes can be made to improve the performance. Such changes are called DEA slacks which also represent inefficiency [19]. The slack movement of outputs is the quantity of insufficient outputs in the current technical level and current inputs. The slack movement and radial movement of inputs are the expression of redundant inputs in the current production level. Therefore, when the slack movement of outputs is greater than zero, this explains that the outputs are insufficient. When the radial movement and the slack movement of inputs are lower than zero, this indicates that the inputs are in redundant state and need to be reduced in the future. To make the inefficient DMUs be crste and vrste, the projections have been made according to the outcomes from program DEAP followed as table 3. The projection value in table 3 can make DMU be efficient, pointing out the direction of the innovative action for the future.

Table 3 the projection of the inefficient DMUs in four DEA models

Model	Year	Variable	original value	radial movement	slack movement	projected value
Model 1	2003	Paper	118211	0	0	118211
		Patent application	8026	0	265.213	8291.213
		Patent granted	3499	0	27.43	3526.43
		Basic research personnel	2.6	-0.066	0	2.534
		Applied research personnel	7.9	-0.201	0	7.699
		Experiment development personnel	9.9	-0.252	-0.54	9.107
		Basic research expenditure	46.9	-1.195	-1.116	44.580
		Applied research expenditure	141.1	-3.594	0	137.506
		Experiment development expenditure	211	-5.375	-1.474	204.151
Model 2	2003	Paper	118211	0	0	118211
		Invent patents application	6200	0	366.51	6566.51
		Invent patents granted	2191	0	0	2191
		Basic research personnel	2.6	-0.06	0	2.54
		Applied research personnel	7.9	-0.183	0	7.717
		Experiment development personnel	9.9	-0.230	-0.511	9.159
		Basic research expenditure	46.9	-1.088	-0.994	44.818
		Applied research expenditure	141.1	-3.274	0	137.826
		Experiment development expenditure	211	-4.895	0	206.105
Model 3	1999	Paper	91872	0	5673	97500
		Invent patents application	2651	0	803	3454
		Invent patents granted	824	0	569	1393
		Total R&D personnel	23.3	-0.232	-0.368	22.7
		Total R&D expenditure	260.6	-2.600	0	258
	2002	Paper	109995	0	3793.824	113788.824
		Invent patents application	5064	0	558.206	5622.206
		Invent patents granted	2088	0	90.133	2178.133
		Total R&D personnel	20.6	-0.183	0	20.417
		Total R&D expenditure	351.3	-3.126	0	348.174
	2003	Paper	118211	0	3162.53	121373.53
		Invent patents application	6200	0	708.214	6908.214
		Invent patents granted	2191	0	159.133	2350.133
		Total R&D personnel	20.4	-0.053	0	20.347
		Total R&D expenditure	399	-1.032	0	397.968
Model 4	2002	Paper	109995	0	0	109995
		Invent patents granted	2088	0	0	2088
		Total R&D personnel	20.6	-0.935	0	19.665
		Total R&D expenditure	351.3	-15.948	0	335.352
	2003	Paper	118211	0	0	118211
		Invent patents granted	2191	0	0	2191
		Total R&D personnel	20.4	-0.796	0	19.604
		Total R&D expenditure	399	-15.576	0	383.424
	2005	Paper	132072	0	0	132072
		Invent patents granted	3102	0	0	3102
		Total R&D personnel	21.5	0	0	21.5
		Total R&D expenditure	513	0	0	513

CONCLUSION

From the above analysis, we can make the following conclusions.

Firstly, the total inputs of R&D personnel and expenditure and total outputs of patents and papers were keeping continual growth since 2001, which kept the same step with Chinese economy growth. This explains that the more R&D inputs, the more R&D outputs. Of course, this depends on national innovation stratagem, government leading role, fund support, policies promoting, market pulling and their interacting.

Secondly, the wave of the annual growth rate of R&D inputs resulted in the decreasing trend of the annual growth rate of R&D outputs directly. This shows that SRDI's effective innovation mechanism had not been formed up to now, the quality of R&D outputs has to be improved and the decreasing trend of the innovation growth must be alert and be paid high attention. In a word, the innovation of SRDI has a long way to go in the future.

Thirdly, the R&D efficiency of SRDI in China from 1999 to 2007 was sound as a whole, not only technical efficiency, but also scale efficiency. And the interesting finding is that the activities of SRDI in China are proactive and well-done generally, but their quality of the outputs needs to be improved.

However, what results will be through comparing innovation activities of SRDIs between China and foreign countries? How to contrast analysis of innovation activities among SRDIs, universities and enterprises in China from different perspective by using interdisciplinary methods? These will be further research topics of SRDI in China in the future.

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