SECTION 1. Macroeconomic processes and regional economies management

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The effectiveness of national R&D investment – an empirical investigation in China

Abstract

The effectiveness of national R&D investment in the economic growth in the developing nations has attracted significant attention during the last two decades. Both positive and negative stories have been reported with different reasoning and explanations. In this paper, an empirical study investigating the effectiveness of national R&D investment in the nation's economic growth and development in China is described. In the study, the DEA (Data Envelopment Analysis) model is used to examine and analyze the related data collected from 1985 to 2003 in terms of the trend and changes of the effectiveness of national R&D investment. The result indicates that during the last two decades, the national R&D investment in China had not resulted in a satisfactory contribution to the nation's economic development, as it has been expected. It also revealed that the R&D investments in different sectors have shown different effectiveness. Managerial implications and suggestions are discussed accordingly.

Keywords: national R&D investment, DEA model application, China economic development.
JEL Classification: C67, O32, O33, O38.

Introduction

While there are many important factors in determining a nation's economic growth and its competitiveness on global market, the level of national R&D investment has been proven to be a key and determinant factor in the reported success of many developing countries (Chen, 2002). Based on an international study, during their early economic development periods, the ratio of national R&D/GDP for most developing countries was remaining in a range of 0.5% to 0.7%, and then up to 1.5% when those nations entered their fast growing stage, reaching 2.0% eventually while their economies maintained a relative stabilized growth (Lin, 2000). Such international experience, however, was challenged in a recent similar study in China (Li et al., 2001). For instance, China has been recognized in an exceptional fast economic growth since early 1990s, but measured by this R&D/GDP ratio, it was only reaching 1.0% in 2000, and remaining on a quite low level for a relatively long period of time. What were the real reasons behind such a count-experience economic trend? What are the managerial implications that could be derived and learned from the related facts and investigations? Those are the primary motivations for this empirical study – to examine and analyze the effectiveness of China's national R&D investment based on the data collected from 1985 to 2003.

In May 1986, Beijing, China, the Great Hall of People – the official governmental meeting palace, then Chinese senior leader, Mr. Deng Xiaoping met, for the first time, with the Chairman of the Board of the Directors of New York Stock Exchange (NYSE). During this historical meeting, the guest presented a badge of the NYSE to the Chinese leader in exchange for a certificate of one share of stock of Shanghai Feile Shareholding Company, signifying the formal return of the stock market to China after 1949 and an official beginning of the reform of state-owned enterprise through the free market system and stock market mechanism. It also started its national R&D investment effort to help and enhance its national economic growth and development.

There have been several key issues in the China's national R&D investment effort. First, after nearly two decades of economic reform and development, a market oriented enterprise economic system has been established since early 1980s and operated under normal conditions. It is reported that the budget for national R&D investment increased from 13.4 billion (Yuan) in 1985 to 345.9 billion (Yuan) in 2003, and the strength of national R&D investment – measured by the ratio of R&D/GDP – increased from 0.7% in 1987 to 1.3% in 2002 (Shi and Xu, 2004). As a result, the government national deficit, however, has also changed from a surplus of 57 million (Yuan) in 1985 to a deficit of 319.8 billion (Yuan) in 2003. That is, it is unrealistic to expect the government to further increase its R&D spending in a near future, and the proportion of R&D investment from enterprises' own budget must be increased accordingly. An international study indicated, among the OECD (the Organization of Economic Cooperation and Development) nations, the government R&D spending normally has a double-effect: the leverage effect and the crowding out effect (Guellec and Pottelsberghe, 2000). In 1998, among 24 OECD nations, the average government R&D spending was close to 30% of total national R&D investment (Guellec and Pottelsberghe, 2000). In comparison, the government R&D spending in China was as high as 33.4% in 2000 (Table 1). It can also be seen from Table 1 that the major financial support for research institutions across the nation was from government spending (82%), while for the R&D units within enterprises, their R&D financial source was more from their own business budgets (86%), a very positive sign for the increased trend of R&D spending by Chinese enterprises. Additionally, the effort to attract more foreign investment into China's R&D seemed quite limited, as it only counted less than 3% nationwide in 2000. A successful promotion in such direction is clearly required for future effort. More specifically, some direct questions about the effectiveness of current China's R&D investment include: Was there such a double-effect existing for China's R&D spending? If so, which effect, the leverage effect or the crowding effect, was dominating over another? And could the inconsistency between the relatively low national R&D/GDP ratio and high national economic growth be attributed to the dominating crowding effect of R&D investment? In the following sections, this paper will examine those issues based on the data collected from the past two decades.

Table 1. China's R&D spending in 2000

	R&D spending sources				
	Government spending	Enterprise spending	Foreign sources	Other sources	Total
R&D institutions	81.38%	5.23%	0.66%	12.7%	100%
Industrial enterprises	6.85%	86.41%	3.99%	2.77%	100%
Universities	58.54%	32.33%	1.17%	7.95%	100%
Other public organizations	30.93%	57.2%	0.42%	11.44%	100%
Total	33.4%	57.59%	2.69%	6.32%	100%

1. Related literature review

It has been well recognized that the investments in R&D activities are different from normal investment in business production and operations, due to the nature of non-excludability and non-appropriation of R&D outcomes (Dominique and Bruno, 2000). As a result, private business sections are traditionally relatively reluctant in their R&D spending decisions, and government support to the R&D activity becomes critical for a nation's success in its advancement of science and technology. It has been well known that four major approaches have been used by developed nations in their support to nations' R&D effort: (1) governmental R&D grants directly to firms; (2) government grants to support R&D activity in public research institutions; (3) government grants allocated to higher education institutions (universities and colleges) to support R&D activity within academic world, and (4) an incentive tax policy by government to encourage businesses to do more R&D efforts (Warda, 1996).

The early study about the assessment on the effectiveness of government R&D investment started in late 1990s – focusing on the issues of the leverage effect, i.e., the stimulated increase of firms' own R&D spending from the related government R&D investment (Capron et al., 1997). One study revealed that among G7 nations, the governmental R&D spending had a significant stimulation to the firms' own R&D spending, especially in the personal computer and telecommunication industries (Capron et al., 1997). Another research on the manufacturing firms in U.S. indicated that while the corporations who received governmental support had increased their firms' own R&D spending, other companies – who didn't receive governmental support, had in fact reduced their own R&D budgets – due to the effect of "technology spillover" (crowding-out effect) (Mamuneas and Nadiri, 1996). That is, those firms (who had reduced their own R&D budgets) were benefited from the availability of the advanced technology resulted from those with increased R&D efforts – due to the fact that many technology advancements from those firms (who had increased own R&D budgets) could not "hidden" and become immediately available to other firms in the same industry (Mamuneas and Nadiri, 1996). This had immediately attracted the international attention to the "crowding-out effect" of the governmental R&D investment, and thus a B-index was developed in 1996 to help the government agencies to measure and evaluate the effectiveness of governmental R&D tax incentive policies (Warda, 1996). Guellec and Pottelsberghe (2000) summarized the real rational behind such a crowding-out effect – the increased governmental R&D investment pushed the demand for all R&D elements (e.g., all R&D equipment, resources, personnel) up, which in turn forced the cost of obtaining and maintaining those R&D elements increasing. That is, the cost of R&D efforts was forced up at the same time. The increased R&D cost eventually resulted in those firms reducing their R&D budgets accordingly. In short, those early studies highlighted that the overall effect of government R&D investment will generate a U-shape trend: at the beginning, the government R&D spending will initiate a positive leverage effect (i.e., for every government R&D dollar, there would be an increase of 0.7 dollar in private firms' R&D spending). Such a positive effect would reach a maximum point when the ratio of government R&D spending over firms' own

R&D spending is at its optimum (threshold point). When this ratio is increased beyond its threshold point, the early positive leverage effect would then be turned into a negative crowding-out effect – i.e., many firms would then reduce their own R&D spending and effort (David and Hall, 1999; Goolshe, 1998). Additionally, there is also a different reactive effect when government R&D investment is allocated into two different directions. For instance, when the government R&D investment is granted to universities and other public research institutions, then there would be more positive leverage effect than negative crowding-out effect, and the higher the intensity of government R&D spending is, the less is the negative crowding-out effect. However, in comparison, Guellec and Pottelsberghe (2000) demonstrated that for most developing nations (among all OECD nations), the government R&D spending will generate a much larger positive leverage effect compared to a relatively much smaller negative crowding-out effect.

The research on the effectiveness of government R&D investment has been very limited within Chinese academic literature. Most published reports are focused on the leading role of government R&D spending and the resulted positive leverage effect (Chen, 2002), a few touched the crowding-out effect and indicated that there was a negative effect on private business organizations' R&D spending from the government R&D investment in public research institutions (Sheng, Zhu & Wu, 1996). As such, this research is in part an attempt to address some key concerns of both the positive leverage effect and negative crowding-out effect from the government R&D investment, while providing important insights for related future policy making process.

2. Analysis of recent government R&D investment in China

Some recent Chinese government R&D investment statistics are summarized in Table 2. As seen from Table 2, despite the fact that the government R&D investment had been increased to 104.3 billion (Yuan) in 2001, this spending was less than half (50%) of the national R&D investment in the same year in South Korea, and only accounted for about 4% for the same time period in U.S. Similarly, the annual R&D/GDP ratio in China was only up to 1.09% (from 0.60% in 1995, Table 2) – very low compared to most developed nations (over 2%, 2.45% in U.S., 2.37% in Germany, 2.90% in Japan, 2.38% in France, and 2.61% in South Korea). Moreover, among current government R&D investments, the proportion spent on the Basic Science section was relatively low, only 5.1%, compared to 16.2% (U.S.), 13.8% (Japan), and 22% (France). It has been reported that for most nations, the current allocation of their national R&D investments for three major sections is as follows: Basic Science, Applied Science, and Lab Science are 15%, 25%, and 60% respectively. In comparison, the allocation in China was 5%, 17%, and 78% in 2001 respectively (Table 2), too much spent in Lab Science – short-term outcome oriented and too little spent on Basic Science – which is the foundation to generate a long-term stream of research outcomes.

In terms of major R&D sources, there was also a significant shift during the last decade. While the proportion from government R&D investment had been declined slightly (from about 30% in 1991 to 25% in 2001), the actual R&D spending by private corporations had almost been doubled from around 28% in 1991 up to 57% in 2001 (Table 3). During the same time period, the proportions from both (government) bank loans and other sources had shown declining, from 17% and 25% in 1991 to 7.4% and 11% in 2001 respectively (Table 3). However, researchers quickly indicated that the R&D contribution from private sector in China is still relatively low (compared to 68% in Japan in 1993 and 76% in South Korea in 1998), and more improvement in this direction should certainly be a long-term strategic objective for the related government agency.

Table 2. China's R&D investment structure – from 1995 to 2001

(Billions Yuan)

R&D investment structure								R&D/GDP
Year	Total	Basic science		Applied science		Lab science		
1995	34.869	1.806	5.18%	9.202	26.39%	23.860	68.43%	0.60%
1996	40.448	2.024	5.00%	9.912	24.51%	28.512	70.49%	0.60%
1997	50.916	2.744	5.39%	13.246	26.02%	34.926	68.60%	0.64%
1998	55.112	2.895	5.25%	12.462	22.61%	39.754	72.13%	0.69%
1999	67.891	3.390	4.99%	15.155	22.32%	49.346	75.68%	0.83%
2000	89.566	4.673	5.22%	15.190	16.96%	69.703	77.82%	1.00%
2001	104.250	5.560	5.33%	18.485	17.73%	80.203	76.93%	1.09%
2002	128.76	7.377	5.73%	24.668	19.16%	96.720	75.12%	1.23%

Source: China Annual Statistics Yearbook, 1995-2002.

Table 3. China's R&D investment sources – from 1991 to 2001

(Millions Yuan)

Year	Major R&D funding sources								
	Total	Government funding		Enterprise founding		Bank loans		Other sources	
1991	42,700	12,638	29.6%	12,161	28.48%	7,193	16.85%	10,707	25.07%
1992	55,732	15,997	28.7%	16,246	29.15%	8,991	16.13%	14,497	26.02%
1993	67,548	17,537	25.9%	18,571	27.49%	11,881	17.59%	19,558	28.96%
1994	78,890	21,813	27.65%	23,435	29.71%	12,146	15.40%	21,493	27.24%
1995	96,250	24,873	25.84%	30,519	31.71%	12,708	13.20%	28,150	29.25%
1996	104,317	27,197	26.07%	31,282	29.99%	14,978	14.36%	30,859	29.58%
1997	118,192	30,987	26.22%	34,836	29.47%	15,518	13.13%	36,850	31.18%
1998	128,975	35,383	27.43%	40,250	31.21%	17,098	13.26%	36,243	28.1%
1999	146,060	47,297	32.38%	51,028	34.94%	12,879	8.82%	34,855	23.86%
2000	234,668	59,339	25.29%	12,963	55.24%	19,621	8.36%	26,071	11.11%
2001	258,939	65,635	25.3%%	14,583	56.32%	19,076	7.37%	28,389	10.96%
2002	293,798	77,621	26.42	16,766	57.07%	20,187	6.87%	28,323	9.64%

Source: China Annual Statistics Yearbook, 1991-2002.

In terms of R&D investment allocation, there are basically three types of primary R&D organizations in China – independent R&D institutions, higher education institutions (universities and colleges), and the R&D units within large industrial corporations. The relative allocation of R&D investments among those three types of R&D organizations from 1995 to 2001 can be seen from Table 4. For instance, while the proportion of R&D investment going to the universities had declined slightly from 12.13% in 1995 to 9.82% in 2001, the R&D spending by large industrial enterprises has been kept in path with the national trend, remaining 40.6% in 1995 to 42.4% in 2001, with the actual spending increased from 14 billion (Yuan) in 1995 to 44.2 billion (Yuan) in 2001, a 200% increase in 6 years. In comparison, the proportion of R&D investment from independent R&D institutions has been decreased from 42% in 1995 to 28% in 2001, even the actual spending was up from 14.7 billion (Yuan) in 1995 to 29 billion in 2001, and during the same time period, the total national R&D investment had been tripled from 34.8 billion in 1995 to 104.2 billion in 2001. Again, compared to OECD counties, while the total national R&D spending in China is still relatively low, but the actual R&D spending by those government supported R&D institutions (non-enterprise) is in fact much higher than that among OECD nations. But when compared to developed nations, the proportions of government R&D investment allocated to government supported institutions then seemed too high. For example, the similar government R&D investment was only 10% in U.S., 15% in Germany, 9% in Japan, and 19% in South Korea. Instead, for those developed nations, the private enterprise R&D spending was accounted most in national total, such as in 1995, 71.1% in U.S., 66% in Germany, 66.1% in Japan, and 73% in South Korea. In summary, from the policy making perspective, more efforts are clearly needed by Chinese government to encourage more future R&D spending from China's private industrial enterprises.

Table 4. China's R&D investment allocation – from 1995 to 2002

(Millions Yuan)

Year	Total R&D allocation						
	National Total	Independent institutions		Industrial enterprises		Universities	
1995	34.87	14.66	42.0%	14.17	40.6%	4.23	12.13%
1996	40.45	17.31	42.8%	16.05	39.7%	4.78	11.82%
1997	50.92	20.67	40.6%	18.83	37.0%	5.77	11.33%
1998	55.11	23.45	42.5%	19.71	35.8%	5.44	9.87%
1999	67.89	26.08	38.4%	24.99	36.8%	6.35	9.35%
2000	89.57	25.82	28.8%	35.34	39.5%	7.67	8.56%
2001	104.25	28.85	27.7%	44.23	42.4%	10.24	9.82%
2002	128.76	35.13	27.3%	56.02	43.5%	13.05	10.14%

Source: China Annual Statistics Yearbook, 1995-2002.

3. A DEA evaluation model and its application

In the existing literature, the effectiveness of an investment is normally measured by the ratio of outcomes to input (i.e., investment). Given the some diffficulties in measuring the direct relationship between the supposed outcome and input, both parametric approach (a pre-estimated quantitative function) and non-parametric approach have been proposed in the published literature (Hu and Li, 2002; Tian, Guo, and Zhang, 2000). While the former (parametric approach) has been used to evaluate the economic performance of enterprises where the relationship between the related outcome and input is relatively more directly related and easy to quantify and measure, the latter (non-parametric approach) is recommended to use where the relationship between the related expected outcome and the supposed input is much difficult (or impossible) to quantify and measure. The relationship between the government R&D investment and the expected outcome – the contribution to the development of national technology advancement and the growth of national economy – is obviously very difficult to measure directly and to quantify in a simply mathematical expression. That is why – the non-parametric approach has been strongly recommended to use for assessing the effectiveness of the national R&D investment in the existing literature.

The DEA (Data Envelopment Analysis) model was first developed in 1978 in Norman and Stocker (1991), as one commonly used non-parametric approach for measuring the relative effectiveness of multi-output with multi-input decision making unit (DMU). Its primary principle is: with multiple (n) DMU (Decision Making Units) each has multiple (m) non-negative inputs and non-negative (k) outputs, represented by vectors $X_j = (x_{1j}, x_{2j}, \ldots, x_{mj})$ and $Yj = (y_{1j}, y_{2j}, \ldots, y_{kj})$, each DMU utilizes input X to produce output *Y,* due to its convexity, then the total final product output can be expressed as:

$$T = \left\langle (X, Y) \middle| \sum_{j=1}^{n} X_j \lambda_j \le X, \sum_{j=1}^{n} Y_j \lambda_j \ge Y, \lambda_j \ge 0, j = 1,2\ldots,n \right\rangle, \quad (1)$$

where there is no restriction for any specific output/input quantitative functions for each DMU. That is, the model is satisfying to the "Principle of Multiple Optimization" – to allow each DMU to adjust its structure to reach optimization separately and differently (Norman and Stocker, 1991). In addition, through setting up LP (Linear Programming) models within DEA to search a relative "satisfied" solution (other than a theoretical optimal solution), the model will be able to provide a practical recommendation to the system addressed in the study.

In terms of consideration of related inputs to R&D activities, in addition to major financial resources and man-power requirements, other items such as: the information, intelligence, materials, and decision-making process should all be included. Similarly, the output of R&D efforts should also include all related selections, such as: desired solutions, products, new technology and techniques, new product design and production process improvement, and new approaches and systems to be used in the national economic development. More specifically, all R&D inputs can be grouped into the following three categories: (1) human resources and intelligence input, (2) capital and materials input, and (3) knowledge and information input. In a similar way, all R&D outputs can also be classified into three categories: (1) the output leading to new knowledge and new theory and concept, (2) the output leading to new benefits and new results (i.e., new products, new patents, and new production tools), and (3) the output leading to the advancement of social and economic system (i.e., new production system, new format of communication).

The application of DEA model requires that each DMU has similar input/output criteria selection and the sample size of DMU is at least equal or larger than the doubled total of the items of all input and output selections. In this study, to use the DEA model to evaluate the effectiveness of China's national R&D investment based on the data collected from 1985 to 2003, the following two assumptions are made:

- Input criteria selection: among the three major categories of R&D input discussed above, the first two: human resources and intelligence input and capital and materials input, are selected for this study, as the third one – knowledge and information input – is very hard to quantify and there is no available method in the existing literature. More specifically, the following two items are selected: (a) national total R&D annual spending ($x_{1,t-1}$) (representing total capital input in the year of t-1) and (b) the total number of scientists and engineers ($x_{2,t-1}$) (representing total human resource input in the year of t-1).
- Output criteria selection: to better measure the positive contribution of R&D efforts, two items are selected for this study: (a) improved national total labor productivity ($y_{1,t}$) – assuming that the positive R&D efforts should improve nation's overall labor productivity, and (b) the average consumption of energy per 10,000 (Yuan) GDP ($y_{2,t}$) – assuming that the advanced technology from R&D efforts should result in the reduction of needed energy for each 10,000

(Yuan) GDP. Here it further assumes that the effect of R&D input in year (t-1) will be reflected in the selected output next year (t).

Based on the data collected from <*China Annual Statistics Yearbook*> from 1985-2003, the above DEA model is applied to evaluate the effectiveness of government R&D investments and the related trend during this period, and the results are summarized in Table 5 below. In the model, (E_i) is defined as the relative effectiveness of each DMU in the model measured by the utilization of given R&D outputs over given R&D inputs. The annual improvement of this effectiveness is determined by the changes compared to the year before.

Table 5. The effectiveness of China's R&D investment – from 1985 to 2003

Year	R&D investment effectiveness (E_i)	Annual improvement Of (E_i) (%)	Year	R&D investment effectiveness (E_i)	Annual improvement Of (E_i) (%)
1985	1.00	——	1995	0.62	-12.22
1986	0.95	-4.72	1996	0.62	-1.16
1987	1.00	4.51	1997	0.57	-8.24
1988	1.00	0.00	1998	0.64	11.18
1989	1.00	0.00	1999	0.79	18.38
1990	0.86	-16.31	2000	0.83	5.13
1991	0.86	0.12	2001	0.73	-13.85
1992	0.86	0.04	2002	0.84	13.27
1993	1.00	13.89	2003	1.00	15.98
1994	0.70	-42.64			

The assessment of (E_i) in the DEA model has four rankings: (1) high (robustly) effective unit (when E_i = 1.00, while its relaxation variables are zero), (2) sub-high (marginal) effective unit (when E_i = 1.00, while its relaxation variables are not all equal to zero), (3) marginal ineffective unit (when E_i = 0.90 to 1.00), and (4) distinctly ineffective unit (when E_i < 0.90). As such, it can be seen from Table 5, from 1985 to 2003 – over 18-year period, only in six years that the government R&D investment reached the high DEA effective standard (1985, 1987-1989, 1993, and 2003), but during other 13 years, the government R&D investments were ranked DEA ineffective or worse, except in 1986 (E_i = 0.90, only marginal effective). In fact, the average effectiveness over 19 years is only 0.84 (average of all E_i), the lowest was reached in 1997 (E_i = 0.57). From the perspective of annual improvement, it can also be seen from Table 5, that the largest improvement (in terms of percentage) was made in 1999, a surprising 18.38% increase. In comparison, from 1993 to 1994, this effectiveness measure was down from (1.0 to 0.7, a 42.64% decrease in one year. Finally, considering the trend, this 19-year period can be divided into two different phases: Phase 1, from 1985 to 1993, and Phase 2, from 1994 to 2003. As displayed in Figure 1, Phase 1 can be characterized as "good" years in which the national R&D efforts were rated quite effective and stable, five out of six were ranked in high effective categories with an average of (E_i) at 0.95 and the largest deviation of only 6.7%. The same can not be said about Phase 2, however, in which the R&D effectiveness started to decline, with (E_i) down from 1.00 in 1993 to 0.70 in 1994, a 30% decrease in one year. The trend then continued until 1997 and then climbed back gradually starting in 1998. Phase 2 can be characterized as that the national R&D efforts were relatively "ineffective" with an average of (E_i) at 0.73, much below the marginal effective mark of 0.9 (at 0.73), and very unstable with large deviations year to year, a largest percentage deviation of 17%. There were obviously many reasons behind this trend, which certainly demands more in-depth future research on this issue. For instance, identifying what had contributed positively to the national R&D effectiveness during this period and what were the major negative factors which should be addressed and corrected in the future will provide meaningful insights to the related policy decision making process.

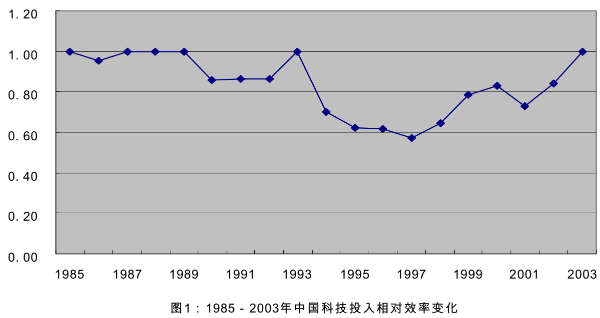

Fig. 1. Recent trend of China's R&D investment effectiveness

In summary, as the above analysis demonstrated, when the positive impact of advanced technology on the national economic growth is used, the effectiveness of China's national R&D investments (during the period studied – from 1985 to 2003) is relatively low, compared to many other countries. To further verify this trend, with the same data collected from 1985 to 2003, a regression analysis has been conducted in which the national economic growth rate is defined as the dependent variable (Y) and both the annual R&D effectiveness measure (E_i – as defined above) and annual total fixed assets increase rate are used as independent variables (X_i). Not surprising to see is that the regression results show there is no significant relationship between the national economic growth and national R&D investment effort (with the correlation efficient is only 0.155 and the p-value is 0.53). In comparison, there is a strong relationship between the national economic growth and national annual total fixed assets increase rate (with the correlation efficient as 0.87 and the p-value at 0.000). This can further explain the argument that the national economic growth in China during the last two decades had been more the result of increased direct investments into nation's industries, rather than the result of technology advancement from R&D effort. (Note: it is not coincident that in 1994, the R&D effectiveness measure (Ei) was down for 30% while the national annual fixed assets increase rate was the highest during that period at 28%.) In other words, the expected shift of national economic growth from more depending on increased direct assets to more depending on the advanced technology has not been materialized yet, and more studies are clearly needed for this purpose.

Conclusions and future research

In this paper, an empirical study investigating the effectiveness of national R&D investment in the nation's economic growth and development in China is described. In the study, the related statistical data from 1985 to 2003 are collected and analyzed with the DEA (Data Envelopment Analysis). The analysis is focused on the measurement of national R&D investment and the trend and changes during the period under study. As discussed in the early sections, the result of this research indicates that during the last two decades, the national R&D investment in China had not contributed to the nation's economic growth and development the way as it has been expected. It also revealed that the R&D investments in different sectors have shown different effectiveness, and the proportion from corporate R&D expenditure is proven to be more significantly important to the nation's economic development.

In conclusion, from the perspective of government policy concerns, it is important to provide certain incentives (i.e., preferred tax policies) to encourage private industrial enterprises investing more financial resources and organizational efforts in their R&D activities, and to develop an effective measurement system to promote and evaluate firms' R&D performance. While enterprises' R&D spending is one of the most important business decisions in relation to the activities of market competition and technology development, and in certain cases, the marketing force will motivate firms to enhance their R&D activities. But appropriate government policy and support can further ensure the potential success of an integrated R&D effort in a more collective way (Yao and Zhang, 2001).

More future research on the issues addressed in this paper is clearly demanded, to help nations, especially developing ones, in determining their national R&D efforts and policies to enhance the economic growth they expected. For example, there was a clear trend in nation's R&D effectiveness during the study period in China, as described in the early discussions. As there might be many reasons and explanations behind such a trend – further research to identify what had contributed positively to the national R&D effectiveness and what were the major negative causes which should be corrected will certainly provide meaningful insights to the related policy decision makers of many nations.

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