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Efficiency Evaluation of Basic Research in China

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Abstract

Following the increasing investment in basic research in China, the outputs of basic research have been greatly enhanced. In this paper, its relative efficiency of performance in basic research is analysed by adopting statistical regressions and Data Envelopment Analysis (DEA) method. Preliminary results show that injecting investments into basic research seems to be the main driving power for the increased research outputs in China. It is found that there were significant improvements on overall efficiency from 1991 to 1996, although this trend has noticeably slowed down since 1996. Possible causes of this slow-down are discussed.

Keywords: Efficiency evaluation, basic research performance, DEA

1. Introduction

Nowadays investment of Research and Development (R&D) is not only a key indicator to reflect the capability of national development of science and technology, but also a major driving force for the development of national economy. In China, the investment into R&D has been greatly increased since late 1980s. The ratio of the R&D investment to the Gross Domestic Production (GDP) reached a historically high record, up to 1.1% in 2001. The total R&D investment was $13 billion[1], although this figure was still not comparable with those in industrialized countries.

Basic research has been played as an important role in the development of economies, as it is a powerful engine to drive the development of high technologies by providing scientific discoveries and technology innovations. In China, since late 1980s, the importance of basic research has been emphasized by the government. Since then, although the ratio of the basic research investment to the total R&D investment has been kept around 5%, the absolute value of investment into the basic research has been significantly increased. The investment on basic research was $0.6 billion in 2001. That was about 5 times as that in 1990[2].

The number of publications included in Science Citation Index (SCI), has been adopted

[1] Data came from "National statistical announcement of R&D investments in 2001", China Science and Technology Statistics. The benchmark exchange rate from Bank of China in 2001, 1$=8.277RMB

as a key indicator to evaluate basic research outcomes (Bhattacharya *et al.* 2000, Herbertz and Muller-hill 1995, Evaristo 2003). The total number of SCI publications and the relative ranking of China in the world have been improved rapidly. As an example, from the 24th position of the world ranking in the 1987, with a total 4,880 publications, China jumped to the 8th position in 2001, with 35,395 publications. In 2003, China was up to 6th with 49,788 publications, which were 10 times than those in 1987[2]. However, the criticism and anxiety even become stronger although the number of SCI publications had greatly increased. These criticism and anxiety not only come from the academic society but also the taxpayers. One of the main issues is related to research quality, such as the numbers of world-class scientists in China are fewer, the average citation number is lower than the average level of the world. Another is related with efficiency of research resources' allocating and operating.

The purpose of this paper is to analyse the drivers of these increased research outputs and the relative efficiency by applying statistical analysis, and econometric analysis (Data Envelopment Analysis (DEA)). The paper is organized as follows. Section 2 presents a concise introduction of basic research in China. In Section 3, statistical analysis is carried out to conduct some preliminary assessments. Section 4 outlines the DEA approach and its applications on evaluating academic activities, and then presents an overall efficiency analysis for the basic research in China during 1991-2000. Conclusion is presented at the end of this paper.

2. Background and circumstance for basic research in China

The history of science and technology development in China can be approximately divided into two phases. From 1950 to 1977, the economical structure of China was a planning economy. Therefore the development of science and technology was also forged by the planning economy, which was thus very slow. Since 1978, a series of reforms have been launched to change the economical structure. Then the importance of the science and technology started to be ever emphasised. Subsequently, a series of science policies have been launched to stimulate and enhance the capability to develop science and technology. Significant reforms of science and technology in the last two decades can be summarized roughly as follows[3]:

- **Creating knowledge-based markets for science and technology**. During the period of planning economy, the government provided the research funding solely. Since 1980s, following the reform of the social economic structure, a series of science polices have been launched to create knowledge-based markets to

[2] Data came from National science and technology year book, from 1987 to 2003.
[3] Summarizing the national guide line for science and technology in last 50 years, *National Science and Technology year book, 2000*

encourage research institutions to communicate with industry, and scientists and engineers to create high-technology companies, *etc*. For instance, the total research funding of the national research institutions was $8 billion in 1999, in which $3 billion came from the government, and $5 billion came from the industries or high-tech companies.

- **Reconstruction of research institutions**. The applied scientific and technological institutions have been reorganized since 1986. These institutions, which used to solely depend on national budgets (not-for-profit), now have to change their operating systems to provide services to the industry to sustain (for-profit). For example, in 2001, there were 869 national research institutions, which now provide their service to the industry.

- **National Innovation System program.** In 1998, the Knowledge Innovation Project was lunched in Chinese Academy of Sciences. Subsequently, the National Innovation System was implemented to enhance the competition of science and technology in 2000, which includes the knowledge innovation and the technology innovation. Independent research institutions and key universities undertake the main missions of the knowledge innovation and the technology innovation, while industrial enterprises also take part in the technology innovation and applications.

Basic research, as a main part in science and technology development, has been emphasised by the Chinese government since 1980s. In China, basic research is heavily dependent on the government funding. For example, 86% of the research funding of basic research came from the government in 2001. The Ministry of Science and Technology (MOST), the National Natural Science Foundation of China (NSFC), are the main agencies in charge of basic research funding allocation. Meanwhile, independent research institutions, such as Chinese Academy of Sciences (CAS) also sponsor basic research. Independent research institutes, and universities (especially state key laboratories which affiliated to universities) are the main forces to undertake basic research. Figure 1 presents the distribution of basic research funding in 2000. There was 38.8% of the research funding aggregated on universities, 55% on the independent research institutes and the rest 6% on industries or companies[4].

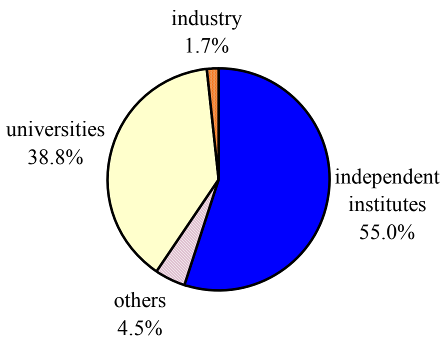

Fig 1 The distribution of basic research funding in 2000

[4] Annual statistical report of national science and technology, 1990-2000.

3. Preliminary Analysis

Let us first carry out some preliminary analysis on the development trends during 1991-2000. The basic data has been summarized in the following table[5].

Table 1 (RMB)

Year	Full-time research staff ($\times10^3$)	investment ($\times10^6$)	SCI publications	Total SCI publications	number of citations	Postgraduate enrolments	Fixed-base Retail Price Index (1991=100)	investment adjusted by RPI ($\times10^6$)
	A	B	C	D	E	F	G	H
1991	61.3	920	6609	7938	30346	13509	100.00	920
1992	58.4	1150	7720	9272	35471	18737	105.38	1091.27
1993	63.3	1260	8024	9595	38965	19787	119.28	1056.34
1994	76.4	1750	8492	10133	42791	22782	145.16	1205.59
1995	66.6	1860	11107	13067	47844	24282	166.64	1116.21
1996	69.6	2020	12425	14655	52104	26366	176.79	1142.60
1997	71.7	2740	14370	17007	62533	27428	178.19	1537.65
1998	78.7	2900	16605	19970	61346	29612	173.56	1670.88
1999	76.0	3400	19853	24553	70788	33413	168.37	2019.40
2000	79.5	4670	22604	30508	70618	41733	165.84	2815.97

Figure 2 presents the trend of the basic research investments from 1990 to 2000. From Figure 2 we can see that the first obviously jump happened in 1997, which was 36% more than that in 1996. Another apparent increase happened in 2000, which was 38% more than that in 1999. The Projects of National Key Basic Research and Development Plan (the 973 plan) started in 1997, which contributed the first jump in 1997. The second jumping was due to the launching of National Innovation System[6].

Figure 3 shows the number of SCI publications by year. In this work we will mainly use the data C since data E are based on them. It is clear that the trends of SCI publications and basic research investment match very well. The following figures illustrate the preliminary productivity analysis of the basic research performance in China from 1991 to 2000.

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http://www.sts.org.cn/Report_3/documents/2002/0218.html

[5] Data (column A, B and F) came from national science and technology yearbook, while Column F counted the numbers of enrolment of postgraduates which subject was attributed to Science. Since 1999, the extended SCI database has been used to count publications. In order to keep consistency of data, data from column C to E were re-searched by WuHan Library of Chinese Academy of Sciences based on extended SCI database. The SCI publications (Column C) included only the papers of first authors whose address was “the People’s Republic of China”. while Column D was searched by any authors’ address with “the People’s Republic of China”. Column E counted the number of citations based on Column C, and data collection was completed on 28th of February. Column G from China Statistical Yearbook (2003) which compiled by National Bureau of Statistics of China.

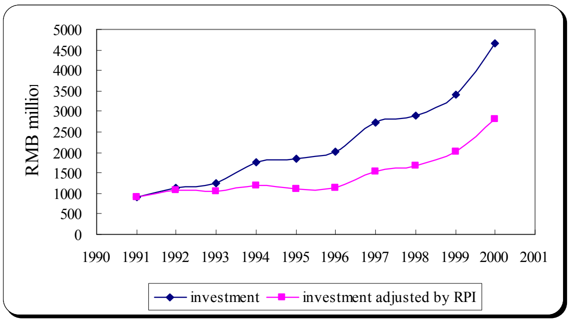

Fig 2 Basic research investment from 1991-2000

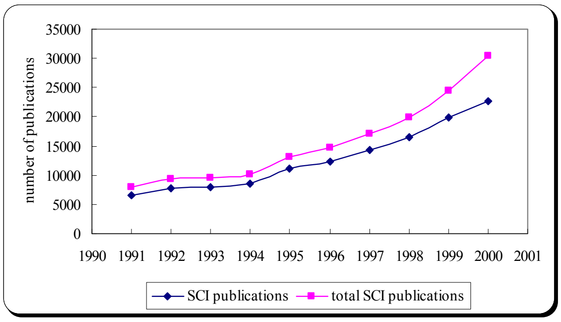

Fig 3 The SCI publication by year

Figure 4 shows the trend of the investment per paper during this period. The analysis seems to show that the investment per paper remained almost the same during this period. If considering the facts of inflation, the investment per paper seemed to be slightly decreased. The average investment per staff had been increased significantly, especially after 1996, as Figures 5 and 6 shown. The average publications per staff seemed to match this pattern, and the average citations and enrolments per staff had also been increased during this period although their growth rates were notably less than that of the average investment per staff, as Figure 7 shown. In order to have further detection about the influence of investment and staff into SCI publication, we carry on multi-regression analysis.

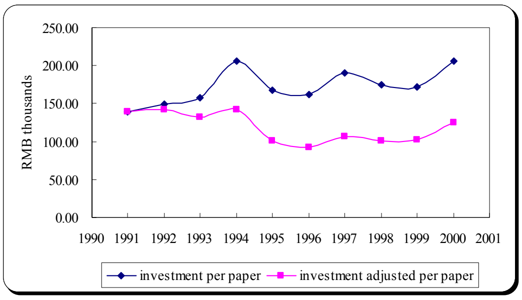

Fig 4 The average investment per paper.

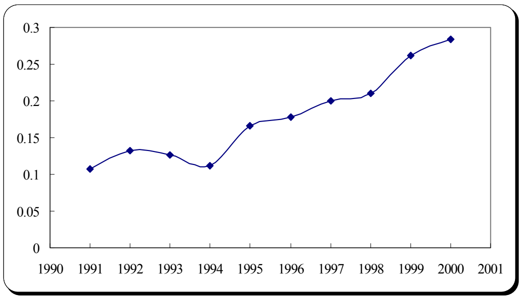

Fig 5 The average SCI publications per research staff

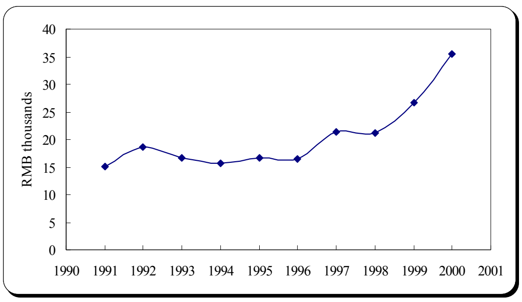

Fig 6 The average adjusted investment per research staff

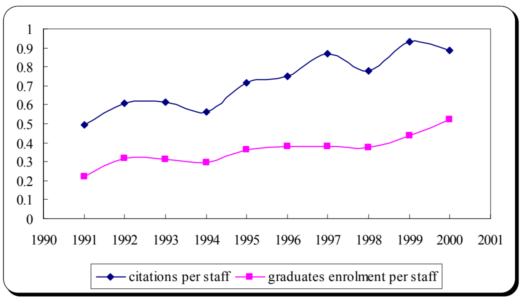

Fig 7 The average citations and graduates enrolment per research staff

In general, research staff and investment are the two main input factors of basic research. Therefore, we can consider research staff and investment as the main

Fig 4.3 The average adjusted investment per research staff explanatory variables of outputs of basic research.

Let Y represent explained variable SCI publications, X_1 and X_2 represent respectively research staff and investments, where the investments are adjusted by the retail price index. We here adopt the standard Cobb-Douglas production function, and thus use the logarithmic linear model. The following equation can be obtained by using ordinary least square regressive analysis:

$$\ln(Y)=0.0307+0.7697\ln(X_1)+0.9397\ln(X_2) \quad (1)$$

$$(0.9017) \qquad (3.5015)$$

$$R^2 = 0.8712, \quad F = 23.6740, \quad DW = 1.5318$$

where the numbers in the brackets are the t-statistic of the estimated coefficients.

The above result indicates that the explanatory variable $\ln(X_1)$ is not significantly different from zero at the 10% level.

The possible reason of yielding the above results is the multicollinearity of X_1 and X_2 (or $\ln(X_1)$ and $\ln(X_2)$). The impact of X_1 on Y or $\ln(X_1)$ on $\ln(Y)$ is partly substituted by X_2 or $\ln(X_2)$.

Because the correlation between (X_2/X_1) and X_1 is much weaker than the correlation between X_2 and X_1 for our data, we choose X_2/X_1 (investment per staff) and X_1 (research staff) as explanatory variables of the dependent variable Y in order to avoid multicollinearity. The logarithmic linear equation we obtain is as follows.

$$\ln(Y)=0.0307 + 0.9397\ln(X_2/X_1) + 1.7094\ln(X_1) \quad (2)$$

$$(3.5015) \qquad (2.5763)$$

$$R^2 = 0.8712, \quad F = 23.6740, \quad DW = 1.5318$$

Here the coefficients of the two explanatory variables are significantly different from zero at the 5% significance level.

Changing equation (2) back to the form of Cobb-Douglas production function ($Y=AX_1^{\alpha}X_2^{\beta}$), we obtain the following equation:

$$Y=1.0312\, X_1^{0.7697}\, X_2^{0.9397} \quad (3)$$

In terms of equation (3), we can find $\alpha + \beta = 0.7697+0.9397 = 1.7094>1$. This indicates that Chinese basic research is in the condition of increasing return to scale. Moreover, $\beta>\alpha$, that is elasticity of investment to output of basic research is greater than the elasticity of staff to output. Meanwhile, we can work out in the considered period that the contribution of increased investment to increasing output of basic research is greater than the contribution of increased staff to increasing output of basic research.

If the dependent variable is the Total SCI publications (which then include the papers with non-Chinese first authors) and the explanatory variables are still investment per staff (X_2/X_1) as well as research staff X_1, the logarithmic linear equation we obtain is as follows:

$$\ln(Y)=0.0753 + 1.0778\ln(X_2/X_1) + 1.6718\ln(X_1) \quad (4)$$

$$(4.3715) \qquad (2.7427)$$

$$R^2 = 0.9032, \quad F = 32.6660, \quad DW = 1.6072$$

Reverting equation (4) to the form of Cobb-Douglas production function, we obtain

$$Y=1.0312\, X_1^{0.5940} X_2^{1.0778} \quad (5)$$

As in equation (3), the elasticity of investment to output of basic research in equation (5) is significantly greater than the elasticity of staff to output. The contribution of investment to increasing output of basic research is also greater than the contribution of staff.

From the above analysis, we can see that increased investment is the more important factor for increasing output of Chinese basic research than increased research staff in the considered period.

The further question appears as what is the aggregate trend of productivity of basic research changed in China in last decade. It follows from the above analysis that although many efficiency indexes like the average SCI publications per staff and average citation numbers per staff have increased substantially, some cost indexes like the average investments per postgraduate have also increased, while the average investment per paper remained more or less the same during the period. It is then important to draw some assessments on the overall efficiency of basic research in last decade.

4. Aggregated Efficiency Analysis

How to evaluate research activities with fairness and effectiveness is a key research project for science policy makers. Peer Review has been adopted as a main method to evaluate research performance in many countries. However, pure Peer Review has been criticized for its fairness and openness, and it is hard to estimate the efficiency. Modified Peer Review becomes common in recent years, while quantitative measurement and qualitative assessment are combined. Bibliometric approach is one of quantitative method to evaluate the academic performance based on publications (Herbertz and Muller-hill 1995, Mode 2000, Bhattacharya *et al.* 2000). However research activities are multi-objectives by nature. The research outputs normally not only include publications, but also educated postgraduates, excellent scientists, and patents *etc*. Therefore, multi-indictors need to be selected if an overall evaluation of research activities is required. In evaluation literature, comprehensive analysis was used to assess overall effects of the multi-indicators by weighting all the indicators and then sum them up to produce total scores for ranking. However it is well-known that how to decide proper weights to these indicators in public sectors remains to be a main source of controversy for the evaluation outcomes, especially when these indicators belong to completely different catalogues.

DEA is one popular econometric method that utilises mathematical techniques, such as linear programming, that can handle many variables and relations (constraints) to evaluate the relative efficiency of homogenous Decision Making Units (DMUs). One of unique features of the DEA approach is that, it is a non-parametric method which can handle multiple inputs and multiple outputs simultaneously, and does not require weight data, which is obviously difficult to obtain in public sectors. DEA focuses on identifying relative best-practice frontier rather than on central-tendency properties. Thus it can measure the potential capability for inefficient DMU to improve efficiency. Therefore, since the first paper was published in European Journal of Operational Research in 1978 (Charnes *et al.* 978), the DEA approach has been adopted as an attractive tool to evaluate efficiency of research and education institutions. A simple classification of the current publications which focus on assessing the education or research performance by using DEA approach is as follows:

1) Evaluation of school efficiency (e.g. Färe *et al.* 1989, Grosskopf *et al.* 1999, Bifulco and Bretschnerder 2001, Portela and Thanassoulis 2001).

2) Performance assessment of universities' departments (e.g. Thanassoulis et al. 1987, Jill and Geraint 1995, Jill 1996, Doyle *et al.* (1996).

3) Performance measurement of universities (e.g. Al-Naji *et al.* 1998, Sarrico and Dyson 1998, Avkiran 2001, Abbott and Doucouliagos 2002).

The first DEA model was introduced as an efficiency ratio and presented by Charnes, Cooper and Rhodes in 1978 (Charnes *et al.* 1978). Let us assume that we have n DMUs using m inputs to produce s outputs. Let x_{ij} and y_{ij} be the level of the i^{th} input and r^{th} outputs to DMU$_j$ (j=1,.2,3,…,n),

$$\max: \quad h_0 = \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}}$$

$$\text{subject to}: \quad \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1, \quad j = 1,2,\ldots,n \tag{1}$$

$$u_r \ge 0, \qquad r = 1,2,\ldots,s$$

$$v_i \ge 0, \qquad i = 1,2,\ldots,m$$

The technical output efficiency of DMU*j_0* is the optimal value h_0 in Model.

The objective is to obtain weights (v_i) and (u_r) that maximize the ratio of the DMU*j_0*. The constraints mean that the ratio of "virtual output" vs. "virtual inputs" should not exceed 1 for each DMU. Thus the idea is that given the most favourable conditions for DMU*j_0*, find out what is the best performance it can achieve. If the ratio is 1 and there is at least one optimal weight with non-zero components, this DMU is efficient, otherwise not.

It is important to point out the weights are decided given most favourable conditions to the DMUs. Thus if a DMU is inefficient, then it can hardly argue possible bias of weight selection in evaluation. In practical applications, the CCR model, which is the dual model of the above ratio one, is among the most widely used:

$$\text{Min} \quad \theta$$

$$\text{Subject to}: \quad \theta x_{i0} \ge \sum_{j=1}^{n} x_{ij}\lambda_j$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j \ge y_{r0} \tag{2}$$

$$\lambda_j \ge 0, i = 1,\ldots m, r = 1,\ldots s, j = 1,\ldots n$$

From the dual model one thing is clear that the radial measurement is used to measure changes in inputs or outputs in the standard DEA model. Consequently the radial proportional reduction of inputs or extension of outputs is considered to be dominated in this model. This is indeed true in many economics systems. However this hypothesis is questionable in studies of input-output relationship in scientific research. It is apparent from our data that the ratios of change in investment and staff are very different during the years. Therefore, the Enhance Russell Measurement (ERM) DEA model was proposed. Färe and Lovell (1978) introduced a non-radial measurement which allowed non-proportional reduction of inputs or extension of outputs. Model (3) presents a input-oriented ERM DEA model.

$$
\begin{aligned}
\min \quad & \frac{1}{m}\sum_{i=1}^{m}\theta_i \\
\text{Subject to}: \quad & \sum_{j=1}^{n}\lambda_j x_{ij} \le \theta_i x_{i0} \\
& \sum_{j=1}^{n}\lambda_j y_{ij} \ge y_{r0} \\
& \theta_i \le 1 \\
& \lambda_j \ge 0,\ i=1,2,...,m,\ r=1,2,...,s,\ j=1,2,...,,n
\end{aligned}
\tag{3}
$$

In principle, one can then apply the above DEA models to the data set in Table 1, by regarding each year as a DMU to be evaluated. However it was found that these standard DEA models are not discriminative enough in the sense that most of the DMUs (years) will be ranked as efficient if these models are applied directly with the full set of inputs (A, B) and outputs (C, E, F). In DEA literature this is not unusual and often indicates that there may be not enough DMUs for the used DEA models.

It is apparent from our data that while each component of the outputs has being increased, the components of inputs can be decreased or increased. This indicates that there may exist compensations between the components of inputs. For such a case we apply the following DEA model, as Model (4) presented, which allows compensations between the two components of the inputs. Model (5) presents output-oriented. Similar models were studied in (Zhu 1996) to study economical development for cities in China. For more explanations of these models, see (Liu, Wu and Sharp, 2004).

$$
\begin{aligned}
\min \quad & \frac{1}{m}\sum_{i=1}^{m}\theta_i \\
\text{Subject to}: \quad & \sum_{j=1}^{n}\lambda_j x_{ij} \le \theta_i x_{i0} \\
& \sum_{j=1}^{n}\lambda_j y_{ij} \ge y_{r0} \\
& \theta_i \ge 0 \\
& \lambda_j \ge 0, i=1,...,m, r=1,...,s,\ j=0,...,n
\end{aligned}
\tag{4}
$$

$$
\begin{aligned}
\max \quad & \frac{1}{s}\sum_{r=1}^{s}\vartheta_r \\
\text{Subject to}: \quad & \sum_{j=1}^{n}\lambda_j x_{ij} = \alpha_i x_{i0} \\
& \sum_{j=1}^{n}\lambda_j y_{ij} \ge \vartheta_r y_{r0} \\
& \theta_r \ge 1 \\
& \sum_{i=1}^{s}\alpha_i \le m \\
& \lambda_j \ge 0, i=1,...,m, r=1,...,s,\ j=0,...,n
\end{aligned}
\tag{5}
$$

In the above DEA models, it is impossible to rank the efficient DMUs as their efficiency scores are the unit. To this end, we follow an idea used in (Zhu 1998) to remove the constraint for DMU_0, as presented in Model (6):

$$
\begin{aligned}
\min \quad & \frac{1}{m}\sum_{i=1}^{m}\theta_i \\
\text{Subject to}: \quad & \sum_{j=1, j\neq 0}^{n} \lambda_j x_{ij} \le \theta_i x_{i0} \\
& \sum_{j=1, j\neq 0}^{n} \lambda_j y_{ij} \ge y_{r0} \\
& \theta_i \ge 0 \\
& \lambda_j \ge 0, i = 1,\dots,m, r = 1,\dots,s, j = 0,\dots,n
\end{aligned}
\qquad (6)
$$

In this model, the efficiency scores for the efficient DMUs may be greater than one.

4.1. Overall efficiency of the basic research performance

In this section we apply the DEA Models (4)-(6) to the data in Table 1. We regard each year as a DMU to be evaluated. In order to give an overall evaluation of productivity of basic research, here we choose SCI publications, total citations, and postgraduate enrolments of science as three outputs to reflect the quantity, quality and education output of basic research. The number of basic-research staff and adjusted investment on basic research are the two inputs, as Table 1 shown. In the follows, Table 2 presents results from Models (4)-(6).

Table 2

Year	Model (4) efficiency score	Model (5) efficiency score	Model (6) efficiency score
1991	0.6896	0.6427	0.6896
1992	0.7955	0.7445	0.7955
1993	0.8185	0.7756	0.8185
1994	0.8030	0.7264	0.8030
1995	0.9526	0.9422	0.9526
1996	1.0000	1.0000	1.0578
1997	1.0000	1.0000	1.0284
1998	0.9409	0.9378	0.9409
1999	1.0000	1.0000	1.1042
2000	1.0000	1.0000	1.0317

* Lingo 8.0 has been used as only software on related calculations.

It can be seen from the results calculated by Models (4)-(5) that there were significant improvements on overall efficiency from 0.6869 in 1991 to 0.9526 in 1996. Then this trend has noticeably slowed down since 1996, and this is probably due to the sharp increment of investment per staff since 1997, see Figure 6, which might not be best utilised during this period. There were four efficient units as year 1996, 1997, 1999 and 2000. Year 1996 and 1997 became efficient as there was not possible to find virtual combination which could use less inputs to produce same outputs, as their peer were year 1996, year 1997 respectively. It is also clear that year 1999 was efficient for its highest total citations, while year 2000 became efficient due to its highest SCI publications and graduates enrolment. Comparing the results between Model (4) and Model (5), they had almost the same ranking and efficient DMUs. The efficiency scores of inefficient DMUs were slightly different because of the different orientations of the models. The efficiency score in 1998 was 0.9409 on Model (4). The peers of year 1998 on Model (4) were 1996 and 1999 with λ_6=0.3053, λ_9=0.6453, and its efficiency score calculated by $\frac{1}{2}(\theta_1+\theta_2)$ while θ_1=0.8931947, θ_2=0.9887016. It implied that the number of research staff should be reduced from 78.7 thousands to 70.29 thousands of year 1998 comparing with year 1996 and 1999, as 70.29=0.3053364×69.6+0.6453027×76. The adjusted investments should be moved down to RMB1652 billions, while original investments was RMB1670.88 billions. Generally, the number of research staff and the adjusted investments of year 1998 should be reduced in order to be efficient comparing with its peer. Similar results analysis with Model (5) is omitted here.

The four efficient units 1996, 1997, 1999 and 2000 were further assessed by Model (6). The results were also shown in Table 2, the best performed year was 1999, then 1996. This confirms our initial conclusion that there is still much space to improve the country's efficiency in utilising its resources invested in basic research. We could have further considered delay effects in the above analysis should more data had been available.

5. Conclusions

Evaristo *et al.* [2003] presented that a valid research evaluation could provide power of stimulus, which could stimulate and increase the research outputs, as well as the stimulation of research investment. In China, the government also recognises the importance of the management and assessment of the research performance. A preliminary evaluation of research performance has been carried out. For example, the NSFC was founded in 1986 to manage national funds into research, the National Centre for Science and Technology Evaluation was founded in 1997 to assist the MOST to manage and evaluate national projects *etc*. However, how to create an open and valid assessment system to allocate and operate limited resources efficiently, to stimulate scientist to aim at the scientific research frontier is still the key question of science policy.

This paper presents a preliminary quantitative analysis on the productivity of basic research in Chin, where statistical and econometric methods are adopted to give some initial assessments of productivity of basic research from 1991 to 2000. The three outputs, SCI publications, number of citations and number of postgraduate enrolments are selected to reflect three main perspectives of research outputs as quantity, quality and education of research outputs. Our preliminary statistical analysis shows that the rapid increase of investment was the main power to stimulate the research outputs. Our analysis on aggregate productivity via DEA suggests that there were significant improvements on overall efficiency from 1991 to 1996, although this trend has noticeably slowed down since 1996.

These studies seem to suggest that increments on research staff and research investment need to be compatible to improve overall productivity of basic research in China. Further studies and closer scrutinise on how to utilise the ever increased investment should be taken. Also research quality should be further emphasized. From this view, we can see that there is still large space to enhance the efficiency and effectiveness of the research performance from the management and assessment aspect in China. Hopefully this paper can provide some useful and helpful insides for the current state of basic research in China, and thus contribute to establishment of open and valid assessment systems of scientific research in China. Meanwhile, research activities are very complicated and multi-objectives, and can be influenced by many "soft" circumstances, such as academic environments, the policies on scientists etc. However addressing them is beyond the scope of this paper.

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