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A DYNAMIC SHIFT-SHARE ANALYSIS ON THE CHINA'S R&D: A STRUCTURE ANALYSIS

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Abstract

To evaluate the R&D development in China, we can inspect both the R&D expenditure and the research talent pool. In this paper, we analyze the structure of the researcher groups by using dynamic shift-share analysis (DSSA). The DSSA results show that there is still much room to improve in the structure of research group. The provinces/municipalities from eastern China did not perform well in engineering and education researcher groups while the provinces/municipalities from central and western China perform well in engineering, agriculture and education researcher groups. We suggest that the government planners should implement more effective measures to improve the structure of the researcher groups in order to spend the R&D fund wisely and attract more extra fund in R&D.

Keywords: R&D; Chinese economy; Dynamic shift-share analysis (DSSA).

Introduction

Underpinned by economic reforms and the "open door" policy, China has made remarkable progress in economic growth and it has grown tenfold in the past three decades. In the cycle of economic growth after 2000, China has been the power engines of the world economy. In 2007, the economy turned in another spectacular performance with gross domestic product (GDP) growing at the fastest clip in the past 13 years and the fifth year in a row in which GDP has expanded by more than 10 percent (Statistical Yearbook of China, 2008). A revision of the GDP figure by the National Bureau of Statistics of China in January 2009 further reviewed that China has leapfrogged Germany to become the world's third-largest economy, with an annual GDP of 3.5 trillion U.S. dollar, only behind the U.S. and Japan. It is believed that it only takes three or four years for China to surpass Japan (4.4 trillion GDP) to become the world's number two economy. Although the GDP growth rate of China has cooled to its slowest pace to 9.1 percent in 2008, which was affected by the global financial turmoil, the economic data released in the past few months has showed various evidences of recovery [1] as domestic strength helps to offset external weakness. It is widely believed that China can achieve its growth target of 8 percent in 2009.

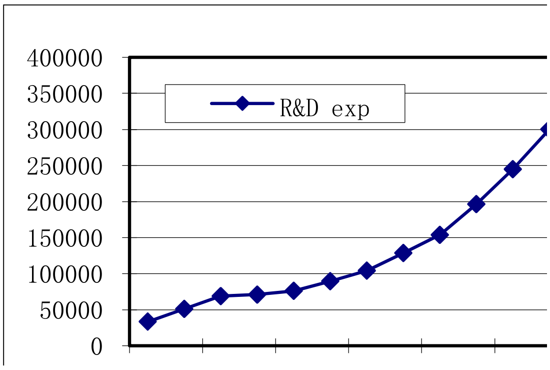
Owning to the high and inefficient consumption of energy and raw materials, environmental degeneration and low technology intensity of the current growth pattern of the Chinese economy, the Chinese government is facing the challenge of making the transition from sustained to sustainable growth from social, economic and ecological and environmental point of view. In order to sustain the excellent performance of economic growth and transform China into an innovation-oriented nation on the basis of the development of a national innovation system with strong innovation capacity, the Chinese State Council has identified research and development (R&D) as a driving force for the progress of society. It is seen as a source and backbone of sustainable economic growth, as well as a precursor to major technology breakthrough and industrial advancement. The National Guidelines for Medium- and Long-term Plans for Science and Technology Development (2006-2020) released by the Chinese State Council set a target to raise the weight of China's R&D expenditure in GDP to 2 percent by 2010 and to 2.5 percent or more by 2020, with an science and technology advancement contribution rate reaching 60 percent, and a reduced dependency on foreign technology by at least 30 percent. The ambitious R&D expenditure target implies that R&D expenditure have to increase at a rate by at least 10 to 15 percent annually.

The R&D in China can be analyzed in two aspects: R&D spending and the scientific and technology workforce. To achieve the ambitious target on R&D, R&D expenditure has been growing rapidly at a staggering average annual rate of 22 percent since 1995 (Figure 1). In particular, this growth rate has remained at least 23 percent since 2004. According to the Statistical Yearbook of China 2008, the total national expenditure on R&D in 2007 continued to grow and reached 371.02 billion yuan (49.33 billion U.S. dollar), up by 23.5 percent. In

[1] The signs of recovery include normalization in credit growth, fixed investment and real sales growth, and raw materials demand rebound.

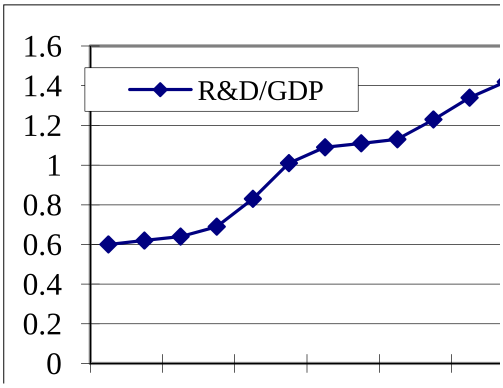
terms of different regions, 12 provinces[2] and municipalities have spent more than 10 billion yuan on R&D and the total expenditure on R&D by these 12 provinces is 299.46 billion yuan (39.82 billion U.S. dollar), which accounts for nearly 81 percent of the total national expenditures on R&D.

Figure 1. Total R&D Expenditure of China (Million yuan)



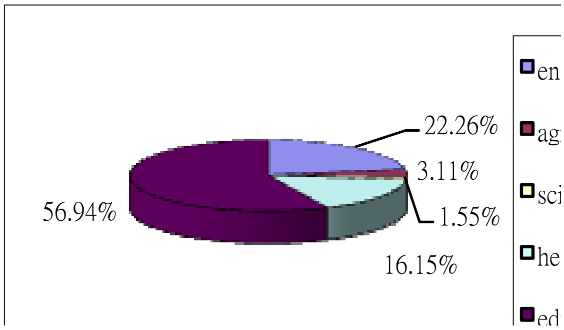
In terms of R&D intensity or R&D spending as a percentage of GDP, it rose from 0.6 percent in 1995 to 1.49 percent in 2007 (Figure 2), with an average annual growth rate of 8.3 percent. Similar to R&D spending, the R&D intensity has been rising rapidly in the last four years. It is clear from both the absolute and relative terms that expenditure on R&D in China is stunning, which makes China one of the influential global R&D players, ranked third in the world, only behind the United States and Japan in terms of total R&D spending[3].

Figure 2. R&D Spending as a Percentage of GDP



Another important aspect to reflect the R&D development in China is the number of researchers. A strong domestic talent pool is vital to successfully achieve the goal on R&D set by the Chinese State Council. From 1995 to 2007, the number of researchers has increased by 267 percent in China, with an average growth rate of 8.3 percent. In 2007, there were 1.74 million research personnel, ranked the second in the world. It jumped 0.23 million as compared with the previous year, up by 15.6 percent. By the classification of the Statistical Year Book of China, the science and technology researchers are divided into five groups: engineering, agriculture, scientific, health care and education. For a closer look of the distribution of the five groups, see Figure 3.

Figure 3. The Distribution of the Five Groups of Researchers in 2007



As we stated earlier in this section, to achieve the goal of R&D development it is implied that the R&D expenditure should increase at a rate of 10 to 15 percent annually, which is a very challenging task. Thus, it is advisable to analyze how to maximize the current resource on R&D by optimizing the structure of the pool of R&D personnel. In this paper, we focus on the second aspect of R&D development, the human resource pool. We are interested in analyzing the regional pattern of the distribution of R&D personnel from the perspective of the efficiency of the national talent pool. To address this research purpose, we use dynamic shift-share analysis (DSSA) to study whether the current distribution of the five groups of researchers is optimal in provincial level. Based on our analysis, we will provide suggestions to those provinces or municipalities on how to optimize the distribution of researchers.

The Chinese government is facing the challenge of making the transition from sustained to sustainable growth. To maintain its rapid growth rate, it is vital to increase the competitiveness of R&D which may provide extra sources of growth. One important issue to increase the competitiveness of R&D in China is to optimize the structure of R&D. DSSA is an ideal method to provide suggestions on the optimization. DSSA will allow us to find the relative competitiveness of each province/municipality for the five groups of researchers in our analysis. Moreover, the analysis of the components of the DSSA equations enables us to find out the sources behind the competitive advantage or disadvantage a particular province/municipality has gained in a particular researcher group. Based on the statistical results from DSSA, we are able to give useful

[2] The 12 provinces and municipalities are: Beijing, Jiangsu, Guangdong, Shandong, Shanghai, Zhejiang, Liaoning, Sichuan, Shaanxi, Tianjin, Hubei and Henan.

[3] For details, please refer to Science, Technology and Industry Outlook, released by OECD.

suggestions on which research group a particular province/municipality should invest more and on which one it can spend less. These structure optimization suggestions are able to help policymakers to achieve the growth target of R&D not only by purely investing more money but also by allocating the limited resources more efficiently.

The paper is organized as follows. Section 1 is an introduction. Section 2 reviews the literature on shift-share analysis and the empirical applications in the competitive advantage analysis using both static and dynamic shift-share analysis in some of the sectors in tertiary industry. Section 3 discusses data and model specifications. Section 4 presents our empirical findings on the issues raised in the introduction. Section 5 contains the concluding remarks and policy suggestions. Topics for future study are also proposed.

Literature Review

The method DSSA we employed in this paper is an improvement from the well-known shift-share analysis proposed by Dunn (1960) and Perloff, et al. (1960). Shift-share analysis has been widely used in empirical analysis because of its obvious advantages over the traditional absolute or percentage value methods. For example ,shift share analysis offer a new perspective to assess the economic performance and provides important descriptive data on structural change for policy makers by analyzing the structural change over time in the competitive position of one or more aspects of a region or a country's economy Moreover, shift-share analysis overcome the disadvantages of traditional absolute or percentage value methods by avoiding the mistake of overrating the importance of large income sources happened in absolute value method and the overrating of small ones happened in percentage value method. Shift-share analysis offers a good complement to those absolute and percentage methods. Empirical studies showed that Shift-share analysis has been recognized as an efficient method to assess and, to some degree, predict regional development and growth (Ashby, 1968; Chalmers and Bechelm, 1976; Dunn, 1980; Andrikopoulos, et al., 1987; and Keil, 1992).

Early application of shift-share analysis has focused mainly on regional economies and political economies. In the early 1990s, shift-share analysis was employed to analyze external trade in aspect of the export of goods at the sub-national level. Markusen, et al. (1991) used the shift-share method and estimated the share of employment growth for export and import penetration in nine US regions. Hayward and Erickson (1995) extended and applied the model to the North American Free Trade Area. Gazel and Schwer (1998) studied the growth of international exports of US states by focusing on demand conditions. Except for those trade related studies, in 1990's, Shift-share analysis has also been employed in several studies analyzing the competitiveness among the East Asia countries (Herschede, 1991; Khalifah, 1996; Voon, 1998; and MAS, 1998a, b).

Because of the availability of longer time-series data, in recent studies, DSSA was more frequently used to analyze the competitiveness related issues. Sirakaya (2002) compared one form of dynamic shift-share techniques with the traditional static techniques using tourism employment data from the US state of Texas, and found that dynamic shift-share was superior to the static shift-share analysis in identifying the whole evolution of structural change. Nazara and Hewings (2004) proposed a dynamic shift-share model that was later applied by Shi et al. (2007) to examine the performance of the travel industry in China's Jiangsu province.

Although shift-share analysis has been applied to study the competitiveness in different industries, it has rarely been used to analyze R&D, especially regional R&D. According to our knowledge, there is no empirical study on R&D in China using the DSSA method. The dynamic shift-share model used in this paper is a modification of the model proposed by Sirakaya (2002) and Nazara and Hewings (2004), and similar to that of MAS (2002) which used the dynamic shift-share technique to analyze the electronic export competitiveness of Singapore against five other East Asian economies (Malaysia, Taiwan, South Korea, Hong Kong and China).

The advantage of our model over those used by Sirakaya (2002) and Nazara and Hewings (2004) is that the differences in the performances of different provinces are accounted for by four components of Net Shift: the industry mix effect (IME), the competitive effect (CE), and the interactive effect (IE). We are not only able to identify whether a particular research group is a promising one, whether a particular province is gaining any competitiveness, but also study the interaction of these two effects. A comparison of the analytical results by analyzing the above three components enables us to optimize the structure of the R&D pool and allow the policymakers to make more wise investment decisions. A detailed description of the model is given in the next section.

Data and Method

Data Selection

In this paper, we use DSSA to investigate the structural composition of the five R&D researcher groups among the provinces/municipalities in China. The analytical results enable us to know whether a particular province/municipality is focusing correctly on the researcher groups on which it has competitive advantage. Moreover, by analyzing the decompositions of the Net shift, we are able to trace the sources behind the advantage this province/municipality has gained. According to the Statistical Yearbook of China, the science and technology personnel are generally grouped into five categories: engineering, agriculture, scientific, health care and education. We collect continuous time series data on provincial level data for these five groups of science and technology persons for 30 provinces/municipalities[4], which provide us a full picture of the relative competitiveness of each province/municipality in mainland China. The data used in this study are the annual provincial numbers of researchers in the five researcher groups. All the data for this study are collected from the China Statistical Yearbook, various issues. The time span of the data is from 1996 to 2007.[5]

Method Description

The method we employ in this study is DSSA, which is a dynamic version of the traditional shift-share analysis. The reason that DSSA is preferred over the shift-share analysis is that the shift-share analysis is generally a comparative static method. This comparative static method has obvious shortcomings as indicated by Barff and Knight (1988): this comparative static approach mainly focuses on the changes between the beginning and the terminal years. To calculate the decomposed effects, either an average of the sector mix effect over the sample period or just the value at the beginning of the period is used. This is an obvious disadvantage because it neglects the dynamic changes during the sample period, which may be of great interest to the empirical researchers or government planners. In Barff and Knight (1988), they use an export dataset as an example. They argued that if a country's exports grow faster than those of the reference group, the comparative static approach will assign too little of the export growth to the "share effect"; and vice versa if the growth of a country's total exports is lower than that of the reference group. Therefore they proposed a dynamic shift-share analysis (DSSA) technique which calculates the IME, CE and IE on an annual basis and then sum up the results over the study period.

We consider DSSA in this study as a measure of the gain or loss in a particular researcher group of a particular province/municipality in relation to a group of reference provinces or municipalities based on the model used in Wilson (2002) and Ha, Fan and Chang (2003),. By definition, any difference between the performance of a particular province/municipality in a particular researcher group and that of the reference economies as a whole is referred to as the shift effect in that researcher group. The resulting net shift can be decomposed into three effects: IME, CE and IE. The composition of the models is as the following:

$$(X_t^j - X_{t-1}^j) - X_{t-1}^j \bullet \sum_i \left(\frac{\hat{X}_{t-1}^{ij}}{\hat{X}_{t-1}^j}\right) \bullet \left(\frac{\hat{X}_t^{ij}}{\hat{X}_{t-1}^{ij}} - 1\right) = \quad (1)$$

$$+X_{t-1}^j \bullet \sum_i \left(\frac{X_{t-1}^{ij}}{X_{t-1}^j} - \frac{\hat{X}_{t-1}^{ij}}{\hat{X}_{t-1}^j}\right) \bullet \left(\frac{\hat{X}_t^{ij}}{\hat{X}_{t-1}^{ij}} - 1\right) \quad (2)$$

$$+X_{t-1}^j \bullet \sum_i \left(\frac{\hat{X}_{t-1}^{ij}}{\hat{X}_{t-1}^j}\right) \bullet \left(\frac{X_t^{ij}}{X_{t-1}^{ij}} - \frac{\hat{X}_t^{ij}}{\hat{X}_{t-1}^{ij}}\right) \quad (3)$$

$$+X_{t-1}^j \bullet \sum_i \left(\frac{X_{t-1}^{ij}}{X_{t-1}^j} - \frac{\hat{X}_{t-1}^{ij}}{\hat{X}_{t-1}^j}\right) \bullet \left(\frac{X_t^{ij}}{X_{t-1}^{ij}} - \frac{\hat{X}_t^{ij}}{\hat{X}_{t-1}^{ij}}\right) \quad (4)$$

where the terms (1) to (4) are the net shift, industry mix effect (IME), competitive effect (CE) and interaction effect (IE), respectively.

The advantages of the DSSA used in this study has the following advantages: firstly, dynamic shift-share analysis allows the industry mix effect and the growth rate to vary over time, which results in the appropriate "share effect" assigned for each period which reflects accurately the structural change in industry over time. Secondly, the structure breaks and obvious trends are now easier to be identified as DSSA tracks the whole evolution of the sample period. Lastly, exceptional years or measurement errors are more easily detected with the dynamic shift-share analysis than with the traditional shift-share method which only uses the beginning and terminal years of the sample data (MAS. 2002). We will explain the three components of DSSA in the remaining section of this paper.

We first discuss the industry mix effect. By definition, industry mix effect measure the share of difference in net shifts attributes to the difference in structure composition between a particular province/municipality and the reference group as a whole. In our study, industry mix effect measures the difference between the share of a particular researcher group in a competing province/municipality and that of the reference group as a whole. If the share of a sunrise research group (defined as a research group with positive growth

[4] The 30 provinces and municipalities in our sample are: Beijing, Tianjin, Hebei, Shanxi, Neimeng, Liaoning, Jilin, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang.

[5] This is the longest time series we are able to find because, not like the commonly used data such as GDP, the classifications for the R&D researchers are not consistent in the past issues of China Statistical Yearbook.

rate of numbers of researchers in the reference group) is higher in a particular province/municipality than that of the reference group or conversely if the share of a sunset research group (defined as a research group with negative growth rate of numbers of researchers in the reference group) is lower in a particular province/municipality than that of the reference group, this competing province/municipality would gain positive IME. A similar logic defines a negative industry mix effect.

The competitive effect identifies the difference in net shifts due to the difference in the growth rate of the number of researchers between a particular province/municipality and that of the reference group as a whole. In other words, the competitive effect reflects the contribution to the difference in net shift due to a deviation from the average growth rate of a particular researcher group in a particular province/municipality during our sample period. For our case, if the growth rate of the number of researchers of a particular province/municipality in a particular researcher group is higher than that of the group level, we say that this particular province/municipality has positive CE. Moreover, we call a particular province/municipality gaining 'competitive advantage' if it has positive CE. In other words, the province/municipality being considered outperforms the reference economy as a whole in that particular researcher group. However, if the growth rate of the number of researchers of a province/municipality in a particular researcher group is lower than that of the reference group, it will result in a loss of competitiveness in that researcher group for that particular province/municipality.

The last component of net shifts is the interactive effect, which is a comprehensive effect that incorporates both the effect of structure change and the issue of competitiveness. The interactive effect reflects the difference in net shift attributable to the interaction between structure composition and competitiveness. For our case, there are two ways that a province/municipality can gain a positive interactive effect. Firstly, in a particular sunrise researcher group if the share of that researcher group is higher than that of the reference group as a whole at the same time when it also gains competitive advantage in that research group. Alternatively, a particular researcher group can also obtain positive IE if a province/municipality has smaller shares in a sunset research group than the average level of the reference economy, and that province/municipality is also losing competitive advantage in that researcher group, then the particular province/municipality Conversely, a province/municipality will gain a negative interactive effect if it focuses on a researcher group where it is losing competitiveness or it is not specialized in a researcher group in which it is gaining competitive advantage.

According to our knowledge, there is no research on R&D in China using DSSA. Our research tries to fill this gap by using DSSA to analyze the researcher groups at the provincial level. One of the reasons why DSSA was not widely used was probably that time series data were not available for dynamic analysis. This kind of data is now easier to obtain from various sources, and therefore we are able to employ the DSSA method to analyze the composition of the researcher groups in R&D.

Estimation Results

In this section, we first present the summary statistics on the scientific and technical personnel which may give some overall impression on the distribution of these research personnel in China. Secondly, we analyze the DSSA results for the five researcher groups. For each of the researcher group, we compare the results of net shift, IME, CE and IE, which show the composition of net shift. We then analyze the breakdown of the net shifts, IME, CE and IE to trace the source behind the competitive advantage or disadvantage one particular province/municipality has gained. Lastly, we compare the DSSA results of the 12 provinces/municipalities which accounts for about 80 per cent of the total R&D expenditure of China. From the analysis of the above three steps, we are able to find out whether the research personnel is properly distributed in province level in China and offers suggestions on which research group a particular province/municipality should allocate more resource.

Summary Statistics on the Research Personnel

Figure 3 shows the shares of each of the researcher group in total number of researchers. Nearly 60 percent of the researchers in China are in education related institutions or enterprises, followed by engineering (22 percent) and health care (16 percent). There are only 3 percent and 2 percent of the researchers in agriculture and science related institutions or enterprises, respectively. Figure 3 indicates that most of the research talents are still in education related institutions or enterprises and to transfer the technologies from the lab to the marketplace, it is important to forge links between the public and private sectors. We can see the distribution of researchers among the provinces/municipalities from Table 1. There are four provinces, Shandong, Henan, Guangdong, Hubei, which have more than 1 million researchers, while the province with the lowest number of researchers, Xizang, only have 42.4 thousands researchers. In Beijing and Shanghai, two of the most important cities in China, there are only about 340 thousands researchers. Note that we stated earlier in this paper that Beijing and Shanghai are among the 12 provinces/municipalities which spent most on R&D. The statistics in this section indicates that there is high R&D per researcher in these two cities. One interesting fact is that regional difference[6] is not obvious in the amount of researchers, which is different from other economic indicators like GDP or tertiary industry output. Among the top ten and bottom ten provinces/municipalities, there are provinces/municipalities from western, middle and eastern China.

Table 1. The rankings of total number of researchers in 2007

Rank	Region	Number	Rank	Region	Number
1	Shandong	1494182	16	Shaanxi	619805
2	Henan	1263425	17	Jiangxi	618036
3	Guangdong	1234792	18	Jilin	558105
4	Hebei	1004636	19	Guizhou	525180
5	Sicuan	999505	20	Fujian	519534
6	Jiangsu	998178	21	Neimeng	486148
7	Hunan	905426	22	Gansu	433827
8	Hubei	804191	23	Xinjiang	411099
9	Guangxi	745589	24	Beijing	340120
10	Liaoning	715461	25	Shanghai	337699
11	Anhui	711492	26	Tianjin	247584
12	Zhejiang	688800	27	Hainan	124419
13	Shaanxi	687679	28	Ningxia	117468
14	Heilongjiang	678135	29	Qinghai	102388
15	Yunnan	659890	30	Xizang	42402

DSSA results for engineering

Engineering is the second largest researcher group in China, accounting for 22 percent of the total research persons, only behind education. Table 2 shows the rankings of cumulative net shifts of engineering for the sample provinces/municipalities from 1998 to 2007. Twenty out of the thirty sample provinces/municipalities have positive cumulative net shifts. For the top ten provinces/municipalities, five of them are from western China, three of them from central China and only two of them from eastern China. In contrast, six of the bottom ten provinces/municipalities are from eastern China. The poor performance of the provinces/municipalities in eastern China is reflected in Figure 4, which shows the cumulative net shifts of the three regions. To see why the rankings of the provinces/municipalities from eastern China, the relatively rich region, are relatively low, we further look at the cumulative IME, CE and IE, which are showed in Tables 3 to 5. Table 3 presents the rankings of cumulative IME of engineering. Eighteen of the thirty provinces/municipalities gained positive cumulative IME. We find that only three of the top ten provinces/municipalities are from eastern China while five of the bottom ten provinces/municipalities are from this region. Similar results can be found in Table 4, which shows the cumulative CE of engineering. There are nineteen provinces/municipalities with positive cumulative CE. Among the top ten provinces/municipalities of cumulative CE, only two of them are from eastern China while seven out of the bottom ten are from this region. Different from NE, IME and CE, only seven of the thirty provinces/municipalities are with positive cumulative IE, which are showed in Table 5. By definition, one province/municipality can have a positive IE if the growth rate and the share of this particular province/municipality are higher or lower than the group level simultaneously. The DSSA results indicate that only seven of our sample provinces/municipalities satisfy this condition. Overall, eighteen, eighteen and nineteen provinces/municipalities got positive cumulative net shift, IME and CE, respectively, which means two third of the sample provinces/municipalities are with positive cumulative net shift, IME and CE. The structure composition of engineering group is satisfactory for western and central China but not for eastern China. By analyzing the breakdown of each of the components of IME, CE and IE, we find that the average growth rate of researchers in engineering

[6] China has traditionally been divided into three economic regions: the eastern region (Beijing, Tianjin, Hebei, Liaoning, Shandong, Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong, and Hainan), the central region (Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan), and the western region (Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Guangxi, and Inner Mongolia)

related institutions and enterprises is -2.46 percent and the annual growth rates are negative in most of the sample years. It is clear that engineering is a sun-set research group. However, the shares in this research group are higher than the group level while the growth rates of the number of researchers in this research group are often lower than the average group level for most of the provinces/municipalities in eastern China. All these facts cause the low rankings in IME and CE and thus net shift for most of the provinces/municipalities in eastern China.

Table 2. Cumulative net shift of engineering from 1996 to 2007

Rank	Region	NS	Rank	Region	NS
1	Shanxi	72839.14	16	Ningxia	5319.75
2	Henan	50626.07	17	Fujian	3442.95
3	Guangxi	45707.54	18	Qinghai	2640.61
4	Hebei	39755.15	19	Zhejiang	1875.11
5	Shandong	29733.30	20	Xizang	1420.81
6	Yunnan	26674.91	21	Hainan	-301.50
7	Shaanxi	25041.99	22	Sicuan	-14385.32
8	Hunan	23696.19	23	Tianjin	-21764.71
9	Gansu	20146.63	24	Jilin	-24329.15
10	Guizhou	18516.14	25	Heilongjiang	-25100.63
11	Jiangxi	17199.90	26	Beijing	-25438.81
12	Neimeng	11955.19	27	Shanghai	-26893.54
13	Anhui	11801.40	28	Hubei	-60350.56
14	Xinjiang	10049.13	29	Liaoning	-101363.21
15	Guangdong	6536.74	30	Jiangsu	-125051.12

Table 3. Cumulative industry mix effect of engineering from 1996 to 2007

Rank	Region	IME	Rank	Region	IME
1	Henan	17209.32	16	Qinghai	638.84
2	Guangdong	11035.18	17	Xizang	634.63
3	Sicuan	9631.54	18	Gansu	307.99
4	Hubei	5606.18	19	Guangxi	-220.88
5	Hunan	5402.48	20	Shaanxi	-344.16
6	Guizhou	5197.13	21	Ningxia	-757.13
7	Anhui	4864.35	22	Jiangsu	-2478.07
8	Hebei	4783.41	23	Jilin	-2597.28
9	Jiangxi	4578.59	24	Tianjin	-5988.46
10	Fujian	4089.21	25	Shanxi	-6469.54
11	Yunnan	3373.75	26	Shandong	-7364.41
12	Xinjiang	2358.13	27	Heilongjiang	-8852.65
13	Hainan	1983.80	28	Shanghai	-11694.90
14	Neimeng	1795.06	29	Liaoning	-11890.05
15	Zhejiang	852.99	30	Beijing	-25685.79

Table 4. Cumulative competitive effect of engineering from 1996 to 2007

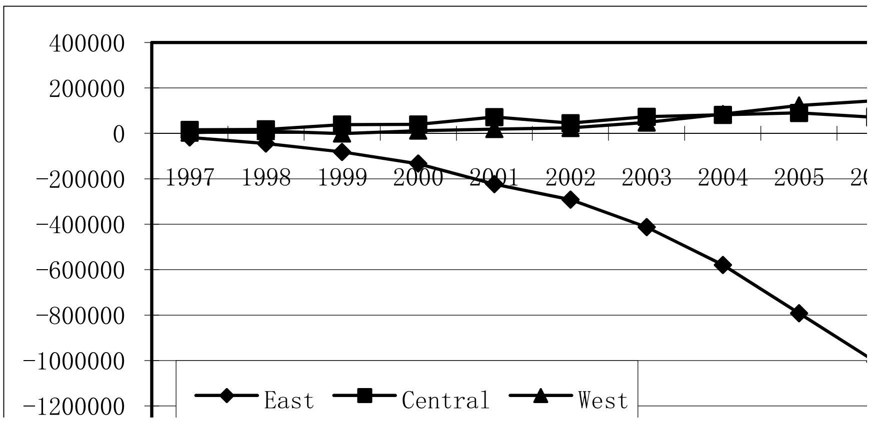
Rank	Region	CE	Rank	Region	CE
1	Shanxi	71579.59	16	Ningxia	5993.93
2	Henan	49309.14	17	Qinghai	2457.52
3	Guangxi	45109.55	18	Zhejiang	2109.09
4	Hebei	41627.05	19	Xizang	1865.54
5	Shandong	37099.86	20	Fujian	-611.58
6	Yunnan	29623.74	21	Guangdong	-1576.08
7	Shaanxi	24975.03	22	Hainan	-3326.65
8	Hunan	23610.51	23	Shanghai	-7712.45
9	Gansu	21413.34	24	Tianjin	-9424.54

10	Guizhou	17783.57	25	Heilongjiang	-11995.86
11	Jiangxi	15573.38	26	Jilin	-18410.49
12	Neimeng	11855.74	27	Sicuan	-27781.01
13	Beijing	11624.08	28	Liaoning	-66487.83
14	Xinjiang	9309.59	29	Hubei	-72945.14
15	Anhui	8302.91	30	Jiangsu	-109838.54

Table 5. Cumulative interactive effect of engineering from 1996 to 2007

Rank	Region	IE	Rank	Region	IE
1	Shanxi	7729.09	16	Neimeng	-1695.61
2	Hubei	6988.40	17	Guangdong	-2922.35
3	Sicuan	3764.16	18	Jiangxi	-2952.06
4	Hainan	1041.35	19	Jilin	-3321.38
5	Guangxi	818.87	20	Heilongjiang	-4252.12
6	Shaanxi	411.12	21	Guizhou	-4464.57
7	Ningxia	82.94	22	Hunan	-5316.81
8	Shandong	-2.15	23	Yunnan	-6322.59
9	Fujian	-34.67	24	Tianjin	-6351.71
10	Qinghai	-455.75	25	Hebei	-6655.31
11	Xizang	-1079.36	26	Shanghai	-7486.19
12	Zhejiang	-1086.96	27	Beijing	-11377.09
13	Anhui	-1365.86	28	Jiangsu	-12734.51
14	Gansu	-1574.70	29	Henan	-15892.39
15	Xinjiang	-1618.59	30	Liaoning	-22985.33

Figure 4. Cumulative Net Shifts of the Three Regions for Engineering



DSSA results for agriculture

The number of agriculture researchers accounts for only 3 percent of total number of researchers in China in 2007. The overall performance of the three regions can be found in Figure 5, which shows the cumulative net shifts of these three regions. From Figure 5, we find that the overall performance of provinces/municipalities in western China is the best, especially after 2003 while the performance of provinces/municipalities in eastern China is poor with a declining trend during the whole sample period. Further detailed DSSA results are showed in Tables 6 to 9. There are twelve, fifteen, thirteen and eighteen provinces/municipalities with positive cumulative net shift, IME, CE and IE, respectively for agriculture researcher group. Table 6 shows the cumulative net shift for the thirty provinces/municipalities. Of the top ten provinces/municipalities in net shift of agriculture, seven of them are from western China and the remaining three are from central China while seven of the bottom ten provinces/municipalities are from eastern China. As most of the agriculture output is from central and western China, this result is consistent from out expectation that research talents in agriculture related institutions and enterprises are mainly in provinces/municipalities from central and western China where R&D expenditure on agriculture is generally more than that of the provinces/municipalities. The growth rates of agriculture researchers are positive in eight of the eleven years of our sample period and the average growth rate is 1.64 percent. Thus, this researcher group is a sun-rise researcher group. By analyzing the results of IME, CE and IE, we find that those provinces in western China which top the cumulative net shift ranking are also ranked high in cumulative IME and CE. For example, Xinjiang and Ningxia are among the top ten provinces/municipalities in both cumulative IME and CE. In contrast, most of the provinces/municipalities from eastern China are ranked low in both IME and CE. By checking the breakdown of IME and CE, we find that those eastern provinces/municipalities are with lower shares and growth rates than the corresponding group levels. The well-structured of the agriculture researchers group is also reflected by eighteen of the thirty provinces/municipalities which all have positive cumulative IE. For the provinces/municipalities in central China, not like their counterparts in western and eastern China, they are evenly distributed in the DSSA rankings for agriculture researcher group. From the above analysis, we know that the distribution of research persons in agriculture researcher group is proper and the overall structure is satisfactory.

Table 6. Cumulative net shift of agriculture from 1996 to 2007

Rank	Region	NS	Rank	Region	NS
1	Xinjiang	9277.40	16	Henan	-628.95
2	Gansu	7347.58	17	Heilongjiang	-1234.92
3	Shaanxi	6819.89	18	Tianjin	-1276.41
4	Hunan	6402.66	19	Shandong	-1582.29
5	Neimeng	6273.59	20	Hebei	-1738.49
6	Shanxi	5184.49	21	Sicuan	-2311.60
7	Ningxia	3724.31	22	Zhejiang	-2384.42
8	Qinghai	3090.17	23	Fujian	-2978.76
9	Yunnan	3082.71	24	Beijing	-3135.56
10	Jiangxi	2929.07	25	Shanghai	-3594.75
11	Jilin	2336.56	26	Anhui	-3796.76
12	Guizhou	1742.61	27	Liaoning	-3818.07
13	Xizang	-280.88	28	Guangdong	-4371.00
14	Hainan	-328.97	29	Jiangsu	-10712.05
15	Guangxi	-552.80	30	Hubei	-13484.34

Table 7. Cumulative industry mix effect of agriculture from 1996 to 2007

Rank	Region	IME	Rank	Region	IME
1	Yunnan	2861.75	16	Hubei	-70.00
2	Xinjiang	2594.57	17	Anhui	-152.51
3	Guizhou	1746.54	18	Jiangsu	-196.06
4	Sicuan	1333.18	19	Jiangxi	-236.05
5	Heilongjiang	1139.86	20	Zhejiang	-457.48
6	Neimeng	1013.51	21	Fujian	-475.21
7	Gansu	1009.16	22	Liaoning	-519.28
8	Jilin	779.36	23	Shanxi	-525.54
9	Ningxia	569.27	24	Hunan	-1005.88
10	Shaanxi	403.18	25	Hebei	-1039.29
11	Qinghai	377.47	26	Tianjin	-1226.06
12	Guangxi	145.85	27	Beijing	-1397.87
13	Xizang	142.00	28	Shanghai	-1645.59
14	Hainan	40.64	29	Henan	-1727.93
15	Shandong	39.80	30	Guangdong	-3521.29

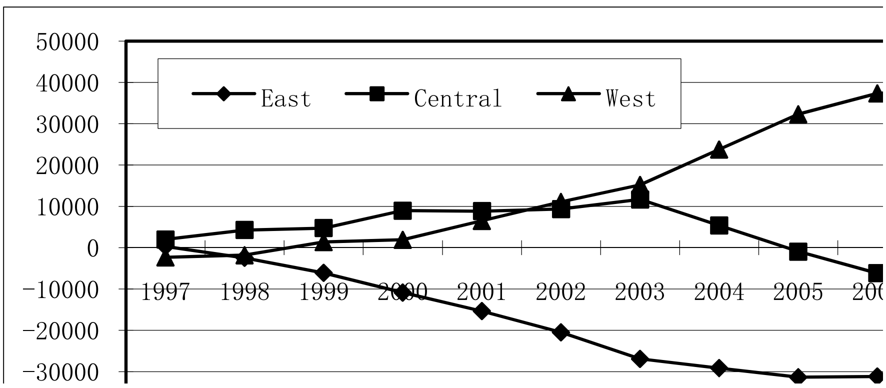
Table 8. Cumulative competitive effect of agriculture from 1996 to 2007

Rank	Region	CE	Rank	Region	CE
1	Hunan	8894.56	16	Hainan	-207.57
2	Shanxi	6801.18	17	Guangdong	-232.66
3	Shaanxi	5706.25	18	Guangxi	-690.51
4	Gansu	4258.95	19	Hebei	-888.56
5	Neimeng	3640.98	20	Shandong	-1813.76
6	Jiangxi	3567.82	21	Heilongjiang	-1847.08
7	Xinjiang	3189.98	22	Zhejiang	-2145.77
8	Jilin	1848.97	23	Sicuan	-2375.65
9	Henan	1765.31	24	Fujian	-2819.24
10	Ningxia	1581.74	25	Liaoning	-3568.81
11	Qinghai	1365.87	26	Beijing	-3681.44
12	Yunnan	181.72	27	Anhui	-3901.03
13	Tianjin	143.08	28	Shanghai	-7259.97
14	Guizhou	-16.36	29	Jiangsu	-10718.55
15	Xizang	-160.39	30	Hubei	-14434.54

Table 9. Cumulative interactive effect of agriculture from 1996 to 2007

Rank	Region	IE	Rank	Region	IE
1	Shanghai	5310.82	16	Hebei	189.36
2	Xinjiang	3492.85	17	Yunnan	39.24
3	Gansu	2079.46	18	Guizhou	12.42
4	Beijing	1943.75	19	Guangxi	-8.15
5	Neimeng	1619.11	20	Hainan	-162.04
6	Ningxia	1573.31	21	Tianjin	-193.42
7	Qinghai	1346.83	22	Xizang	-262.49
8	Hubei	1020.20	23	Jilin	-291.77
9	Shaanxi	710.46	24	Jiangxi	-402.70
10	Fujian	315.69	25	Heilongjiang	-527.71
11	Liaoning	270.01	26	Guangdong	-617.05
12	Anhui	256.78	27	Henan	-666.33
13	Zhejiang	218.84	28	Shanxi	-1091.15
14	Jiangsu	202.55	29	Sicuan	-1269.12
15	Shandong	191.67	30	Hunan	-1486.02

Figure 5. Cumulative Net Shifts of the Three Regions for Agriculture



DSSA results for scientific research

In this subsection, we investigate the scientific researcher group. The number of scientific researchers in institutions and enterprises only accounts for 2 percent of the total number of researchers in China. During our sample period, we see that, for the growth rates of the number of scientific researchers, except for a sudden drop of 6 percent in 2007, followed by a 6.48 percent recovery, there were only two small declines of 0.87 and 0.21 percent in 1997 and 2001, respectively. The average growth rate in our sample period is 2.43 percent and we can say that scientific researcher group is a sunrise researcher group. The overall performance of the three regions for scientific researcher group is presented in Figure 6. The provinces/municipalities in eastern China has obvious advantage in the scientific researcher group as reflected by the consistently positive cumulative net shifts during the whole sample period. In contrast, the overall performance of the provinces/municipalities in western China is not satisfactory with negative cumulative net shifts for the whole sample period. Tables 10 to 13 are the DSSA results, which show the net shift, IME, CE and IE, respectively. There are fourteen, fourteen and fifteen of the thirty provinces/municipalities with positive net shift, IME and CE respectively. The provinces/municipalities from eastern China seems better in scientific researcher group as reflected by six of the top ten and only one of the bottom ten provinces/municipalities in net shift are from this region. In contrast, none of the top ten provinces/municipalities in net shift of scientific researcher group is from western China and we are able to find six of them in the bottom ten. Following our standard procedures, we check the results from IME, CE and IE. We find that seven of the top ten provinces/municipalities in IME are from eastern China. The breakdown of IME equation further shows that most of the provinces/municipalities in eastern China have higher shares in scientific researcher group than the average group level, which together with the property of sunrise researcher group results in the good rankings of IME for provinces/municipalities in eastern China. For IE, five of the eleven provinces/municipalities with positive IE in scientific researcher group are from the western China. By checking the breakdown of IE, we find that provinces/municipalities in western China usually have lower share and slower growth rates than the average levels of the group in the scientific researcher group. The interaction between low shares and low growth rates results in the relatively high rankings of IE for provinces/municipalities in western China. The DSSA results from this subsection indicate that the regional distribution of scientific researchers in institutions and enterprises are not even, where the absolute numbers and growth rates of scientific researchers in provinces/municipalities from eastern China are higher than those of western China. One exception from the provinces in eastern China is Guangdong province which was ranked twenty in cumulative net shift and twenty eight in cumulative IME. The breakdown of the DSSA equations shows that both the shares and growth rates of Guangdong province in scientific researcher group are not satisfactory. The shares of the number of scientific researchers in total number of researchers are consistently lower than the average group level, although the magnitudes are not high. Six of the eleven growth rates of Guangdong provinces in the number of scientific researchers are negative, which is also a poor result.

Table 10. Cumulative net shift of science from 1996 to 2007

Rank	Region	NS	Rank	Region	NS
1	Jilin	3419.55	16	Qinghai	-366.39
2	Hunan	2560.86	17	Neimeng	-384.78
3	Shandong	1850.35	18	Gansu	-406.71
4	Liaoning	1471.46	19	Ningxia	-503.01
5	Heilongjiang	1412.74	20	Guangdong	-677.48
6	Beijing	872.18	21	Shanxi	-728.01
7	Hubei	837.82	22	Henan	-795.63
8	Zhejiang	744.59	23	Xinjiang	-868.54
9	Fujian	563.91	24	Yunnan	-898.97
10	Tianjin	254.90	25	Shaanxi	-985.05
11	Xizang	251.63	26	Anhui	-1248.18
12	Jiangsu	182.46	27	Guangxi	-1402.10
13	Shanghai	109.52	28	Guizhou	-1535.38
14	Jiangxi	60.78	29	Sicuan	-1654.07
15	Hainan	-312.36	30	Hebei	-1826.08

Table 11. Cumulative industry mix effect of science from 1996 to 2007

Rank	Region	IME	Rank	Region	IME
1	Shanghai	1019.39	16	Ningxia	-5.95
2	Beijing	825.06	17	Hainan	-47.10
3	Jilin	545.22	18	Yunnan	-125.06
4	Liaoning	470.90	19	Neimeng	-179.02
5	Heilongjiang	399.95	20	Gansu	-209.19
6	Hubei	370.51	21	Shaanxi	-224.76
7	Fujian	287.00	22	Jiangxi	-250.00
8	Zhejiang	229.01	23	Hunan	-252.72
9	Tianjin	142.43	24	Sicuan	-275.72
10	Jiangsu	66.03	25	Guangxi	-279.78
11	Xizang	50.36	26	Anhui	-331.89
12	Xinjiang	27.59	27	Guizhou	-353.02
13	Shanxi	3.36	28	Guangdong	-515.49
14	Qinghai	1.77	29	Henan	-669.49
15	Shandong	-4.61	30	Hebei	-714.34

Table 12. Cumulative competitive effect of science from 1996 to 2007

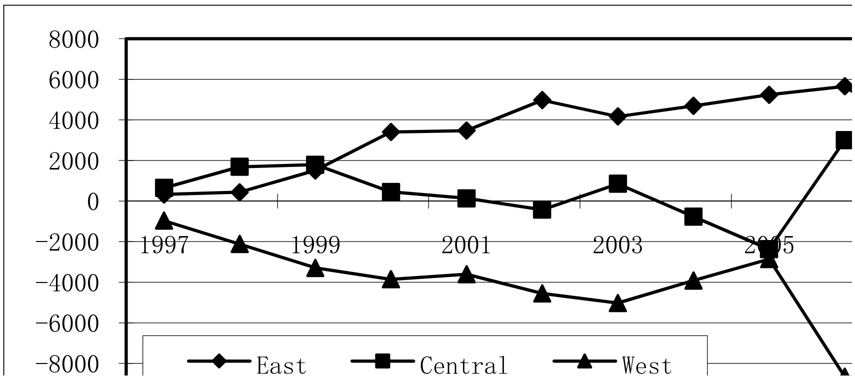
Rank	Region	CE	Rank	Region	CE
1	Hunan	4351.62	16	Guangdong	-143.83
2	Jilin	3178.95	17	Qinghai	-226.45
3	Shandong	2204.03	18	Neimeng	-251.83
4	Gansu	1628.51	19	Shanghai	-277.42
5	Liaoning	1044.90	20	Hainan	-316.86
6	Hubei	977.97	21	Ningxia	-496.57
7	Heilongjiang	855.48	22	Yunnan	-715.57
8	Jiangxi	487.92	23	Shanxi	-735.46
9	Zhejiang	484.28	24	Shaanxi	-762.56
10	Jiangsu	359.44	25	Xinjiang	-803.44
11	Fujian	352.60	26	Sicuan	-1101.93
12	Henan	293.62	27	Anhui	-1174.15
13	Beijing	198.11	28	Guangxi	-1447.84
14	Tianjin	182.71	29	Hebei	-1853.16
15	Xizang	108.35	30	Guizhou	-1975.88

Table 13. Cumulative interactive effect of science from 1996 to 2007

Rank	Region	IE	Rank	Region	IE
1	Guizhou	793.53	16	Tianjin	-70.24
2	Hebei	741.43	17	Fujian	-75.69
3	Guangxi	325.51	18	Xinjiang	-92.69
4	Anhui	257.86	19	Qinghai	-141.71
5	Heilongjiang	157.31	20	Beijing	-150.99
6	Xizang	92.92	21	Jiangxi	-177.14
7	Hainan	51.60	22	Jiangsu	-243.01
8	Neimeng	46.06	23	Sicuan	-276.43
9	Zhejiang	31.30	24	Jilin	-304.62
10	Shanxi	4.09	25	Shandong	-349.08
11	Shaanxi	2.27	26	Henan	-419.76
12	Ningxia	-0.49	27	Hubei	-510.66
13	Guangdong	-18.16	28	Shanghai	-632.46
14	Liaoning	-44.33	29	Hunan	-1538.03

15	Yunnan	-58.33	30	Gansu	-1826.03

Figure 6. Cumulative Net Shifts of the Three Regions for Scientific Research



DSSA results for health care research

The number of health care researchers are ranked third of the five researcher group, accounting for 16 percent of the total number of researchers. The time series of annual growth rates of the number of researchers in health care related institutions and enterprises are consistently positive during the whole sample period and the average growth rate is 2.29 percent, which implies that the health care researcher group is a sunrise researcher group. Different from the scientific researcher group, the overall performance of provinces/municipalities in central China is better than those of the other two regions (Figure 6). Except for the beginning year of the sample period, the cumulative net shifts are consistently positive in the remaining sample period for provinces/municipalities in central China. In contrast, the cumulative net shifts of provinces/municipalities in eastern and western China are negative in most of the sample period. However, the gap in the cumulative net shifts is narrowing down since 2001 between central and eastern China. In 2007, the performance of central and eastern China is very similar. The DSSA results for this researcher group are in Tables 14 to 17. There are twelve, fifteen, fourteen and eleven positive net shift, IME, CE, and IE, respectively, none of which have positive numbers more than half of the total numbers of provinces/municipalities. For regional distribution, we find that the regional distribution is even. There are four, four and three top ten provinces/municipalities of net shift in health care are from eastern, central and western China respectively. Similar results can be found in IME, CE and IE as we can see that the numbers of provinces/municipalities from each region in top ten and bottom ten of the rankings of IME, CE and IE are quite similar. In other words, no region has competitive advantage in terms of attracting more health researchers. However, eastern China has relatively higher attractiveness to health researchers as three of the top five provinces/municipalities are from this region. Guangdong province is the top performer in this researcher group as it is not only ranked top ten in all the four DSSA results but also ranked first in net shift, IME and IE. By checking the breakdowns of IME and CE, we find that the shares in health care researcher group are higher than the average group level from 1999 and nine of the eleven annual growth rates are positive in Guangdong province. The DSSA results indicate that Guangdong province has done an excellent job in attracting researchers in health care. In contrast to the competitive advantage Guangdong province has gained in health care researcher group, we find that Beijing is only ranked twenty one in net shift of health care. The breakdown of the IME and CE shows that Beijing do have higher share in health care than the average group level which is reflected by the high ranking in IME. However, the annual growth rates of researcher number are lower than the average group level in seven of the eleven years, which leads to a very low ranking in CE. The DSSA results indicate that although Beijing have competitive advantage in terms of absolute number of health care researchers and the shares of health care researchers in total number of researchers, it needs to increase its investment in attracting health care research persons to keep up the pace of development in China.

Table 14. Cumulative net shift of health care from 1996 to 2007

Rank	Region	NS	Rank	Region	NS
1	Guangdong	55415.97	16	Guangxi	-934.71
2	Shandong	22623.54	17	Xinjiang	-1590.20

3	Hunan	22439.09	18	Ningxia	-2967.78
4	Shanxi	14515.03	19	Fujian	-5383.06
5	Zhejiang	14085.56	20	Guizhou	-6644.18
6	Henan	12166.33	21	Beijing	-6756.30
7	Shaanxi	11516.29	22	Yunnan	-7341.64
8	Jiangxi	9930.44	23	Shanghai	-10948.16
9	Hebei	9041.18	24	Anhui	-11006.19
10	Neimeng	8276.21	25	Sicuan	-14962.53
11	Hainan	3559.24	26	Heilongjiang	-15686.11
12	Jilin	2962.24	27	Tianjin	-17405.46
13	Gansu	-61.59	28	Jiangsu	-24470.19
14	Qinghai	-392.73	29	Hubei	-25807.39
15	Xizang	-493.36	30	Liaoning	-33679.55

Table 15. Cumulative industry mix effect of health care from 1996 to 2007

Rank	Region	IME	Rank	Region	IME
1	Hubei	10390.80	16	Shandong	-133.60
2	Shanghai	5045.48	17	Neimeng	-151.88
3	Liaoning	4983.77	18	Hunan	-220.58
4	Zhejiang	3917.58	19	Yunnan	-386.04
5	Heilongjiang	3632.17	20	Guangxi	-525.79
6	Tianjin	3341.12	21	Guizhou	-1398.59
7	Guangdong	2359.27	22	Gansu	-1883.19
8	Beijing	1761.67	23	Shaanxi	-1906.67
9	Jilin	1574.00	24	Sicuan	-2252.20
10	Jiangxi	983.97	25	Jiangsu	-2652.13
11	Xizang	549.33	26	Shanxi	-2689.39
12	Qinghai	508.53	27	Anhui	-5403.03
13	Xinjiang	381.78	28	Fujian	-6448.81
14	Hainan	208.80	29	Henan	-6698.72
15	Ningxia	122.13	30	Hebei	-7009.63

Table 16. Cumulative competitive effect of health care from 1996 to 2007

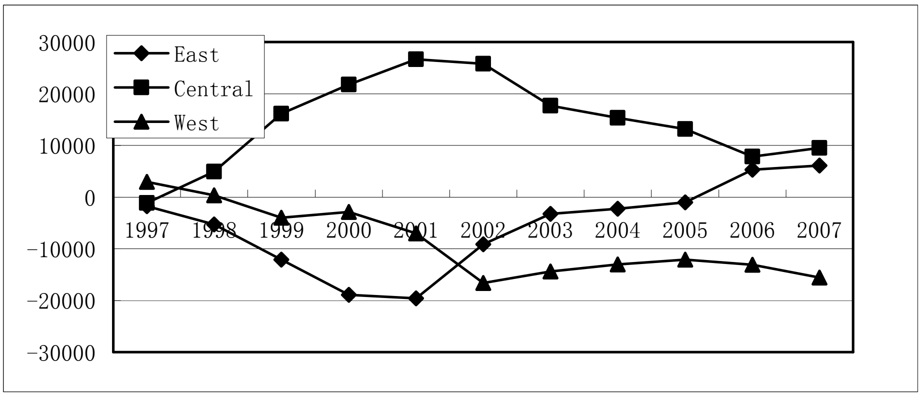
Rank	Region	CE	Rank	Region	CE
1	Guangdong	49623.17	16	Xizang	-474.72
2	Hunan	24752.15	17	Qinghai	-654.66
3	Shandong	23219.46	18	Xinjiang	-1953.39
4	Henan	22066.88	19	Ningxia	-3102.62
5	Hebei	20207.96	20	Guizhou	-5872.74
6	Shanxi	19378.40	21	Yunnan	-7251.62
7	Shaanxi	14810.43	22	Anhui	-7310.71
8	Jiangxi	8858.98	23	Beijing	-8142.08
9	Zhejiang	8758.20	24	Shanghai	-12005.34
10	Neimeng	8566.13	25	Sicuan	-12885.42
11	Hainan	3298.55	26	Tianjin	-15961.37
12	Gansu	2472.54	27	Heilongjiang	-17084.11
13	Fujian	1547.50	28	Jiangsu	-23426.79
14	Jilin	1042.76	29	Hubei	-27851.75
15	Guangxi	-346.20	30	Liaoning	-32918.77

Table 17. Cumulative interactive effect of health care from 1996 to 2007

Rank	Region	IE	Rank	Region	IE

1	Guangdong	3433.53	16	Beijing	-375.90
2	Anhui	1707.55	17	Shandong	-462.33
3	Jiangsu	1608.73	18	Fujian	-481.74
4	Zhejiang	1409.78	19	Xizang	-567.97
5	Guizhou	627.15	20	Gansu	-650.95
6	Jilin	345.47	21	Shaanxi	-1387.47
7	Yunnan	296.02	22	Hunan	-2092.47
8	Sicuan	175.10	23	Shanxi	-2173.98
9	Jiangxi	87.49	24	Heilongjiang	-2234.18
10	Hainan	51.89	25	Henan	-3201.83
11	Ningxia	12.71	26	Shanghai	-3988.30
12	Xinjiang	-18.59	27	Hebei	-4157.15
13	Guangxi	-62.72	28	Tianjin	-4785.21
14	Neimeng	-138.05	29	Liaoning	-5744.55
15	Qinghai	-246.60	30	Hubei	-8346.45

Figure 7. Cumulative Net Shifts of the Three Regions for Health Care Research



DSSA results for education research

The number of education researchers in institution and enterprises are the highest among the five researcher groups, which accounts for 57 percent of the total number of researchers. To provide an overall picture of the performance of the three regions, we consult to Figure 8, which shows the dynamics of cumulative net shifts in education research for the three regions. From Figure 8, we find that both central and western China have positive cumulative net shifts in education research for most of the time period. In contrast, the overall performance of the provinces/municipalities in eastern China is weak and the cumulative net shifts are consistently negative. As most of the researchers are from universities and the Chinese government invests huge amount of fund in supporting research activities in universities, it is not surprised that nearly 60 percent of researchers are in education related institutions and enterprises. Firstly, we look at the time series of annual growth rates of this researcher group. Although the magnitudes of the growth rates are declining, all of them are consistently positive during the whole sample period, which means that the education researcher group is a sunrise researcher group. Secondly, we check the DSSA results for the education researcher group which are presented in Tables 18 to 21. After checking the rankings of net shift, IME, CE and IE, we find that the distribution of education researchers in top ten provinces/municipalities is quite even among the different regions in China. For net shift, three, three and four top ten provinces/municipalities are from eastern, central and western China. Similar distribution patterns can be found in the rankings of IME and CE. However, we also find that more than half of the bottom ten provinces/municipalities are from eastern China. The breakdown of the IME and CE of these eastern China provinces/municipalities shows that both the shares and the annual growth rates are lower than the average group level. The reason for the lower than the share and growth rate of the whole country for these eastern provinces/municipalities may be that to ease the inequality in education among different regions, universities are encouraged to admit more students and there were so many new universities, either state-own or privately set up, founded in central and western China. In contrast, the numbers of students in universities in eastern China were quite stable in the last ten years. Moreover, the property of the research work done in those top universities in eastern China also determine that the orientation of their development may be technology intensive not researcher intensive, as the most advanced machines and technologies are applied in research centers in those universities while universities researchers, limited by technology, may do more fundamental researches which are more researcher intensive.

Table 18. Cumulative net shift of education from 1996 to 2007

Rank	Region	NS	Rank	Region	NS
1	Henan	188194.23	16	Xinjiang	5144.56
2	Hebei	79985.78	17	Qinghai	-973.25
3	Guangdong	68875.11	18	Hunan	-5133.91
4	Guizhou	60711.76	19	Ningxia	-7364.57
5	Shanxi	60184.54	20	Zhejiang	-8388.35
6	Shaanxi	59520.75	21	Fujian	-18599.45
7	Gansu	56410.21	22	Tianjin	-52240.44
8	Shandong	44476.74	23	Jilin	-61731.40
9	Anhui	40823.63	24	Jiangsu	-62033.87
10	Yunnan	27652.71	25	Beijing	-71630.09
11	Jiangxi	21908.42	26	Shanghai	-76755.47
12	Guangxi	19678.52	27	Heilongjiang	-80322.05
13	Neimeng	16445.97	28	Sicuan	-82482.94
14	Xizang	10791.68	29	Hubei	-89130.44
15	Hainan	8219.39	30	Liaoning	-152237.83

Table 19. Cumulative industry mix effect of education from 1996 to 2007

Rank	Region	IME	Rank	Region	IME
1	Henan	28397.89	16	Xizang	-265.41
2	Hebei	17373.85	17	Neimeng	-318.26
3	Guangdong	12191.64	18	Qinghai	-907.22
4	Fujian	11803.15	19	Ningxia	-1297.21
5	Anhui	11134.08	20	Xinjiang	-1635.47
6	Hunan	10817.68	21	Shandong	-2081.29
7	Sicuan	8990.47	22	Zhejiang	-4058.41
8	Jiangxi	5092.44	23	Jilin	-5876.38
9	Guizhou	4330.83	24	Jiangsu	-8464.10
10	Shanxi	2132.81	25	Hubei	-9634.29
11	Gansu	1897.80	26	Tianjin	-11599.39
12	Hainan	1747.49	27	Heilongjiang	-15524.83
13	Guangxi	1670.55	28	Beijing	-17724.57
14	Yunnan	1495.39	29	Shanghai	-18262.07
15	Shaanxi	739.72	30	Liaoning	-22166.85

Table 20. Cumulative competitive effect of education from 1996 to 2007

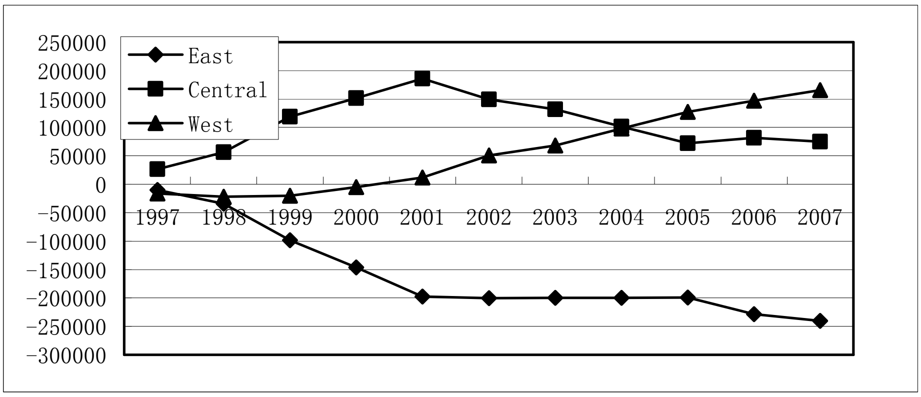
Rank	Region	CE	Rank	Region	CE
1	Henan	137552.11	16	Hainan	5949.15
2	Shanxi	58359.46	17	Qinghai	-176.08
3	Shaanxi	58132.42	18	Zhejiang	-4481.86
4	Hebei	56017.50	19	Ningxia	-6459.00
5	Guangdong	53715.25	20	Hunan	-17154.13
6	Guizhou	53185.84	21	Fujian	-26811.75
7	Gansu	53164.50	22	Tianjin	-53900.60
8	Shandong	46789.43	23	Jiangsu	-55255.17

9	Anhui	27465.38	24	Jilin	-59241.10
10	Yunnan	25930.21	25	Heilongjiang	-74091.59
11	Guangxi	18101.32	26	Beijing	-74733.23
12	Neimeng	16801.61	27	Shanghai	-81986.48
13	Jiangxi	15981.33	28	Hubei	-84452.59
14	Xizang	11125.79	29	Sicuan	-86664.52
15	Xinjiang	7095.70	30	Liaoning	-152551.38

Table 21. Cumulative interactive effect of education from 1996 to 2007

Rank	Region	IE	Rank	Region	IE
1	Shanghai	23493.09	16	Jiangxi	834.65
2	Liaoning	22480.40	17	Shaanxi	648.61
3	Henan	22244.23	18	Hainan	522.75
4	Beijing	20827.71	19	Ningxia	391.63
5	Tianjin	13259.55	20	Yunnan	227.11
6	Heilongjiang	9294.36	21	Zhejiang	151.92
7	Hebei	6594.43	22	Qinghai	110.05
8	Hubei	4956.44	23	Neimeng	-37.37
9	Jilin	3386.08	24	Xizang	-68.70
10	Guizhou	3195.09	25	Guangxi	-93.36
11	Guangdong	2968.22	26	Shandong	-231.40
12	Anhui	2224.18	27	Shanxi	-307.73
13	Jiangsu	1685.40	28	Xinjiang	-315.68
14	Gansu	1347.91	29	Fujian	-3590.86
15	Hunan	1202.53	30	Sicuan	-4808.88

Figure 8. Cumulative Net Shifts of the Three Regions for Education Research



Spearman rank correlation analysis

In the previous sections, we analyze the structure of the researchers in China by DSSA. For each of the five researcher group, we judge the performance of provinces/municipalities by comparing their rankings in cumulative net shifts and further explain the results from cumulative net shifts by comparing the rankings in cumulative IME, CE and IE respectively. However, one may argue that these rankings may be attributable to other factors such as per capita GDP growth. A province/municipality with higher economic growth may help gaining competitiveness in attracting more researchers. In other words, these rankings may be just a reflection of the per capita GDP growth.

To answer this equation, we may refer to a non-parametric correlation analysis, called Spearman rank correlation analysis. Spearman (1904) proposed a simple method to assess how well an arbitrary monotonic function could describe the relationship between two variables. The most significant advantage of this method is that it does not require any specific assumption on the distribution and particular nature of the relationship between variables. The equation of Spearman rank correlation,

Table 22. Spearman Rank Correlation Analysis

	Growth	Engineering	Agriculture	Science	Health
Engineering	-0.27				
	0.14				
Agriculture	-0.33	0.53			
	0.08	0.01			
Science	0.03	-0.54	-0.22		
	0.87	0.01	0.24		
Health	-0.47	0.66	0.43	-0.06	
	0.01	0.01	0.01	0.75	
Education	-0.31	0.86	0.39	-0.59	0.67
	0.10	0.01	0.04	0.01	0.01

Note: The correlations and their *p*-values are reported.

denoted by ρ , is[7]:

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)} \qquad (5)$$

where $d_i = x_i - y_i$ is the difference between the ranks of corresponding values of series X_i and Y_i. *n* is the number of observations in each dataset (assume that the same number of observation for each dataset).

We perform the Spearman rank correlation analysis to examine the relationship between the average per capita GDP growth rate and the rankings of cumulative net shifts for the five researcher groups respectively. The statistical results of Spearman rank correlation analysis is presented in Table 22, where we provide the correlation coefficients and the corresponding *p*-value for each pair of series examined in our statistical analysis. We find that except for the health care researcher group, the cumulative net shifts rankings of the other four researcher groups do not have any significant correlation with per capita growth rate.

Concluding Remarks

In this paper, we analyze the structure of the research talent pool of China by studying the relative competitiveness in the five researcher groups for the 30 provinces/municipalities from 1996 to 2007. To analyze the R&D development of a country, we can judge from two aspects: R&D expenditure and the number of researchers. In 2007, the R&D expenditure in China was the third largest, only behind the United States and Japan. The R&D intensity has risen 248 percent from 1995 to 2007, reaching 1.48 percent of GDP. The National Guidelines for Medium- and Long-term Plans for Science and Technology Development (2006-2020) released by the Chinese State Council set a target to raise the share of China's R&D expenditure in GDP to 2 percent by 2010 and to 2.5 percent or more by 2020. Except for increasing expenditure on R&D, the research talents also play a crucial role to achieve the R&D goal, because they not only determine how to use the money efficiently but also attract further investment in R&D if they are able to generate more inventions and the inventions or innovations generated can be transferred to commercial products smoothly. The scientific and technological personnel in institutions or enterprises are divided into five researcher groups in China: engineering, agriculture, science, health care and education. We are interested in analyzing whether the structure of the R&D talent pool is appropriate by means of DSSA. DSSA is a mathematical method to analyze the competitiveness of each of the provinces/municipalities under investigation. A province/municipality is said to gain competitive advantage if it has a positive net shift in a particular researcher group. The net shift can further be divided into four components: IME, CE and IE. For each of the researcher group, we rank the provinces/municipalities by their values of net shift, IME, CE and IE, respectively. Through comparing the rankings of net shift, IME, CE and IE respectively, we are able to find out not only whether a particular province/municipality invests on the five researcher groups appropriately but also whether there is region inequality among the researcher groups investigated and what the source behind this

[7] If the ranks of the two series X_i and Y_i are equal, we should use the traditional Pearson's correlation coefficient

$$\rho = \frac{n(\sum x_i y_i) - (\sum x_i)(\sum y_i)}{\sqrt{n(\sum x_i^2) - (\sum x_i)^2}\sqrt{n(\sum y_i^2) - (\sum y_i)^2}}$$

inequality is.

For the engineering researcher group, we find that provinces/municipalities from eastern China occupy most of the places in the bottom of the rankings of net shift, IME, CE and IE. By analyzing the breakdown of the DSSA equations, we find that the shares in this researcher group are higher than the group level for provinces/municipalities in eastern China while this researcher group is a sunset researcher group. Furthermore, the growth rates of provinces/municipalities from eastern China in this researcher group are often lower than the group level, which lead to negative CE. The low IMEs and CEs lead to the low net shift of the provinces/municipalities in eastern China. In contrast, most of the provinces/municipalities on the top rankings of net shift, IME, CE and IE are from central and western China. In a word, the provinces/municipalities from western and central China are generally gaining competitive advantage because they pay smaller attention to this sunset researcher group. For the agriculture researcher group, the provinces/municipalities from central and western China occupy the top ten positions for net shift, IME and CE while most of the bottom ten provinces/municipalities are from eastern China. This result is consistent with the reality in China as the agriculture output in China is mainly from central and western China. It is not surprised to see that the local governments of provinces/municipalities in these two regions to place more attention to attract the agriculture research personnel. For the scientific researcher group, the provinces/municipalities from eastern China seems more attractive as six of the top ten and only one of the bottom ten provinces/municipalities in net shift are from this region while none of the top ten provinces/municipalities in net shift of scientific researcher group is from western China and we are able to find six of them in the bottom ten. One exception from the provinces/municipalities from eastern China is Guangdong province in terms of its lower shares and growth rates than group level in the scientific researcher group. As for the health care researcher group, the distribution of provinces/municipalities from different regions is quite even and no region has competitive advantage in terms of attracting more health researchers. Eastern China seems having some competitive advantage as three of the top five in net shift are from this region. Two provinces/municipalities have attracted our interest. In contrast to the poor performance in attracting researchers in scientific researcher group, Guangdong province is the top performer as it is ranked first in net shift, IME and IE. In contrast, Beijing has not a good job in attracting research persons in this researcher group. The last sector we analyzed is the education researcher group, which is the largest researcher group in China. The consistently positive annual growth rates indicate that this group is a sunrise researcher group. The performance of the provinces/municipalities from eastern China is poor as the shares in education researcher group are consistently lower than the group level. Furthermore, the annual growth rates in these provinces/municipalities are also lower than the group level. These two facts cause the low rankings in net shift, IME and CE for most of the provinces/municipalities from eastern China. The reason may be that the top universities are mainly located in eastern China and the researches conducted in those eastern China universities are normally more technology intensive not researcher intensive. Moreover, to achieve the balanced education, local governments of provinces/municipalities in central and western China were encouraged to found more universities to provide more opportunities for students in those regions, which may lead to the high growth rates of research persons in those regions.

Some researchers may argue that the rankings in the cumulative net shifts may be influenced by other factors like per capita GDP growth. They postulate that provinces/municipalities with higher per capita GDP growth may obtain higher rankings in cumulative net shifts of the DSSA analysis. To offer some insights to this problem, we perform the Spearman rank correlation analysis on per capita GDP growth and the cumulative net shifts of the five researcher groups. The statistical results show that except for the health care researcher group, we are not able to find statistical significant correlation between per capita GDP growth and rankings in cumulative net shifts in DSSA.

To put everything into a nutshell, the structure of the researcher groups in the provinces/municipalities of eastern China is not suitable as those provinces/municipalities allocated too much on engineering which is a sunset researcher group by our definition. In contrast, they did not pay enough attention to attract education researchers, which is reflected by the lower shares and growth rates than the corresponding growth levels. The provinces/municipalities from central and eastern China seem having better structure in the five researcher groups as they invest more on agriculture and education researcher groups, where the central and western provinces/municipalities are the main producers of agriculture products and they are less developed in education.

As the huge research talent pool is the main factor that attracts foreign direct investment in China, we suggest the Chinese government planners should implement more effective measures to enlarge the researcher base and more importantly improve the structure of the researcher groups by investing more on the sunrise researcher groups.

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