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Comparative Studies on Efficiency of China's Regional Innovation System on the Basis of Cooperation Measurement Model

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Abstract
In this paper, taking an advanced economics standpoint, we specify the concept of synergy degree as the basis to the discussion of regional innovation system. Few literatures analyze the efficiency of regional innovation system from the angle of synergy effect between initial R&D technology stage and final commercial technology stage. Super efficiency data envelopment analysis is applied to calculate the efficiency of 27 selected provinces in China over 3 individual periods from 1998 to 2006. Then, a cooperation measurement model is introduced to measure the synergy degree between two sub-technological stages. We divided 27 provinces into four synergy categories to further measure correlation between each stage and the whole innovation stage. On the basis of the comparison of the efficiency of the whole innovation system and the synergy degree, the empirical results illustrate that most Chinese regions are still in the low efficiency and the cooperation level of each stage is relatively low. Finally, some policy suggestions are recommended accordingly.

Keywords: regional innovation system, two-stage innovation production process, super efficiency DEA, cooperation measurement model, synergy degree

INTRODUCTION

Looking back upon the past 30 years, China's science and technology process has experienced a dramatic change from planned economy to a market-oriented economy. Because of historical reasons, there are huge imparities in the S&T efficiency among Chinese regions, especially the economy gap from eastern regions to western regions. Since China joined the WTO in 2001, the high growth of national economy has also changed the relationship of central government and local regions. The regional provinces now become relatively independent on central government. Each province contributes more to local innovation efficiency and to the harmonious national economy. In 2006, Chinese government launched the S&T strategy called "National medium and long-term science and technology development plan". In this outline, the government wanted to enhance the S&T innovation efficiency to support the social and economy of the whole nation. For the development of the regional innovation capability, the provinces within regions need to strengthen their ability in the digestion, absorption and recreation of the introduced technology. However, China's innovation system has stretched over 34 provinces, the inequities between regional S&T and economy still exist.

In traditional research, the regions that have better technological resources may consider to own a higher innovation capability. However, some other researches turned the different way. Using the Cobb–Douglas production function as the research framework, and after analyzing the postal inquiry collected from 11 European regions, Fritsh (2004) found out there are significant differences of R&D efficiency within the 11 regions. Those regions with lower level of urbanization can also have relatively high output elasticity. The relation of cooperation and efficiency of R&D activities are discussed. Relevant research in Zabala-Iturriagagoitia (2007) illustrated that the amounts of technological resources are significant to the regional innovation system, and there is no evidence to show that the region that have a larger technological resources perform better in making profits. The cooperation within the innovation system may lead to a higher technological level of a region.

All the previous researches have mainly focused on the analysis of the efficiency of regional innovation system, while they neglect the cooperation between the technological development stage and technological application stage. The intermediate variables between the two-stage innovation systems that seems like a black box need to be revealed, yet little attention was diverted to the intermediate variables embedded in the two-stage innovation system. The comparison of different periods embedded in the regional innovation system in the movement like dramatic science and technology revolution is not accounted in the previous research. Furthermore, regarding the analytical efficiency, the researchers do not have one united method and measurement; thus their results in the analysis of the factors that may influence the efficiency have obvious difference.

The paper is organized as follows: In section 2, the idea of regional innovation system is introduced. Then, in section 3, a framework of two consecutive technological processes is used to explain how to develop S&T product in R&D technical stage and then make profits by commercialized intermediate innovation products in commercialization stage. The innovation system is transformed into two technological processes in which there are a parallel structure to ensure that the efficiency of the innovation system can be measured. Section 4 illustrated the empirical analysis results by using super efficiency DEA (data envelopment analysis) and cooperation measurement model. Finally, in section 5 some conclusions are reported according to previous analysis.

1. Conceptual framework

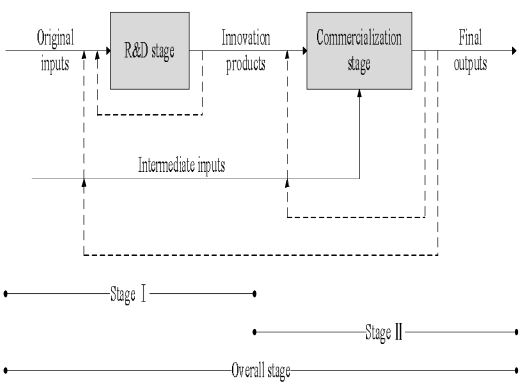


Fig.1. A typical regional innovation production process

The regional innovation system is first analyzed by Cooke (1992); he proposed the definition of Regional innovation system and compare three key innovative sections- the grassroots model of Japan, the dirigiste model of French and the network model of German. Regional innovation system is generally defined as the process of generating the interactive knowledge and sub-systems linked to regional systems to commercialize new knowledge. Regional innovation system is distinctly different from national innovation system (Autio, 1998), the RIS is constructed by two technical sub-stages embedded in one social economy and cultural background. In order to measure the efficiency of the innovation system, Nasierowski and Arcelus (2003) designed a two-stage model in which they included 8 intermediate variables. They have proposed a new input-output framework and used DEA in calculating the efficiency of 45 countries and regions analyzing information provided by the European Innovation Scoreboard. This two-stage model greatly inspired later researchers in the area of regional innovation system. Lee and Park (2009) measured the efficiency of the R&D technical of 27 countries in Asian. They find out that Singapore ranks the first in efficiency of the R&D technology development while China and Korea are at the bottom.

Fig.1 describes the simplified technological process of the regional innovation system. This framework is the basis for the empirical study in the following text. In Fig.1, we can easily discover the innovation process from original technology inputs to final economic outputs. In the innovation process, the original inputs are invested in the stage 1(R&D technical stage) to conduct innovation products. However, during this process, the innovation products fail to transform to market profits, so the intermediate inputs are added as well as the innovation products into the stage 2(commercialization stage). The whole stage is linked by innovation products between the R&D technical stage and commercialization stage. After transforming the developed technology into the market, the final profits are gained. As shown in the dotted line, all the outputs also have the feedback influence to the inputs. On the other hand, this is not the essential relation in regional innovation system; we will thus just focus on the forward influence from initial inputs to final economic outputs (show in black line).

The structural imbalance of these two processes is the key reason why the S&T development level and the commercialization ability of regional innovation system to make profits are relatively low. The imbalance of two processes will produce huge inequalities among regions. In fact, the efficiency of the regional innovation system is not only determined by the amount of investment in S&T resource, but also subject to its two-stage structure. The coordination of technological research development process and the technological application process, to some extent, will affect the development level of the whole regional innovation system.

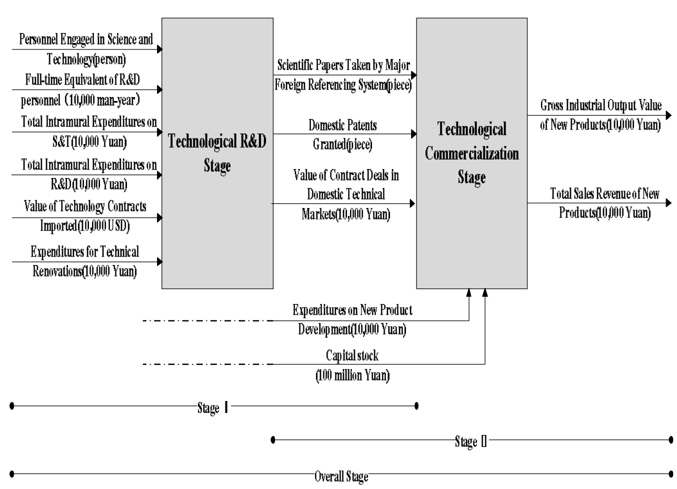


Fig.2. Framework of technical two sub-stage of an innovation system

Following the typical two-stage technological framework used in many former researches (Moon and Lee, 2005; Jeffrey, Michael and Scott 2002), we divided the regional technological innovation process into two consecutive stages from the angle of innovation production process, the technological R&D stage and the technological commercialization stage. The extant empirical study (Guan and Chen, 2012) shows that there is no one to one correspondence relation between the two stages. Traditional studies on regional system often neglect the influence of technological commercialization or even the whole innovation process. It is important to calculate the innovation system as whole processes instead of two sub-stage one. The efficiency of the whole system is measured by the multi input-output level instead of a single factor embedded in the single sub-stage. Additionally, the efficiency of the whole system has a close relationship because of the cooperation level between each sub-stage.

In the technical R&D stage, namely stage 1, the region focused on the research of the technological achievement by investing in capital fund and labor force. We use personnel engaged in science and technology, full-time equivalent of R&D personnel to illustrate the policy effect of human source strategy issued by the regional government. The factors like total intramural expenditures on S&T, total intramural expenditures on R&D, value of technology contracts imported and expenditures for technical renovations are added to explain the regional government's willingness in investing areas like science and technology funding as well as the tax preference. But the new technical achievements attaining from stage 1 cannot be sufficiently industrialized.

In order to make profits from the original S&T achievements developed from the first stage, more investments are needed in commercialization stage. Only by renovating the original technological achievement and putting the innovation products into the market then the technological commercialization stage are able to fulfill its economic value. As the outputs gaining from stage 1, Chinese scientific papers taken by major foreign referencing system and value of contract deals in domestic Technical Markets are acted as the innovation products, which link between the two-sub stage of the whole innovation system. In the technological commercialization process, we add two new inputs as well as the innovation products derived from the original stage 1. The expenditure on new products development included 4 sections: expenditure for acquisition of foreign technology, expenditure for assimilation of technology, expenditure for purchase of domestic technology, and expenditure for technical renovation. And these 4 sections are combined together. Capital stock is also included in stage 2.

Usually, the method to calculate the capital stock is PIM (perpetual inventory method) (Goldsmith 1951). As China has no large-scale asset census, so the common method is to set up a base year. Each region is calculated at a fixed price under the PIM method. Based on the Goldsmith's PIM method, the basic idea can be calculated by the following formula:

$$K_{it} = K_{it-1} \times (1 - D_{it}) \qquad (1)$$

This formula explain the capital stock K_{it} in year t, where i is the selected province i, t stands for year t. I is gross fixed capital formation, D is the depreciation rate. In this paper, take into account of the special conditions of China, we take Zhang Jun (2004) as reference. Following Zhang Jun's research, the depreciation rate was 9.6 by declining balance (depreciation) method.

RESULTS AND FINDINGS

Methods

Super Efficiency DEA Model

The regional innovation system is a rather complex process, especially in a big country covering numerous regions like China. To calculate the efficiency of the whole innovation system, many methods were applied historically. The measuring methods wildly used are divided into 2 categories: Parametric estimation approach and non-parametric estimation approach. The representative method of parametric estimation approach is SFA (Stochastic Frontier Analysis) while the non-parametric estimation approach is DEA (Data Envelopment Analysis) and Malmquist index.

The non-parametric method of DEA has a certain advantage in analyzing the efficiency of public activities in the regional innovation system (Frisch, 2004; Zabala iturriagogoitia, 2007). Unlike the parametric method like SFA, DEA are not limited to the non-linear form of multi-level of inputs and outputs. The two common model of DEA method is CCR and BCC model. Based on the assumption of variable return to scale, Banker, Charnes and Cooper (1984) proposed the BCC model in the first place. Although the extend version of BCC model can distinguish between the pure technology efficiency and the scale efficiency. In this case, all the decision making unites(DMUs) are simply divided into 2 groups; one group is operating on the best efficiency frontier in which their score equal to 1 while the other group belongs to the inefficiency DMUs that score less than 1. The result of the traditional DEA model like BCC model may have several effective DMU, which is hard for the comparison when their efficiency is equal to 1.

Usually, the purpose of decision maker in reality is not only to separate the effective DMUs from the ineffective DMUs. BCC model is not suitable when we need to discriminate the ranking of all the DMUs embedded in the innovation system. Furthermore, it also fails to differentiate the relative efficiency of the DMUs that are already on the efficiency frontier. Aiming at solve this problem, Banker&Gifford（1988）and Banker et al（1989）separate the effective DMUs from the reference set and build a super efficiency DEA model on the basis of CCR model. To break the limitation of efficient DMUs, the super efficiency model of Banker&Gifford（1988）is modified by Andersen and Petersen (1993) when a DMU under evaluation is excluded from the reference efficiency unit.

In order to study the synergy degree of the two-sub stage, highlight the difference between each selected regions within the innovation system, the super-efficiency model is used in this paper. In detail, we used the multi-stage super-efficiency model to study the cooperation relationship between the technological R&D stage and the technological commercialization stage. The basic idea of this model can be described as the following formula:

$$\min[\theta-\varepsilon(\hat{e}^T S^- + e^T S^+)]$$
$$S.T\begin{cases} \sum_{j=1, j\neq 0}^{n} X_j\lambda_j + S^- = \theta X_0 \\ \sum_{j=1, j\neq 0}^{n} Y_j\lambda_j - S^+ = Y_0 \\ \lambda_j \geq 0, j = 1,2,\cdots,k-1,k,K_n \\ S^+ \geq 0, S^- \geq 0 \end{cases} \quad (2)$$

Where X is the input possibility set while Y is the output possibility set of DMU (j) under evaluation. θ is the value of efficiency of the DMU. The economic implication in the above model is: when θ>1, the technological output is higher than the optimal output; when θ=1, the technological output is equivalent to the optimal output that is to say, the DMU has super efficiency; when θ<1, the technological inputs haven't got its optimal super efficiency. S^-, S^+ is the deficient number of input and output respectively. The model (1) is calculated from the angle of input index. The super efficiency model can also have an output-oriented version.

Cooperation measurement model

(The synergy degree between two sub-stages)

The synergy degree is the quantitative index used here to describe the cooperation level between two sub-stages, specifically, the cooperation relation between technological R&D stage and technological commercialization stage of the whole innovation system. This can be measured in the following formula:

$$C_v(t) = \frac{|F_1(t,x) - F_2(t,y)|}{\frac{1}{2}[F_1(t,x) + F_2(t,y)]} = \sqrt{\frac{[F_1(t,x) - F_2(t,y)]^2}{\left[\frac{1}{2}(F_1(t,x) + F_2(t,y))\right]^2}} = 2\sqrt{1 - \frac{F_1(t,x) \cdot F_2(t,y)}{\left[\frac{F_1(t,x) + F_2(t,y)}{2}\right]^2}} \quad (3)$$

Where F1 is the efficiency of technological R&D stage, F2 is the efficiency of technological commercialization stage; the synergy degree can be expressed as C_v. The smaller value of C_v is, the better the two sub-stage cooperate with each other, which can finally lead to the super efficiency of the whole innovation system.

Because F1 is greater than 0, F2 is also greater then 0, the necessary and sufficient condition of the minimum C_v is as following:

$$g(t) = \frac{F_1(t,x) \cdot F_2(t,y)}{\left[\frac{F_1(t,x) + F_2(t,y)}{2}\right]^2} \rightarrow max \quad (4)$$

So we can define the synergy degree of technological R&D stage and technological commercialization stage as following:

$$G(t) = \left\{\frac{F_1(t,x) \cdot F_2(t,y)}{\left[\frac{F_1(t,x) + F_2(t,y)}{2}\right]^2}\right\}^K \quad (5)$$

Where k is the discriminate coefficient and K is greater than 2. G(t) is the synergy degree between the two sub technological stages, from the angle of mathematics, only when F1=F2, can the F1*F2 reach its maximum. That is to say, when F1=F2, the cooperation between technological R&D stage and technological commercialization perform efficiently and attain its optimal efficiency, also the whole innovation system is on the best practice frontier.

However, this formula can only reflect the synergy degree of the whole innovation system, but it cannot tell the difference of two sub-stage's efficiency level. For example, when F1=0.5, F2=0.5, the synergy degree is 1; when F1=0.7, F2=0.7, the synergy degree is also 1, but obviously, the efficiency level of later data is higher than the previous. Therefore, in order to differentiate the efficiency level of two sub-stage, we combine the synergy degree of whole stage and the efficiency level of two sub-stage together, GD(t) represent the synergy degree,

$$GD(t) = [G(t) \cdot F_1^{\alpha}(t) \cdot F_2^{\gamma}(t)]^{\frac{1}{2}} \quad (6)$$

Where α, γ is underdetermined coefficient $\alpha + \gamma = 1$.

Sample Data

All the data are collected from the China statistical yearbook on science and technology, China statistical yearbook on High technology industry, China statistical yearbook and some relevant data released on the internet organized by the ministry of science and technology of the people's republic of China from year 1998 to 2010. Only the capital stock is taken Zhang Jun's study (2004) for reference. There is obvious time lag from technological input to innovation product output, in the extant study (Wang, 2007; Sharma and Thomas, 2008; Fritsch and Slavtchev, 2010), they are normally considered 1 year or 2 years time lag. When the enterprises applied for the legal patent rights of their innovation products, it usually takes 1 or 2 years for the companies to get permission from the government.

Likewise, when new technology is developed, the innovation patents may wait several years before investing into the market and own profits. Therefore, in this paper, we use 2 years lag in calculating input-output efficiency of each stage within the regional innovation process. So the total time lag is amount to 4 years. The original technological R&D input in stage 1 coming from year t, the intermediate technological innovation product (the output of technological R&D in stage 1 and the input of technological commercialization in stage 2) coming from year t+2, the final technological commercialization in stage 2 coming from year t+4.

In order to compare the variances embedded in innovation efficiency brought by the science and technology reforms which are issued by the Chinese government. We divided 3 consecutive periods for comparison, 1998-2002, 2002-2006, and 2006-2010. We choose these years because it is also the milestone when Chinese government joined the WTO (world trade organization) in 2001 and launched the S&T strategy called "National medium and long-term science and technology development plan" in 2006. All of these actions will certainly influence the innovation efficiency in each period. In summary, the input year of stage 1 are 1998, 2002, 2006; the intermediate output year of stage 1 as well as the input of stage 1 are 2000, 2004, 2008; the final output year of stage 2 are 2002, 2006, 2010.

EMPIRICAL ANALYSIS

Super Efficiency and Synergy Degree of Each Stage

According to the previous two sub-stage framework of innovation system, we use Matlab 7.0 to calculate the efficiency of two sub- processes as well as the whole process. The differences between the efficiencies of each process are compared to evaluating China's regional technical development and commercialization capability. What's more, the coordination measurement model is imported to find how much two sub-stages cooperate with each other. The coordination between two sub-stages will finally influence the efficiency of the whole innovation system. As can be seen from table 2, the average efficiency of whole innovation system show in table 3 over 3 periods is 0.710471, 1.0182, and 0.948437 separately. From the period 1998 to 2002, only 6 provinces, which are approximately 22% of the 27 provinces, reach the efficiency above 1 of the whole innovation system. The result turned better from the period 2002 to 2006; there are 13 provinces that are almost 50%, reached its super efficiency which is half of the selected 27 provinces. Then, 11 provinces performed efficiently during the period 2006 to 2010. In total, Chinese innovation system and its two subordinate technical stages are still under low level, only few provinces are on the best efficiency frontier. The development level of technological innovation system among the 27 provinces is unbalanced severely.

Table.1. Super efficiency and synergy degree score of R&D stage, commercialization stage and overall stage in innovation system of 27 Chinese regions in 3 individual periods

Region	Period 1 : 1998-2002				Period 2 : 2002-2006				Period 3 : 2006-2010			
	Stage1	Stage2	Overall stage	Synergy degree	Stage1	Stage2	Overall stage	Synergy degree	Stage1	Stage2	Overall stage	Synergy degree
1.Beijing	5.7339	0.8894	1.0104	0.6988	7.2442	0.3703	0.9834	0.2368	6.6367	0.8662	1.0862	0.6325
2.Tianjin	0.8397	1.5052	1.5463	0.9749	1.1375	2.3658	2.1176	1.1233	0.7771	1.3418	1.0945	0.9387
3.Hebei	0.5152	0.5182	0.3008	0.7188	0.8116	0.6520	0.6107	0.8428	0.6594	0.6275	0.6873	0.8015
4.Shanxi	1.7700	1.0214	0.9295	1.0761	2.2140	0.7321	1.2773	0.8429	0.6541	0.6245	0.6511	0.7990
5.Neimenggu	1.3992	0.8578	0.5427	0.9864	0.9785	1.2228	1.2902	1.0330	1.0125	1.3239	1.4271	1.0569
6.Liaoning	0.6349	0.7593	0.7593	0.8266	0.8861	0.5321	0.7573	0.7770	0.8348	0.6410	0.6746	0.8405
7.Jilin	0.9809	0.8802	0.5373	0.9611	1.0895	1.1901	1.6978	1.0650	0.9838	1.2660	1.2529	1.0398
8.Heilongjiang	0.7044	0.2675	0.2675	0.5258	1.2853	0.3048	0.5286	0.4904	1.3873	0.4090	0.4449	0.6104
9.Shanghai	1.1962	1.1034	1.3997	1.0701	1.7520	0.7068	1.1599	0.8643	1.2649	1.0576	1.1293	1.0669
10.Jiangsu	0.6553	0.9803	0.8380	0.8599	0.5865	0.5967	0.5158	0.7691	0.7969	0.8476	0.7311	0.9057
11.Zhejiang	1.5026	0.7090	1.0280	0.8852	1.7164	0.5996	1.0913	0.7730	1.8404	0.8033	0.8558	0.9330
12.Anhui	1.4261	1.1450	0.8928	1.1169	0.9790	0.6780	0.5764	0.8729	0.9789	1.1834	1.0110	1.0282
13.Fujian	1.4337	0.8750	1.1496	0.9964	0.9754	1.3696	1.5719	1.0447	0.6335	1.3248	0.8687	0.8378
14.Jiangxi	0.7767	1.1119	0.5370	0.9337	0.6333	1.2165	0.9313	0.8438	0.4843	0.8397	0.6914	0.7410
15.Shandong	0.5759	1.1457	0.9565	0.8026	0.8665	0.8247	1.3314	0.9189	0.6620	1.0434	1.2960	0.8660
16.Henan	0.5828	0.5127	0.3611	0.7363	1.3171	0.6853	1.3552	0.8777	2.2265	0.6513	1.5430	0.7686
17.Hubei	0.7452	0.4683	0.4683	0.7286	1.2427	0.2339	0.9170	0.3915	1.0320	0.8904	0.9277	0.9737
18.Hunan	1.4335	0.4321	0.4321	0.6315	1.0438	0.2560	0.4761	0.4549	1.1580	0.9298	1.2189	1.0065
19.Guangdong	1.6193	1.1119	1.0266	1.1184	2.4100	1.4559	1.4543	1.2853	1.4740	2.0737	2.0575	1.2844
20.Guangxi	1.2831	1.3528	1.3491	1.1470	0.6775	0.8146	0.8795	0.8546	0.6634	2.0028	1.1920	0.8027
21.Sichuan	0.5579	0.7925	0.4977	0.7908	0.6365	0.5963	0.6176	0.7841	0.7524	0.5124	0.5245	0.7596
22.Guizhou	1.1163	5.5699	0.6483	0.8785	1.5833	1.1637	1.4024	1.1379	0.7070	0.7941	0.7735	0.8627
23.Yunnan	1.3872	0.3356	0.3356	0.5182	1.4597	0.3206	0.7110	0.4885	0.5551	0.5620	0.5519	0.7473
24.Shaanxi	1.5692	0.3408	0.3664	0.5015	1.8342	0.3154	0.7501	0.4368	3.4814	0.6108	0.9742	0.6134
25.Gansu	0.8978	0.2342	0.1748	0.4445	1.3731	0.6844	1.4016	0.8743	0.9560	0.6833	0.6600	0.8741
26.Ningxia	1.2943	0.7529	0.5555	0.9241	0.7756	2.4206	0.5809	0.8605	0.5307	1.3408	0.5402	0.7464
27.Xinjiang	0.9892	0.2717	0.2717	0.4869	1.7235	0.3437	0.5044	0.4865	1.3279	0.7287	0.7425	0.9076
Mean	1.2452	0.9609	0.7105	0.8274	1.4531	0.8390	1.0182	0.7937	1.2767	0.9622	0.9484	0.8683

Beijing performs best in develop and research technology stage (5.7339) while Hebei (0.5152) displays the opposite in the first period. Beijing, as the capital of China, has many national key universities and research institutions like Peking University and China academy of science. Compared with Hebei, it owns better advantage of a great quantity of technological resources. Hebei, often known as a major agricultural province in China, is lack of technology development motivation, not to mention the ability to foster these technologies into market and make profits.

Guangdong is the only province that performs efficiently in two sub-stage and whole innovation stage. Its synergy degree is also above the high level across the 3 periods. As the pilot province in reform and opening of China began in 1978, Guangdong is always on the technological developing frontier. Guangzhou government often launched some technological policies to attract the foreign investment and foster self-innovation competence. All these policies and technology resources help Guangzhou's economy booming in high speed. From table 3, we can see the efficiency of Guangdong in the whole innovation process increased year by year and reached to 2.575 which rank the 1 position among 27 provinces over the period from 2006 to 2010.

Because of the differences of natural condition, technology resource and geometry position, the innovation system has a significant gap from provincial level. The eastern region in general performs better whether from technological development capability or from technological commercialization process to make profits. Traditionally, the western and middle regions of China are considered below the average efficiency of innovation production system. This phenomenon will be discussed in the later chapter.

From the angle of systematic synergy degree between technological R&D development and technological commercialization, the efficiency of the whole innovation system is influenced by the cooperation relation of each sub-stage. Table 3 illustrates the run chart of average performance for two sub-stages as well as the whole innovation stage across 3 periods.

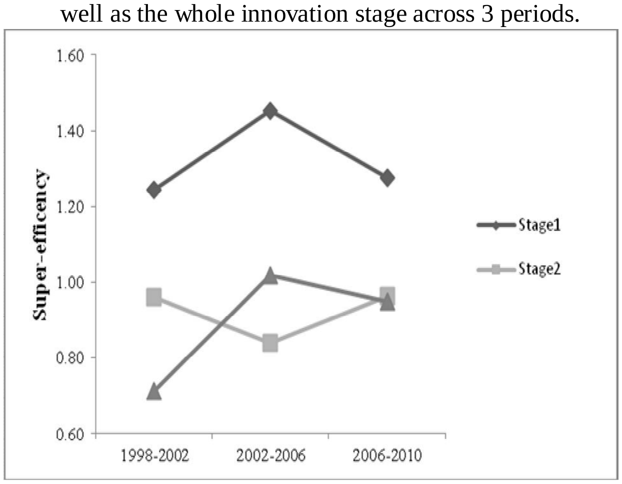


Fig.3. Comparison between average value of super efficiency of stage 1, stage 2 and overall stage

Observing the dynamic tends of the fluctuation from the whole innovation system, the stage 1 increased continuously from 2002 to 2006, reached the optimal level, and then decreased from 2006 to 2010. The efficiency of stage 2, which represent the region's capability to transform technology into profit, decreased first from 2002 to 2006 then increased later from 2006 to 2010. According to the chart, the overall innovation stage has same moving trend with stage 1 which indicates that the stage 1 influenced the efficiency variation of the overall innovation system to a large extent. The value of stage 1 lay above the stage 2 thus generates variances between technological R&D stage and technological commercialization stage. Though the technology development ability is great in stage 1, due to the lower level of stage 2, the whole stage still remains in the inefficient condition.

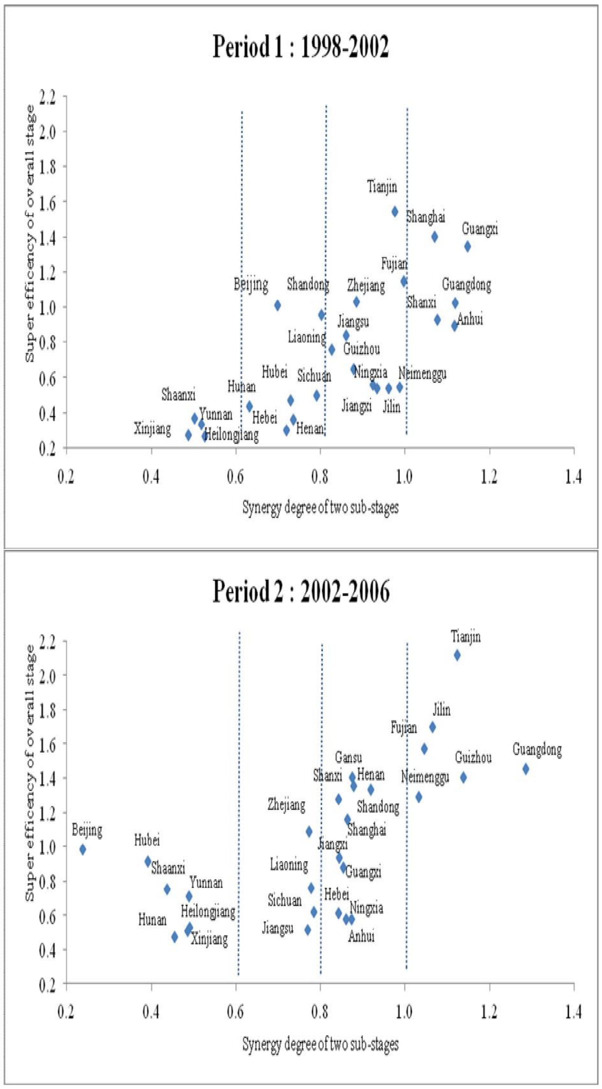
Viewing the static tends, stage 1 is greater than 1, which reveal the technological develop ability of a region is efficiency across the 3 periods from 1998 to 2010. Compare to stage 1, though the score of stage 2 is close to 1, the efficiency of technological commercialization stage is by and large low. The score of stage 1 is better than stage 2. This lead the efficiency of the whole innovation production process lay in a relative low level. Specifically, the score of stage 1 in 2010 is already on a high level which is full of efficiency. However, the score of whole innovation system is still below 1. This mainly owns to the low score attained by stage 2, thereby constrain the development of the whole technology process.

As Guan and Chen's research (2012), the efficiency of the whole innovation system is determined by the multi input-output technological stages instead of by a single stage. Only when the two sub-stage reach to balance level, the attention diverted to technological commercialization stage is equivalent to technological R&D stage, can then the whole innovation stage reach to the optimal efficiency.

Comparison between Synergy Degree and the Efficiency of the Whole Innovation Stage

In order to analyze the relation between two sub-stages and the influence each stage applied to the efficiency of whole innovation process deeply, we introduce synergy degree to explain the cooperation between two sub-stages. The scores of efficiency of whole innovation system is x-axis while the scores of synergy degree is y-axis. That is to say, the x-axis means cooperation level the technological R&D process and technological commercialization process interact with each other. The y-axis means the super efficiency of a region for whole innovation system performance. During this chapter, three rectangular coordinate systems are imported to compare the dynamic change of each region performed in the technology innovation development across 3 periods over 10 years.

Also, on the basis of value of synergy degree, we divided the whole innovation system into 4 categories-I, II, III, and IV (divided by the dotted line in Fig 4) to analyze synergy degree variance among 27 provinces from 1998 to 2010. I category scores below than 0.6 is discordant synergy degree; II category scores from 0.6 to 0.8 is weak synergy degree; III category scores from 0.8 to 1 is normal synergy degree; IV category scores greater than 1 is strong synergy degree in sequence.



In different synergy degree categories, the average efficiency of whole innovation system applied by each region change with different period. From vertical point of view, the super efficiency of discordant synergy degree from 1998 to 2006 is 0.2832 and the number is 0.6958 from 2002 to 2006. There is no province lay in the category I from 2006 to 2010.

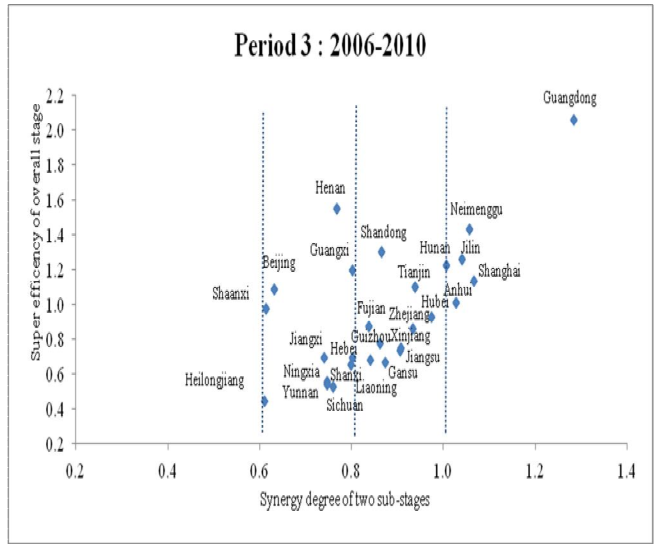


Fig. 4. Comparison between synergy degree of two sub-stages (R&D stage and commercialization stage) and super efficiency of overall stage in three individual periods

The efficiency of whole innovation system increased fluctuant with time. This can be found in the later categories, the efficiency of normal synergy degree change from 0.8174 to 1.0104, and then score 0.8809 at the last period. When we observe the chart from horizontal point of view, the increasing trends still exist. The efficiency of whole innovation system increased progressively from 0.6958 to 1.5890. Other periods can also verify this trend. In summary, from table 2, we can see a positive correlation between synergy degree and super-efficiency of whole innovation stage. Those provinces which located in the IV category usually score greater than 1 and perform a high efficiency of the whole stage. Regions performed well in both stage 1 and stage 2 can have a better efficiency level in whole innovation system. The positive correlation can be verified in each province alone.

Table.2. Average value of each synergy categories from 3 individual periods

Period	Average value of synergy degree			
	Discordant	Weak	Normal	Strong
1998-2002	0.2832	0.5117	0.8174	1.1196
2002-2006	0.6958	0.8000	1.0104	1.5890
2006-2010		0.7786	0.8809	1.3494

Guangdong perform stably efficiency across 3 periods that stands out from the 3 charts, it has a strong capability not only in the technological R&D development but also in the transformation of technology into owning market profits. Guangdong scores greater than 1 from 1989 to 2020, no matter from the efficiency in each sub-stage and the whole stage, or from the synergy degree. The strong competitiveness of Guangdong owns to many complex reasons. Guangdong is the first group of east provinces in China joining in the reform and opening up revolution in 1978.The revolution and its great geometry condition enables it to gain more technology resource than the other provinces. Other provinces like Shaanxi, Heilongjiang, Xinjiang and Yunnan located in the discordant synergy degree performs inefficiently as their efficiency score less than 1 from 1998 to 2006. In Provinces like Shaanxi, Heilongjiang, Xinjiang and Yunnan, their GDP development are often under the average level of China since they are located in the western part of China and they are lack of technological resources. Their economy development patterns are still in the labor intensive model. So that they ability to translated the innovative production into market profits remain low from 1998 to 2002. The highest efficiency score for technological commercialization stage among them is no more than 0.5.

The positive correlation can also see from the comparison between Tianjin and Beijing. We can see from Fig 4, Beijing which is located in the weak synergy degree with the efficiency of whole stage, scores at about 1, Tianjin, which is located in the normal synergy degree, scores about 1.6 in period 1. From 2002 to 2006, Beijing decreased to discordant synergy category while Tianjin increased to the strong category ranking the first in the efficiency level of whole innovation stage. Beijing turned better in either synergy degree or the efficiency level of whole stage later. Yet, Tianjin still performs better than Beijing. When we check table 2, the reason for this phenomenon can be easily discovered. Beijing scored 7.2442, 0.3703 in stage 1, stage 2 separately. The huge distance between two sub-stages displaying a low synergy degree thus caused a low efficiency in the whole stage.

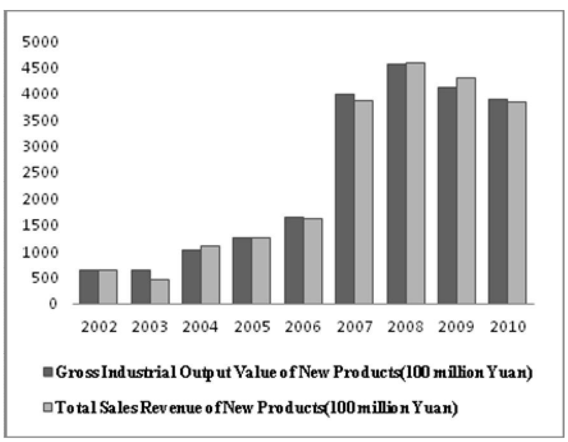
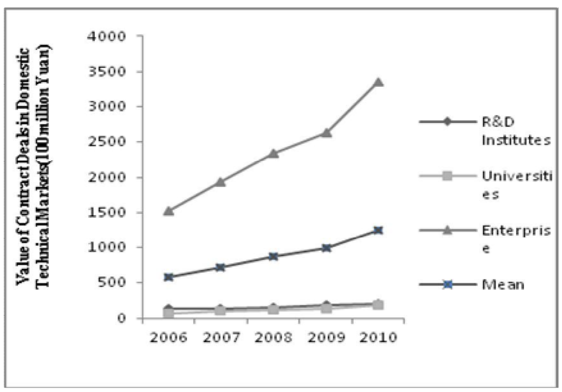


Fig.5. Gross industrial output value of new products and total sales revenue of new products from 2002 to 2010

The two provinces located along side each other in the eastern China while Beijing is the capital of China is the economy and political center. Generally speaking, Beijing is considered to own more technology resources, stronger economy background and larger amount in science and technology researchers. However, according to the analysis above, Beijing is not performing better than Tianjin across 3 selected periods. In fact, by analyzing the panel data of Beijing further, we find out that it rank first in scientific papers and patent output of the first stage, so we can see from table 1 it also rank first in stage 1 that score 5.7339, 7.2442 in period 1, period 2 separately. The output in stage 1 act as the intermediate variable is also the input in stage 2. Beijing has a rich education system and technology resources, but it is not able to transform these resources to market profit. As seen from Fig 4, the output value of stage 2 is very low before 2006. So the efficiency is very low scoring 0.3703 of stage 2 in from 2002 to 2006. After the S&T strategy launched by centre government in 2006, Beijing may begin to focus on the technology commercialization problem. As a result, the efficiency value of technological commercialization stage increased to 0.8662 from 2006. Fig 5 illustrates the gross industrial output value of new products in Beijing increasing dramatically since 2006.

By comparing the change trends of synergy degree from the overall 3 charts, we can easily find that the efficiency of most regions increased as the synergy degree climbed up. Particularly, those provinces like Shaanxi, Yunnan, Heilongjiang and Xinjiang that are located in the discordant synergy category in the past from 1998 to 2006 increased to a higher synergy degree in the third period. There is no province lay in the discordant synergy category from 2006 to 2010 that also coincide with the science and technology revolution strategy enacted by Chinese central government in 2006. In addition to the above analyzed provinces, most of the other regions are also located in the weak synergy and normal synergy categories across the 3 selected periods. Also, most of them are beneath 1 of efficiency level in the whole technological stage. Most provinces like Sichuan, Shandong and Jiangxi do not have a significant change during the 3 periods, which means the efficiency of those provinces remain inefficient from 1998 to 2006. There is no obvious regional division among Chinese regions. In summary, though the efficiency of some provinces increased as the deeply development of Chinese S&T strategy, most regions remain inefficient in both whole stage and two sub-stages.

In traditional thoughts, regions with higher value of industrial output like Jiangsu and Zhejiang should perform effectively. However, they located in the normal synergy degree with an inefficient whole innovation system from 2006 to 2010, wherein Jiangsu lay in the weak synergy degree from 2002 to 2006. They have great technology resources and more opportunities to cooperate with foreign investment. The technological R&D ability and technological commercialization ability of the two eastern provinces that also profit from the first technology revolution are not equal with their economic level. However, some regions like Neimenggu and Jilin that have lower value of industrial output in traditional views but have an efficient in whole innovation system in reality. Though Neimenggu lay in the normal synergy degree and score about 0.5 in the first period, it has climbed up to the strong synergy degree and scores 1.29 in the second period. What's more, it scores 1.4271, just second to Guangdong in efficiency of the whole innovation system in the third period. Jilin also displays the similar movement like Neimenggu and attains the super efficiency in later periods. The amount of new industrial output is obviously an important part in the technology innovation system. We should focus more closely on the efficiency of innovation during the technology development progress. As is indicated in S&T strategy, the technology resources are significant to the innovation progress of a region. Nevertheless, the abundant in technology resources is not proportional to the



efficiency of the innovation itself.

One reason for the abnormal phenomenon is the policy environment amid technology market development. The local governments place first the importation of foreign advanced technology when making technological marketing development strategy. It is a common case that when the governments from provincial level neglect the transformation of technology, these regions are then not able to make use to foreign technology to increase their self-innovation profits. The local government used to pay less attention to the technology transformation process, despite of the fact that the enterprises and R&D institution have developed some advanced technologies. Most of the advanced technologies have failed to enhance market efficiency. The extensive technology development and planned economy pattern are important to Chinese innovation production system in the past decades. However, when the technology development stage expands, the efficiency of the technological commercialization stage has not increased synchronously. Since China joined the WTO in 2001, the expansion of Chinese technology scale begins to call for the self-innovation technology in innovation system. The overlook of the technological commercialization stage constrain the economy development potential of each region, and it has also had adverse effect on the usage of technology resources. This will be a restriction for regional economy and national region development strategy in long run.

The other reason is because the R&D institutions and universities in those inefficient regions are lack of the technological transformation ability. Fig 6 is the change trends of value of contract deals in Chinese technical markets from 2006 to 2010. The value of contract deals from enterprises may be above the value from R&D institutes or universities. Although value of the enterprises attains a high level, the large distance between value of enterprises and R&D institutes along with universities lower the average value of contract deals. During the research, we find out that some provinces have a comprehensive education system and S&T personnel. However, the final technological production conducted by the S&T personnel is limited. Because of the asymmetric information and slow information spreading speed in the market, the companies are hard to find the suitable R&D institutions to solve technological problem. In the mean time, R&D institution and universities often deviated from the actual demand of market. As they can't gain financial fund from companies, most of technology they developed limited to the scientific area. The low participation on technological commercialization process is one of the reasons for the inefficient in stage 2.

Fig.6. Value of contract deals in domestic technical markets of R&D institutes, universities and Enterprise from 2006 to 2010 (the statistic number changed from 2006, the number of 2005 are not belong to the same standard, so in this paper we count the value from 2006)

CONCLUSION AND POLICY IMPLICATIONS

Empirical Findings

This paper used the super- efficiency DEA method to calculate the efficiency of 27 Chinese regions based on the network two sub-stages from technological R&D stage to technological commercialization stage from 1998 to 2010. A synergy degree model is imported to analyzing the cooperation relation between two sub-stages and the whole technology innovation stage. Four synergy categories is divided from collaborate coefficients between two sub-stages to help further analyzing the efficiency of Chinese technology innovation system. This study is a preliminary discussion that hopes to make up the emptiness in the study of relation between two sub-technological stages and the effect it does to the whole innovation stage from empirical study.

Overall, the whole efficiency of technology system presented a growth trend. Only 6 provinces are efficient during technology production process from 1998 to 2002. After China joins WTO, the regions are facing more opportunities. The number of provinces with good efficiency grows bigger since 2002. On the other hand, the number has yet not reached to be more than half of the selected 27 provinces from 2006 to 2010. Most regions in China still remain inefficient both in the technology R&D ability and technological commercial ability. Also, there is huge development division from R&D technology stage to commercial technological stage. In fact, the R&D development stage scores greater than the commercial stage over 3 periods. This means that there is still great potential for the improvement both in commercial technology stage and the whole innovation stage of Chinese technology innovative system.

The empirical study shows that the synergy degree of two sub-stages is a key factor that will affect the efficiency of the whole innovation stage. The efficiency development of whole innovation system is like the "Cask Effect", the shortage of any sub-stage of technological production process will influence the level of whole technology innovation process. The increasing value of any technological sub-stage may on the other hand decrease the efficiency of the whole innovation system when other technological stages remain in a low level. So the policy maker in China should pay more attention to the importance of commercial technology. An equivalence policy strategy in both stages is in high demand.

The local governments often focus on the technology R&D ability and neglect the technological commercial ability. According to the previous studies, the R&D efficiency is a way that is better than commercial ability. Those provinces located in the eastern regions with great economy advantages yet attain a low level of commercial efficiency. Although the technology market scale grows with the opening S&T strategy, the market transaction frequency remains still very inactive. The scientific findings and patents developed in the technological R&D stage are been downplayed and wasted due to the lack of market transformation capability. The insufficient cooperation between R&D-oriented institution and market-oriented enterprises should be broken down.

An in-depth research in the synergy degree by comparison of value of new products from R&D institution, universities and enterprises showed that, regions that have a comprehensive education and research institution background fail to commercialize their technology output successfully to the market. The output value from R&D institution and universities is much less than the value created from enterprises.

The extensive development model in the past has helped Chinese economy increase with a rapid growth. However, after the S&T technology revolution in 2006, the technology model on longer adapt to the current technology development. The extensive importation of foreign technology without being transformed to self-innovative technology is not suitable any more. Though the large amount of investment in S&T resource is still important, it does not guaranteed a high efficiency in technology innovative output.

POLICY IMPLICATIONS

Based on the empirical results above, we can summarize some important policy implications. As Chinese economy stepped into a new technological era, the planned strategy in technology development needs to be translated to a more market-oriented strategy. Firstly, the regions with a low efficiency of whole innovation system and low synergy degree should focused more on the commercial technology process. It is significant for the government to make full use of the technology resources and search for a way to transform the imported technology to self-innovation product.

Secondly, regions at all levels need to enhance the cooperation between R&D institutions and enterprises. The cooperation blank has already led to the inefficiency of many regions in China. The local governments should analyze the successful cooperation pattern from foreign samples and reform it into the Chinese characteristic model. The R&D institutions and universities can try to apply the patents and try to link with market demands as well. By supporting the technological intermediary organizations and building a cooperation platform, the enterprises and R&D institutions are expected to be able to have a mutual information communication, thus helping to improve the efficiency of commercial technology process.

Thirdly, the regions that enjoy a geometry connection can build a regional cooperation city zone among different provinces. On July 18th of 2012, at the meeting of national innovative pilot city, the ministry of science and technology of China is calling for the rising of urban construction in regional innovation development. Chinese government is calling for the construction of such city zone to put all the useful technology resources together and try to maximize the cooperation value of technological resources from different regions.

LIMITATIONS AND FUTURE STUDIES

Like extant studies, this paper also suffers some limitations. In this research, a two sub-stage which includes some endogenous and controllable inputs is applied to measure the efficiency of technical innovation system, but the exogenous and uncontrollable effects like policy strategy, economic environment and government enforcement from macro level are also important and worthy of attention. Notwithstanding the above limitation, the efficiency study on the basis of cooperation measurement model is a fertile area for future research. As a continuation of this paper, we strongly encourage research on applying detailed measurements as important factors into the framework of DEA model. In particular, some uncontrollable factors like policy strategy and social environment which have a great influence on the performance of innovation production process. In addition, it is interesting to explore the exact sources from macro environment (like government's ability to help enterprises develop technical products in technical development stage) to micro entrepreneurial capabilities (the ability to take the technical production to market and make benefits) that might cause the efficiency performance differences between regional areas. Finally, the innovation framework is not subject to China's case, so it can contribute to more specific innovation systems adapting to different regions and countries.

REFERENCE

Andersen P. and Petersen N. C, 1993. A procedure for ranking efficient units in data envelopment analysis, Management Science 39, 1261–1264.

Banker, R.D. and Gifford, J.L. 1988, A Relative Efficiency Model for the Evaluation of Public Health Nurse Productivity. School of urban and public affairs, Carnegie Mellon University.

Banker R D,Charnes A,Cooper W W. 1984, Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis[J] .management science, 30(9):1078-1092.

Cooke P. Regional Innovation Systems: Competitive Regulation in the New Europe [J]. Geoforum, 1992,23(3):365-382.

Erkko Autio, 1998, Evaluation of RTD in regional systems of innovation, European Planning Studies, Volume 6, Issue 2, , pages 131-140

Fritsh, 2004, Cooperation and the efficiency of regional R&D activities, Cambridge Journal of Economics 2004, 28, 829–846

Fritsch M,Slavtchev V. 2010, How does industry specialization affect the efficiency of regional innovation systems?[J].The Annals of Regional Science, 45(1):87-108.

Goldsmith, Raymond W. 1951, A Perpetual inventory of national wealth, Studies in income and wealth: National of Economic Research, (14):5-61

Jeffrey L. Furman, Michael E. Porter and Scott Stern, 2002, The determinants of national innovative capacity, Research Policy 31 (2002) 899–933

Kaihua Chen & Jiancheng Guan (2012): Measuring the Efficiency of China's Regional Innovation Systems: Application of Network Data Envelopment Analysis (DEA), Regional Studies, 46:3, 355-377

Lee H,Park Y,Choi H. 2009, Comparative Evaluation of Performance of National R&D Programs with Heterogeneous Objectives: A DEA Approach[J]. European Journal of Operational Research, 196(3):847-855.

Moon H. S. And Lee J. D. (2005) A fuzzy set theory approach to national composite S&T indices, Scientometrics 64, 67–83.

Nasierowski W, Arcelus F J 2003, On the efficiency of national innovation systems[J].Socio-Economic Planning Sciences, 37(3):215-234.

Sharma S,Thomas V J. 2008, Inter-country R&D efficiency analysis: An application of data envelopment analysis[J]. Scientometrics, 76(3):483-501.

Wang E C. 2007, R&D efficiency and economic performance: A cross-country analysis using the stochastic frontier approach [J].Journal of Policy Modeling, 29(2):345-360.

Xiao huaxiu, 2004, Research on relationships between sci-tech advancement and urban sustainable development, Master Dissertation of Wuhan University of Technology

Zabala-Iturriagagoitia J M, Voigt P, Gutiérrez-Gracia A, et al. 2007,Regional Innovation Systems: How to Assess Performance[J].Regional Studies, 41(5):661-672.

Zhang Jun, 2004, Provincial capital stock estimation in China from 1952 to 2000, Economic Study