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The Spatial Correlation Analysis of China's Regional R&D Technical Efficiency

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Abstract
The paper uses SFA technique to measure the regional R&D technical efficiency in China during 1999~2008, applies spatial measurement economics technique to analyze the correlation and convergence characteristics, and builds a spatial convergency model to analyze the spatial convergency characteristics of the regional R&D technical efficiency. The analysis result shows that there appears positive correlation characteristic and an absolute convergence trend on the regional R&D technical efficiency in China, and the effect of spatial geographical factors on the regional R&D technical efficiency is significant.

Key words: R&D Technical Efficiency; Spatial Correlation Characteristic; Spatial Convergence Characteristic

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INTRODUCTION
The research of R&D technical efficiency appears to be increasingly important in the theories of economic growth. After Farrell (1957) first introduced it[1], people get better understanding of the original sources of economic growth. R&D technical efficiency is an important index to measure the quality of the R&D activities. The term Regional R&D technical efficiency mentioned under this article is use to measure the maximum productivity of the major company under current techinique. That reveals the provincial R&D activities close to its front which reflects the current exercising level of the R&D technology. This topic based on China's regional R&D technical efficiency has draw great attention from the related academic scholars. However, few research was done.

Knowledge and technology spillover leads the economic development to grow similar under regional area which indicates the integration of industries under spatial agglomeration and accelerating regional economy[2]. The effect of knowledge and technology spillover would also be affected by space, indicated by professor Grilliches(1979), Adams (2002), Keller(2002) and many others who have done researches about technology spillover[3, 4]. The study shows that the spacial influence decrease while the geographic distance grows; however, the traditional convergence hypothesis didn't include the spatial factors. For a long time, that limitation existed in the spatial correlation and heterogeneity assumption study, and also in widespread use of ordinary least squares. That lack accuracy applied in practical applications caused great bias in the model, further, that lead the results and inference of the related economics research to be unprofessional and lack of scientific meaning.

Our local Chinese scholars had already started to pay their attentions to the influence of spatial factors while study China's economy convergency issue. For example, in the study of the country's per capital GDP growth and China's regional economy growth, Lin Guangpin applied the spatial econometrics method[5], and Wu Mingyu in 2009 studied the spatial correlation and convergence of people's consumption level[6]. Both above studies reveal that the spatial factor plays a significant role in China's economic growth convergence. Then the question rises

to be, does the geographic factors affect the convergence of our country regional R&D technical efficiency as well? The following article will explain the question by focusing on China's regional R&D input-output efficiency problem; through stochastic frontier analysis and spatial econometrics method, to measure the regional technical efficiency and analyze the convergence of spatial correlation.

1. MEASUREMENT OF CHINA'S REGIONAL R&D TECHINCAL EFFICIENCY AND ANALYSIS OF ITS SPATIAL DIFFERENCE

1.1 Measurement of China's Regional R&D Technical Efficiency

1.1.1 0utput Index

It exists highly significant correlation between R&D and patent, even-through it lack effectiveness (Goto, Suzuki, 1989)[7]. Patent is a reliable index to measure the innovation activities (Acs, Anselin, 2002)[8]. Patent is also being widely used to measure the efficiency of innovation, for example, Nasierowski, Arcelus (2003), Wang (2007), Akihiro and Shoko (2008)[9, 10]. Patent index includes patent accepting quantity index and patent authorization amount index. Since the patent authorization amount index is more easily to be affected by the government and other social influence, this index resulted to be uncertain[11]. The patent accepting quantity index reflects to be more accurate on the other hand, and that be the reason we choose to use the quantity of domestic patent accepting (unit:a) as the R&D output index to measure the R&D activities in this article.

1.1.2 Input Index

This article uses perpetual inventory system to calculate R&D capital stock.Calculatioon model as follow:

$$K_{it} = (1-\delta)K_{i(t-1)} + E_{i(t-1)} \quad (1)$$

In this equation, K_{it} indicates the i province, $K_{i(t-1)}$ indicates the phase of the R&D capital stock, and δ is the depreciation rate. According to the Griliches[12],Wu Yanbing[13] who estimated R&D capital depreciation rate, the depreciation rate is assumed to be 15%.$E_{i(t-1)}$ indicates the number i province in the $t-1$ phase the actual expenditure of R&D research,and it is assumed as R&D price index which Zhu Pingfang and Xu Wwimin[14] structure. And R&D price index=0.55×consumption price index+0.45×investment in fixed assetes price index,taking 1998 as the base year on the R&D expenditure deflator.

This article assumes that the growth rate of R&D capital stock is equal to the growth rate of R&D expenditure. The measurement model of the base-year capital stock as follows:

$$K_{i0} = \frac{E_{i0}}{g+\delta} \quad (2)$$

In this equation, K_{i0} is the R&D base-year capital stock, E_{i0} is the actual R&D base-year expenditure, g is the average growth rate of actual R&D expenditure in inspection period,and δ is R&D capital depreciation rate. According to the model (4) and model (5) which can calculate R&D capital stock of China's 30 provinces from 1999 to 2008.

1.1.3 Influent Factors Variables

Griliches(1990) and other scholars think that R&D action itself is a productive process and each province is regarded as productive unit of R&D activities which ueses some R&D resource to get R&D output. Regional R&D activities is hard to aviod a lots outside factors, therefore this article focuses on these factors how to effect inefficient item of R&D technical efficiency which are government surpport, science activies and foreign direct investment. The specific variables are set as follow: i) GOV_{it} is government support for the technical activities, and it is the i province in t year the proportion of the fiscal investment into technology, which is used to reflect the situation that government support for regional R&D technical is inefficiency; ii) $TRAD_{it}$ is foreign trade dependence, and it is the ratio of total volume of import and export trade on GDP, which is used to show that the effcet of foreign trade dependence on regional R&D technical is inefficient. In this situation, according to the average exchange rate of RMB for the year can convert the dollar which express the total of import and export value into RMB; iii)FDI_{it} shows foreign investment dependence, and it is i province in t year the ratio of actually directly used foreign investment on GDP which it used to reflect that the provinces of the absorption of foreign direct investment affect regional R&D activities relative scale inefficiently. And in this situation, according to the average exchange rate of RMB for the year can convert the dollar of the actually directly used foreign investment into RMB; iv) IND_{it} indicates industrialization level, and it is i province in t year the ratio of industrial output value on GDP, which is uesd to reflect that the effect of industrialization on R&D technical activities is inefficient.

1.1.4 Measure of R&D Technical Efficiency

According to the basic principles of Battese & Coelli model, this article builds a model of stochastic frontier production function to measure[15]. China's regional R&D technical efficiency as follow:

$$\ln y_{it} = \beta_0 + \beta_1 \ln K_{it} + \beta_2 \ln L_{it} + \beta_3 t + \frac{1}{2}\beta_4 (\ln K_{it})^2 + \frac{1}{2}\beta_5 (\ln L_{it})^2 + \frac{1}{2}\beta_6 t^2 + \beta_7 \ln K_{it} \ln L_{it} + \beta_8 t \ln K_{it} + \beta_9 t \ln L_{it} + v_{it} - u_{it} \quad (3)$$

$$TE_{it} = \exp(-u_{it}) \quad (4)$$

$$\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2) \quad (5)$$

In (3) equation, i is the number of provinces, $i=1,2,\cdots,N, N=30$; t is time serial, t=1,2...,T, T=10 (from 1999 year); y_{it}, K_{it}, L_{it} is $i$province in $t$year the domestic patent acception quality, R&D capital stock and R&D staff investment, β_0, β_1,...,β_9 is estimating parameter. And errors are made up of two parts. One part is $v_{it} \in iid$,and it follows normal distribution $N(0,\sigma_v^2)$.σ_v is standard deviation of the normal distribution which shows outside factors of China's regional R&D and some statistical errors on dates. The another part is $u_{it} \in iid$ and it follows $N(mit,\sigma_u^2)$, and m_{it} is technical inefficient item, and σ_u is standard deviation of truncated normal distribution which reflects these random factors about i province in t year. v_{it} and u_{it} are independent. In (4) equation, TE_{it}=exp(–u_{it}) indicates the technical level of i province in t year. As u_{it}=0,TE_{it}=1,which shows this province in the technical avairable state. At that time, the prodcutive point of the province is on production frontier. As $u_{it}>0$,$0 \le TE_{it} <1$,this statement is technical inefficiency. At that time, the productive point is under the production frontier.

The assumption model whether to be reasonable, it should be taken the proportion of invaild random errors,which means the value of γ in this equation that is $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$ $(0 \le \gamma \le 1)$.when γ is more and more close to 1,it means efficient meansure errors mainly from inside controlling factor u_{it}. In contrast, when γ is increasing close to 0, it means efficient meansure errors mainly from outside controlling factor.

1.2 Date Source and Measurement Results

The article's date source is from *China Technical Statistical Yearbook*(1999~2011) and *China Statistical Yearbook*(1999~2011) and *Fifty-five Years of new China's Compilation of Statistics*. The sample contains China's 30 provinces (excluding Hong Kong and Tibet),which is divided into eastern, central,western regions. Eastern regional includes Beijing, Tianjing, Liaoning, Shanghai, Jiangsu, Zhejian, Fujian, Shandong, Guangdong and Hainan provinces.The central region includes Shanxi, Jilin, Heilongjian, Anhui, Jiangxi, Henan, Hubei, Hunan. Western region includes Neimenggu, Chongqing, Sichuan, Shaanxi, Guizhou, Yunnan, Gansu, Qinghai, Ningxia, Guangxi, Xinjiang. Using Frontier 4.1 software to measure the regional R&D technical efficiency, its result is γ=0.9861 which is very close to 1 and it is through significant test with $p \le 0.01$, which means combined errors item is mainly from technical inefficient u_{it} and random errors item v_{it} brings little influence. These results prove the rationality of the article using stochastic frontier technology. China's regional R&D technical efficient distribution as follow figure 1:

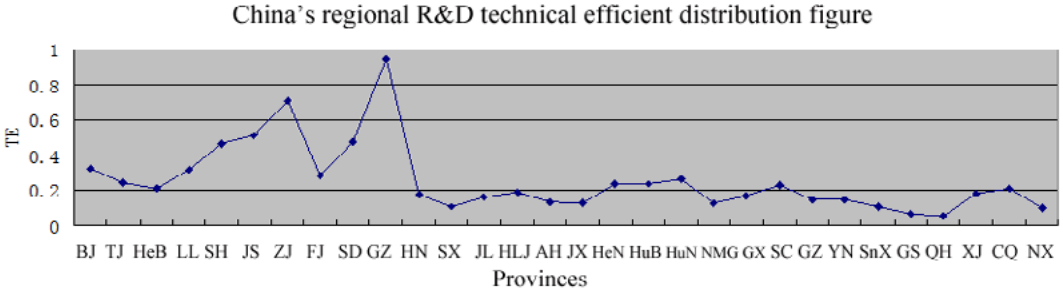

Figure 1
China's Regional R&D Technical Efficient Distribution.
Abbreviation of provinces present: BJ-Beijing, tj-Tianjing, HeB- Hebei, LL-Liaoling, SH-Shanghai, JS-Jiangsu, ZJ-Zhejiang, FJ-Fujian, SD-Shandong, GD-Guangdong, HN-Hainan, SX-Shanxi, JL-Jilin, HNJ-Heilongjiang, AH-Anhui, JX-Jiangxi, HeN-Henan, HuB-Hubei, HuN-Hunan, NMG-Neimenggu, GX-Guangxi, SC-Sichuang, GZ-Guizhou, YN-Yunnan, SnX-Shannxi, GS-Gansu, QH-Qinghai, XJ-Xinjiang, CQ-Chongqing, NX-Ningxia.

According to figure 1, our country regional R&D technical efficiency is basicly decreasing from east region to western region. Eastern regional R&D technical efficient level is obviously higher then other regions. And the difference of R&D technical efficiency between central and western region is unobvious.From this figure,these eastern provinces included Beijing, Liaoning, Shanghai, Jiangsu, Zhejiang, Shandong, Guangdong, Fujian and some central provinces included Hunan have higher R&D technical efficiency. At the same time, most central and western provinces are at the lower R&D technical efficient level. What does reason cause this phenomenon? It maybe have two reasons. One of them is eastern region has better economic base then central and western regions,and the another reason may be that eastern,central and western regional R&D technical efficient convergency causes the unbalance of R&D technical efficiency in different regions.

To specificly study R&D technical efficient convergency, this article define regional R&D technical effcient value to be three levels:the first level is Beijing, Shanghai, Liaoning, Shangdong, Jiangsu, Zhejiang, Fujiang, Guangdong provinces, which make the highly R&D technical efficient convergency phenomenon;the second level is Sichuan, Chongqiang, Hubei, Hunan, Hebei, Henan, Heilongjiang, Tianjing, Xinjiang, Yunnan, Guizhou, Guangxi, Hainan, Jiangxi, Anhui,

Jilin provinces, which make the middle R&D technical efficient convergency phenomenon;the third level is Gansu, Qinghai, Ningxia, Shaanxi, Shanxi, Neimenggu provinces which make low R&D technical efficient convergency phenomenon. On the whole,our country R&D technical efficiency has the obvious regional distribution characteristic which is two lager ends,and small middle.

1.3 Regional R&D Technical Efficient Spatial Difference and Region How to Effact R&D Technical Efficiency

1.3.1 Analysis of Spatial Difference

The spatial difference is the first resource to recognize the spatial effect. It is made from the inspection of the lack dependence between the spatial organized inspected unit[16]. Anselin considered that it was relative between the same phenomenon or attribute value in one regional spatial unit and the same phenomenon or attribute value in an adjioning regional spatial unit[17]. These economic phenomena exist a geographical spatial interaction which is element flow, technology spillover and innovations diffusion. And these show spatial agglomeration and spatial divergence phenomena. Using Moran's I index method, this article measure our country regional R&D technical efficient spatial difference.

The calculation formula for any year's statistic:

$$I_t = \frac{n}{s_0} \cdot \frac{z_t' W_{z_t}}{z_t' z_t} \tag{6}$$

z_t is the n area deviation vector of regional observed value for n year. W is spatial weighted matrix with rock spatial weighted matrix to explain the regional close relationship. Rook first order weighted matrix W as follows:

$$\text{wij} = \begin{cases} 1, & \text{when i region and j region is anjacent} \\ 0, & \text{when i region and j region is not adjacent} \end{cases}$$

s_0 is equal to the sum of all weighted matrix elements. To standardize outside effect of each area, spatial weighted matrix is defined to be standard matrix(to make the sum of all elements of each row to be 1). Row standard matrix $s_0=n$, so (6) can be simplified:

$$I_t = \frac{z_t' W_{z_t}}{z_t' z_t} \tag{8}$$

When I_t is bigger than expectation value($E(I_t)= -1/n$-1), it means variables exist positive autocorrelation. Conversely, it exists negative autocorrelation.

1999~2011 Moran's index and P test value of China's regional R&D technical efficiency are shown as table 1:

Table 1
China's Regional R&D Technical Efficiency Moran's I Index Number

Time	R&D technical efficiency Moran's I index number	P test value	time	R&D technical efficiency Moran's I index number	P test value
1999	0.1015	0.056	2006	0.1185	0.039
2000	0.1495	0.021	2007	0.1363	0.061
2001	0.1724	0.029	2008	0.1699	0.035
2002	0.2029	0.013	2009	0.1455	0.036
2003	0.1586	0.023	2010	0.1667	0.066
2004	0.1524	0.019	2011	0.1685	0.043
2005	0.1142	0.044			

Moran's I index number is positive value in table 1, and all these index number is through the significant test which means our country regional R&D technical efficiency have obvious positive correlation characteristic. It also means spatial relation degree is close,and is affected by geographical factors.

1.3.2 Effect of Spatial Difference Factor on Regional R&D Technical Efficiency

When we talk about spatial difference factor how to affect regional R&D technical efficiency, for the purpose of comparison the change of R&D technical inefficienct item between before and after considering spatial factors, this article build two R&D technical inefficient item functions without spatial factors and with spatial factors,specific assumption as follows:

$$m_{it} = \delta_0 + \delta_1 GOV_{it} + \delta_2 TRAD_{it} + \delta_3 FDI_{it} + \delta_4 IND_{it} + \varepsilon_t \tag{9}$$

$$m_{it} = \delta_0 + \delta_1 WGOV_{it} + \delta_2 WTRAD_{it} + \delta_3 WFDI_{it} + \delta_4 WIND_{it} + \varepsilon_t \tag{10}$$

In this equations, m_{it} is R&D technical inefficient item. When m_{it} is increasing, it means efficiency is lower. GOV_{it} is the government support degree for R&D activities, $TRAD_{it}$ is foreign trade dependent degree, FDI_{it} is foreign direct investment dependent degree, IND_{it} is industrialization level, and $WGOV_{it}$,$WTRAD_{it}$,$WFDI_{it}$,$WIND_{it}$ are spatial weighted effect factor index which are used to reflect spatial factors how to affect R&D technical inefficiency. δ_0, δ_1, δ_3 and δ_4 are estimating parameters which are the effect degree of these factors to our country regional R&D technical efficiency, ε_t is random error item of technical invaid equation which is followed by normal distrubition$N(0,\sigma_w^2)$. Regression result as shown in table 2:

Table 2
Technical Inefficient Item Factors Analysis

Variable	OLS regression	Variable	Spatial weighted regression 1	Spatial weighted regression 2
GOV	-0.342*** (0.001)	*WGOV*	0.3402** (0.041)	-0.170 (0.338)
TRAD	-0.152*** (0.020)	*WTRAD*	0.613** (0.030)	-0.099 (0.721)
FDI	-0.034** (0.012)	*WFDI*	-1.308*** (0.003)	-0.119 (0.790)
IND	-0.222 (0.000)	*WIND*		-0.436*** (0.000)
C	-0.529*** (0.004)	*C*	-0.217 (0.246)	-1.192*** (0.000)
Lnsig2v	-4.932	Lnsig2v	-3.839	-4.313
Lnsig2u	-13.166	Lnsig2u	-13.294	-13.454
Sigma_v	0.085	Sigma_v	0.147	0.116
Sigma_u	0.001	Sigma_u	0.001	0.001
Sigma2	0.007	Sigma2	0.022	0.013
Lambda	0.016	Lambda	0.008	0.010
LOGL	31.412	LOGL	45.010	52.123
Wald chi2	122.790	Wald chi2	21.190	52.250

Note: In this table datum is the regression coefficient of each variable. The value in brackets is correspongding P test value. **, *** means each regression coefficient is through test under 5%, 1% significant level.

According to table 2, before taking spatial factors into consideration, regression coefficient of government support for R&D activities, foreign trade dependent degree and foreign direct investment dependent degree is negative in OLS regression results. They are all through test of 1% or 5% significant level, which means these factors have positive influence on our country regional R&D technical efficiency; after spatail factors taken into consideration,spatial weighted regression result without *WIND* item is similar as OLS regression result. But after thinking about *WIND* item,other of spatial weighted variable regression coefficient become insignificant,while *WIND* item regression coefficient become significant. Spatial weighted regression 2 research result seems to be contadicted by spatail weighted regression 1 research result. Therefore the interactions significant influence of spatial factors and industrialized level makes the spatial weighted regression 2 different from two situation. According to spatial weighted regression 2 research result, the interaction influence of the original spatial factors and government support on technical activities,foreign trade dependent degree and foreign direct investment dependent degree on regional R&D technical improving of efficiency positively are transferred to *WIND*. And spatial factors on China's regional R&D technical efficiency positive spillover effects mainly through the conduction of industrialization.

Conclusion: China's regional R&D technical efficiency exists positive spatial correlation,and spatial factors on R&D technical efficiency spillover effect have its independent conduction path.

2. CONCLUSION AND SUGGESTIONS

Firstly, China's regional R&D technical efficiency exists positive spatial correlation,and spatial factors on R&D technical efficiency spillover effect have its independent conduction path.So the main path to improve China's regional R&D technical efficiency and reduce regional difference is improving regional industrialization,technical spillover and knowledge spillover.

Secondly, China's regional technical efficiency has obviously absolute convergency trend. Therefore we should futher improve central and western R&D technical efficiency level,and constantly play "late dominant position",then reduce theregional R&D technical efficiency gap of eastern,central and western region.

Thirdly, China's regional R&D technical efficiency has positive correlation with spatial dependence, and geographical and spatial factors have obviously effect on China's regional R&D technical efficiency. Therefore, we should strengthen and promote regional communication,and strengthen these three area's R&D activity spatial dependence. Then it can form an effective interaction situation of these three regions to promote overall level of China's regional R&D technical efficiency and promote to implement innovation country strategy.

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