International Journal of Management Science
2015; 2(3): 21-34
Published online April 30, 2015 (http://www.aascit.org/journal/ijms)
ISSN: 2375-3757

Keywords
Regional Innovation Efficiency,
Influence Factors,
SFA,
Trans-Log Production Function

Received: March 24, 2015
Revised: April 13, 2015
Accepted: April 14, 2015

Research on China's Regional Innovation Efficiency and Influence Factors Based on SFA

Gao Hua

School of Economic and Management, Wuhan University, Wuhan, China

Email address
xth6800@163.com

Citation
Gao Hua. Research on China's Regional Innovation Efficiency and Influence Factors Based on SFA. *International Journal of Management Science.* Vol. 2, No. 3, 2015, pp. 21-34.

Abstract
The paper applies SFA method to analyze regional two-stage innovation efficiency consisting of R&D and commercialization and its influence factors based on panel data in 30 provinces of China from 1998 to 2010. The result shows that: (1) The regional innovation efficiency is low, and commercialization efficiency is lower than R&D efficiency, but both are improving. The output elasticity of R&D personnel is higher than the R&D expenditure. (2) The commercialization efficiency and R&D efficiency in the Eastern region are higher than the Central and Western regions. The R&D efficiency in the Eastern and Central region is higher than the national average level, while R&D efficiency in the Western region is lower than the national average level. The commercialization efficiency in the Central region is less than the Western region, and both are lower than the national average level. (3) Laborer's quality and government subsidies have significantly positive correlation with R&D efficiency and commercialization. Market competition has significantly positive correlation with R&D efficiency, but has significantly negative correlation with commercialization. FDI and regional opening degree have significantly negative correlation with R&D efficiency, but have significantly positive correlation with commercialization. Industrial structure has significantly negative correlation with commercialization, and has negative correlation with R&D efficiency, but is not significant. Finally, some suggestions are provided.

1. Introduction

In the late 1980s, the concept and essential meaning of "National Innovation Systems (NIS)" was widely discussed in the international community. Innovation systems and governance have been shown to be of particular importance for economic development (Fagerberg, 2008). Initially, the study of innovation systems made reference to the national environment (Freeman, 1987; Lundvall, 1992; Nelson, 1993), but soon researchers applied the concepts also at the regional level (Cooke, Gómez Uranga, & Etxebarría, 1997; Cooke, 2000, 2001; Buesa, Heijs, Pellitero, & Baumert, 2006; Guan & Liu, 2005). A regional innovation system is a geographical subset of a larger (often but not necessarily, national) system whose main identifying characteristics are similar at both levels of observation. The impact of technology and industrial policies on the economic growth of a nation cannot be understood unless their impact on the geographical regions is understood (Hilpert, 1991).

Efficiency is an issue in need of focus during the process of technological innovation. Especially with the increase in national and local technological innovation resources recently, efficiency becomes more prominent. The government has maintained strong support on science and technology activities all along. The scientific and technological resources investment intensity also continues to enlarge year by year. The data from "China Science and Technology Statistics Yearbook" show that: R & D intensity (R&D/GDP) has risen from 0.65% in 1998 to 1.76 % in 2010, R&D expenditure ranked the third in the world according to the exchange rate in 2010, and R&D staff also risen from 75.52 million in 1998 to 255.38 million in 2010. But as a developing country, R&D intensity of China is still far lower than those developed countries as Japan of 3.26%, the United States of 2.83%, Korea of 3.74%, Singapore of 2.09% in 2010, while China is only 1.76 % at the same time. On the other hand, the benefits of R&D are also rising. The number of granted patents is rising from 54,994 in 1998 to 740,620 in 2010, the technology market turnover is rising from 43.6 billion yuan in 1998 to 390.6 billion yuan in 2010.

Facing with China's R&D activities of high input and high output, such questions have cause some scholar's attentions: Whether R&D efficiency is high or low? What factors will have an effect on innovation efficiency? Many studies show that regions have a decisive role and becoming more important in promoting economic growth based on innovation and entrepreneurship. Regions are considered as being more adequate for the promotion of a development strategy based on innovation due to stakeholders' spatial proximity and other advantages offered. Each region has the capacity to become an innovation center in the fields of activity where a higher specialization is registered (Mihai,2012). Therefore, the research on innovation efficiency and influence factors about regional independent innovation road under the conditions of limited resources for the developing country has important practical significance. The purpose of this paper is to measure the region innovation efficiency and find out some influence factors.

Relevant studies on evaluation of the China's regional innovation efficiency are burgeoning in the extant literature (e.g., Liu, 2002; Chi, 2004; Guan, 2005; Li, 2008; Zhao, 2013). Some scholars studied regional R&D efficiency (Wu, 2007; Liu, 2011; Shi, 2011; Cai, 2013). Some scholars studied provincial innovation capability (Liu, 2001, 2002; Zhou, 2006). There are also some researches on influence factors of regional innovation efficiency (Zhou, 2011; Hou, 2013; Li, 2007; Guan, 2011; Bai, 2009; Diao, 2011), but did not have the same opinion. For example, Zhou (2011)、Hou (2013) think that human capital stock have a positive relationship with regional innovation efficiency. Li Xibao (2007) studies regional innovation environment's effect on innovation efficiency. Guan (2011) considers some factors as labor's quality and financial support. Bai (2009), Diao et al. (2011) consider the government subsidies effect on innovation efficiency.

Although researches on region innovation have paid attention to in recent years, the theory and empirical researches are not enough. There still exist some limitations: firstly, from research content, most studies consider only R&D efficiency without thinking about commercialization, which means incomplete comprehension of innovation meaning. Besides, researches on regional innovation efficiency influence factors have not make an agreement. Secondly, from research method, most researches draw conclusions by using DEA method. In order to find influence factor, they use two-step DEA which is not better than SFA. Thirdly, from research reliability, some researches did not consider innovation time lags. And innovation input indicators use flow index other than stock index. So this paper will make an improvement of previous studies. The remaining structure of this paper is organized as follows: Section 2 gives some theoretical hypotheses. Section 3 introduces the research model. Section 4 introduces the variables and data. Section 5 makes an empirical analysis. Section 6 explains the research results. The conclusions and suggestions are summarized in Section 7.

2. Theoretical Hypotheses

Some hypotheses can be singled out to guide the interpretation of our empirical results.

2.1. Region Innovation Efficiencies

One of the most noteworthy features of transitional Chinese innovation systems is an increasing variation in regional innovation performance. With the rapid economic development in China, innovation output has become progressively more concentrated into a few highly innovative regions. With respect to invention patent grants a geographical agglomeration trend also existed. As a result, the most innovative 10 regions accounted for more than 80% of the invention grants in 2005, with less than 20% coming from the remaining 20 regions. These arguments lead us to propose the following hypothesis:

Hypothesis 1. There exists gap on the innovation efficiencies among provinces due to economic gap, geographic variation and social customs.

2.2. Efficiency Factors

Identifying the determinants of regional innovation efficiency is one of the most widely studied but least understood and most contentious areas in innovation management studies. Although there are some researches about efficiency influence factors, there still not make an agreement. Considering exist literature, this paper suggests efficiency factors as follows:

2.2.1. Laborer's Quality

Because of the interactive nature of the innovation process, innovation will benefit from the presence of a large number of highly qualified labor forces. The more abundant human capital of an area, the more R&D personnel can be utilized by enterprises and research institutions. The higher the quality of workers, the more supply of creative talents. And it is also conducive to the development, absorption and utilization of new knowledge, which can promote innovation activities. Zhu(2011) finds that the stock of human resources have a positive correlation with the regional innovation capability and reasonable human resource structure can improve the level of regional innovation capacity. Zhou et al. (2009) find that the level of human resources makes positive contribution to regional innovation efficiency. Li (2007), Li (2009), Zhao (2014) believe that improving the quality of workers has a positive effect on enhancing regional innovation capability. These arguments lead us to propose the following hypothesis:

Hypothesis 2a. Laborer's quality will have a positive effect on the regional innovation efficiency.

2.2.2. Government Subsidies

In the catch-up stage of late-comer economies, government agencies play an indispensable role. They not only contribute important institutions, including laws and innovation policies for regulating and coordinating innovation activities between the innovation actors, but they also provide direct financial support or research grants to the innovation actors. In recent years, the investment in science and technology innovation of Chinese government is increasing, which shows the government pays more attention to science and technology innovation which effectively promotes the related technology, especially the development of sophisticated technology to promote economic growth. Yu (2009) believes that government subsidies is conducive to innovation and enhance the efficiency of high-tech industry. Zhao(2014) also thinks that government investment have a significant positive effect on provincial innovation efficiency. Tang et al (2009) analyzes the influence factors of China's large and medium industrial enterprises' innovation efficiency, and find adequate government funding is in favor of R&D efficiency. These arguments lead us to propose the following hypothesis:

Hypothesis 2b. Government subsidies will have a positive effect on the regional innovation efficiency.

2.2.3. Market-Oriented

Since 1978, the market-oriented reform prompted profound changes in China's economic systems. There exist huge differences of different regions during the reform processes. For three decades, rapid economic development has benefited from market-oriented reforms. Market process mainly covers: the relationship between government and the market; non-state economic development; product market development; elements market development; market intermediaries development and legal environment improvement. Dang(2012) analyzes the important factor of regional innovation- the influence of marketization degree on regional innovation capability of 31 provinces in 2009 and Poisson distribution model. Results show that marketization degree can promote regional innovation capability significantly. Li et al. (2012) find that marketing process has a significant adjustment effect on relations between knowledge transfer and regional innovation ability. These arguments lead us to propose the following hypothesis:

Hypothesis 2c. The market-oriented degree is positively correlated with the regional innovation efficiency.

2.2.4. FDI

For developing countries, or economically backward regions, its technological innovation activities will be subject to technology spillover from the outside to a certain extent, especially in the more backward areas of science and technology activities. Technology spillover from outside has a very important role to promote the local technological level. During the process of improving regional innovation efficiency, the international technology spillovers can not be ignored, while foreign direct investment (FDI) is an important channel for international technology spillovers. Li et al. (2012) find that the knowledge transfer has a significant role in cultivation and promotion of regional innovation capacity. Zhou et al. (2009) find that FDI makes positive contribution to regional innovation efficiency. Jin (2013) shows that external technology spillover has a positive impact on technology innovation efficiency. These arguments lead us to propose the following hypothesis:

Hypothesis 2d. FDI will have a positive effect on the regional innovation efficiency.

2.2.5. The Degree of Openness

In recent years, among researches on regional innovation, whether the inter-regional commodity trade, capital flows and foreign capital inflows can promote technological progress between regions is an important issue. Foreign Trade of China's central and western regions have significant gaps compared with economically developed eastern regions because of its economic development and geographical environment. The more open an area, the more free flow of production factors, thus contribute to the rational resource allocation. Coe and Helpman (1995) considers that there exist technology spillover between international trade, which depends on R&D expenditures stock and trading nations dependence; Connolly (2003) constructs a theoretical model that demonstrates the technology import and learning in developing countries from developed countries is beneficial to the enhancement of developing countries' technical standards. Many studies (eg SUN (2012), Luo (2013), Fan (2012), Zhao (2014)) show that the openness of an area has a significant role in promoting technological innovation efficiency. Hence:

Hypothesis 2e. The openness degree of a region is positively correlated with the regional innovation efficiency.

2.2.6. Industrial Structure

For most regions in China, industrialization is far from complete. Compared to developed countries, regions in China have too much output from the primary industries. On the other hand, high-tech industries account for a relatively large proportion of the total industrial output in some regions. Changes in the industrial structure have a certain impact on innovation efficiency. Under normal circumstances, industries in the previous period of industry life cycle will have more innovation opportunities and achievement than those in the later period of industry life cycle. As Jin (2013) shows that the proportion of high-tech industry has a positive impact on technological innovation efficiency. Hence:

Hypothesis 2f. The proportion of high-tech industry output is positively correlated with regional innovation efficiency.

3. Research Methodology

There are two methods of efficiency measurement: DEA and SFA, who have their own advantages and suitable for different case. Stochastic frontier approach (SFA) (Aigner et al., 1977) can overcome the impact of statistical noise and random environment factors on efficiency measures (e.g., Li, 2009), while data envelopment analysis (DEA) is more competent in the efficiency measure for the multi-output innovation system and does not need to impose an explicit functional form and an explicit distributional assumption. However, DEA fails to identify the impact of random variables, and thus undermining the accuracy of research results. Battese and Coelli (1995) proposed the one-stage SFA model in which the parameters of the stochastic frontier and the technical inefficiency models are estimated simultaneously given appropriate technical inefficiency distributional assumptions. One-stage SFA can not only decompose technical efficiency from productivity but also can control noises from random errors and avoid contrasting assumptions. Considering the purpose of this paper, we think it is better to use one-stage SFA approach to measure efficiency and influence factors.

Based on the model proposed by Battese and Coelli (1995), the following SFA function is defined:

$$y_{it} = f(f_{it}, t)\exp(v_{it}, u_{it}) \tag{1}$$

where for all provinces indexed with a subscript i and for all years indexed with a subscript t; y_{it} denotes the production level; x_{it} is a vector of normal inputs; v_{it} is a symmetric random error term, independently and identically distributed as $N(0, \sigma_u^2)$, intended to capture the influence of exogenous events beyond the control of researchers; u_{it} is a nonnegative random error term, independently and identically distributed as $N^+(\mu, \sigma_u^2)$.

Battese and Coelli (1988, 1992) have proposed the technical efficiency estimator:

$$TE_{it} = \frac{E[f(x_{it})\exp(v_{it} - u_{it})]}{E[f(x_{it})\exp(v_{it})]} = \exp(-u_{it}) \tag{2}$$

To derive a stochastic version of the efficiency measure, we need to specify a functional form for the deterministic kernel of the stochastic production frontier. To avoid excessive misspecification, we use a flexible trans-log functional form to model the production technology.

Writing (1) in trans-log form gives

$$\ln y_{it} = \beta_0 + \sum_j \beta_j \ln x_{jit} + \frac{1}{2}\sum_j \sum_l \beta_{jl} \ln x_{jit} \ln x_{lit} + v_{it} - u_{it} \tag{3}$$

The technical inefficiency model is:

$$u_{it} = z_{it}\delta + w_{it} \tag{4}$$

Where z denotes the explanatory variable of the technical inefficiency; δ is the parameter to be estimated; w is random error, distributed as $N^+(0, \sigma_u^2)$ such that the point of truncation is $-z_{it}\delta$, i.e. $w_{it} \geq -z_{it}\delta$. If in this model, coefficients of the explanatory variable are significantly positive, the variable will increase the technical inefficiency significantly, that is lowering technical efficiency; if the coefficients of the explanatory variable are significantly negative, the variable will decrease technical inefficiency significantly, meaning higher technical efficiency.

The coefficient of variation for stochastic frontier production function γ is defined as:

$$\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2). \tag{5}$$

Thus the null hypothesis and alternative hypothesis are H_0: $\sigma_u^2 = 0$ and H_1: $\sigma_u^2 \neq 0$ respectively or H_0: $\gamma = 0$ and H_1: $\gamma > 0$. In validation, preliminary conclusions can be reached from γ, if γ is significantly not equal to 0, technical inefficiency effects are taken into consideration and the stochastic frontier production function is feasible; and otherwise, no consideration is given to technical inefficiency effects and the stochastic frontier production function is proven not feasible. Meanwhile, more strict validation is required by constructing the following likelihood ratio statistics:

$$LR = -2[\ln(H_0) - \ln(H_1)] \tag{6}$$

4. Data and Variables

4.1. Data

This paper takes the sample of 1998-2010 panel data of 30 provinces from Science &Technology Statistical Yearbook of China, Statistical Yearbook of China, and Statistical Yearbook of all provinces. China's development exhibits regional imbalance in terms of economy and technique. To analyze the imbalance, China's provinces are divided into three regions according to their position and economy. Due to data incomplete, Xi Zang is deleted from the sample. So in this paper, the Eastern region consists of 11 provinces: Beijing, Tianjin, Shanghai, Hebei, Liaoning, Shandong, Jiangsu, Zhejiang, Fujian, Guangdong, Hainan. The Central region includes 8 provinces: Jilin, Heilongjiang, Sanxi, Anhui, Jiangxi, Henan, Hubei, Hunan. The remaining provinces are grouped to the Western region. The Western region consists of 11 provinces: Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shanxi, Ningxia, Inner Mongolia, Gansu, Qinghai, Xinjiang.

4.2. Variables

4.2.1. Innovation Output

Due to its availability and reliability, patent data remains one of the most popular sources from which various indicators can be constructed. Domestic patent data have been systematically collected by the State Intellectual Property Office (SIPO) of China for over 20 years and constitute a rich dataset. As we know, domestic patents in China are classified into three categories: inventions, utility models and designs. These three patent types are very different in terms of economic value, technological importance and resource commitment. Inventions represent the most technologically sophisticated innovation output and are "new-to the-world." To measure and compare innovation performance between regions, this paper employs the number of domestic invention patents granted as a proxy for R&D output in R&D stage. In the stage of commercialization, the paper employs technology market turnover as a proxy for the stage of commercialization. All expenditures indicators are adjusted by comparable price index in 1998 in order to remove the inflation impact.

4.2.2. Innovation Input

According to the conceptual and empirical framework discussed above, explanatory variables in this analysis are classified into two groups: input factors and efficiency factors. They are classified on the basis of their relationship with the knowledge production process. Specifically, in a regional innovation system, the flow of R&D resource commitments (including both financial and human capital) and the accumulated knowledge stock are considered as direct input factors to the process of innovation output. In this paper, we use R&D capital stock and R&D personnel FTE as input variable.

4.2.3. R&D Capital Stock

Constructing and measuring R&D stock are techniques that were first discussed in Griliches (1979). A perpetual inventory method was suggested in constructing R&D capital stock. By now, this method is commonly used in a large body of literature concerning the impact and contribution of R&D upon productivity and growth of productivity (e.g., Hall and Mairesse, 1995; Hasan, 2002; Hollanders and ter Weel, 2002; Hu and Jefferson, 2004). Following the method of Griliches (1979), the R&D capital stock of the i th province in the year of t (K_{it}) is constructed in the following manner by using the perpetual inventory method as

$$K_{it} = E_{it-1} + (1-\delta) K_{it-1} \tag{7}$$

where δ is the depreciation rate of R&D capital, and E_{it} is R&D expenditure of the i th province in year t. R&D expenditure should be adjusted by R&D price index in 1998 in order to remove the inflation impact. As Zhu (2003) provided method for reference, we construct R&D price index as, R&D price index =0.55×consume price index+0.45×fixed assets invest price index

Just as suggested by Hollanders and ter Weel (2002), Hall and Mairesse (1995), and Hu and Jefferson (2004), the initial R&D capital stock is constructed by assuming a constant growth rate of R&D expenditure. That is, the initial R&D capital stock is defined as

$$K_{i0} = \frac{E_{i1}}{\delta + g} \tag{8}$$

where g is the annual growth rate of R&D expenditure. It should be pointed out that the choice of depreciation rate for R&D capital makes little difference (Hall and Mairesse, 1995). For example, Hollanders and ter Weel (2002) used an annual depreciation rate of 15% for the R&D stock, and found that taking other reasonable rates of depreciation does not change the estimation results substantially. In addition, Hasan (2002) found that experimentation with lower depreciation and longer impact lags for both in-house R&D and imported technologies yielded similar results to those based on a 15% rate of depreciation.

An important aspect to keep in mind when analyzing the transformation of innovation inputs into innovation outputs is the existence of time lags. According to the extant study, there is no generally accepted length of time lags for R&D to output (Wang and Huang, 2007). In China, it usually thinks about 2 years for an invention patent application to be approved (Liang, 2005). So in this paper, a 2-year time lag is used for invention patent grants and a 2-year time lag is used for commercialization.

4.2.4. Efficiency Factors

(i) Laborer's Quality

At present, there are such indicators as years of education, school enrollment, percentage of GDP spending on education, ratio of college student number and one million people to measure laborer's quality. Considering the availability of data and certain knowledge base of technical innovation, we use the ratio of college student number to one million people as a proxy for the laborer's quality.

(ii) Government Subsidies

To test the impact of the government role on scientific and technological innovation, the paper selected financial technology funding accounted for the proportion of local fiscal expenditure as government behavior assessment indicators.

(iii) Market-Oriented

Foreign scholars usually use market-oriented process indicators to reflect the market-oriented degree of economic system transformation. So this article also uses market-oriented index to reflect the China's economy transformation. It is typical of provincial market index computed by Fan et al (2011), which measures China's market-oriented degree from five aspects: the relationship between government and the market, non-state economic development, product market development, factor markets development, as well as market intermediaries development and legal environment, generally reflecting the status and role of the market mechanism in promoting technical innovation actors and other economic activities. In this paper, we use the market-oriented index as a proxy for market-oriented degree.

(iv) FDI

In this paper, we use the ratio of provincial FDI to GDP as a proxy for technology spillovers.

(v) The Degree of Openness

In this paper, we use the ratio of provincial export and import to GDP as a proxy for region openness.

(vi) Industrial Structure

For the measure of industrial structure, relevant literature generally use the ratio of secondary industry and tertiary industry to GDP, or the ratio of provincial industrial output and nation industrial output. As we know, the innovation capability of high-tech industry is stronger than other industries, which have an important role in promoting regional innovation efficiency. Since the high-tech industry development is an important assessment of a regional technical innovation level, and considering the availability of data, we use the ratio of provincial high-tech industrial output to GDP as a proxy for industrial structure.

4.3. Model

According to the above analysis, we use a logarithmic beyond stochastic frontier production function model to establish the following model:

The first stage: R&D

$$\ln fam_{it} = \beta_0 + \beta_1 \ln rdz_{it} + \beta_2 \ln rdp_{it} + 1/2\beta_3(\ln rdz_{it})^2 + 1/2\beta_4(\ln rdp_{it})^2 + \beta_5 \ln rdz_{it} \ln rdp_{it} + v_{it} - u_{it} \quad (9)$$

$$u_{itf} = \delta_0 + \delta_1 dxsb_{it} + \delta_2 gov_{it} + \delta_3 mark_{it} + \delta_4 fdi_{it} + \delta_5 kfd_{it} + \delta_6 ind_{it} \quad (10)$$

where fam_{it}、rdz_{it}、rdp_{it} are patent output、R&D capital stock 、R&D personnel of the i th province in year t, and $dxsb_{it}$、gov_{it}、$mark_{it}$、fdi_{it}、kfd_{it}、ind_{it} are laborer's quality、government subsidies、market index、FDI、Openness、industrial structure of the i th province in year t. β and δ are the regression coefficient.

Second stage: commercialization

$$\ln jssc_{it} = \beta_0 + \beta_1 \ln rdz_{it} + \beta_2 \ln rdp_{it} + 1/2\,\beta_3(\ln rdz_{it})^2 + 1/2\,\beta_4(\ln rdp_{it})^2 + \beta_5 \ln rdz_{it} \ln rdp_{it} + v_{it} - u_{it} \quad (11)$$

$$u_{itz} = \delta_0 + \delta_1 dxsb_{it} + \delta_2 gov_{it} + \delta_3 mark_{it} + \delta_4 fdi_{it} + \delta_5 kfd_{it} + \delta_6 ind_{it} \quad (12)$$

where $jssc_{it}$、rdz_{it}、rdp_{it} are technology market turnover 、R&D capital stock 、R&D personnel of the i th province in year t, and $dxsb_{it}$、gov_{it}、$mark_{it}$、fdi_{it}、kfd_{it}、ind_{it} are laborer's quality、government subsidies、market index、FDI、Openness、industrial structure of the i th province in year t. β and δ are the regression coefficient.

5. Results

Based on the model and the data, using Frontier 4.1 software, China's regional innovation efficiency and influencing factors of 30 provinces are estimated from 1998 to 2010, results are shown as follow.

5.1. Stage I: Output Variable: Invention Patents Granted

According to equation (9), (10), max likelihood estimation and related test are shown in Table 1, while Table 2 shows innovation efficiency of 30 provinces from 1998-2010 based on the granted invention patents.

As shown from Table 1, γ = 0. 9675, and is significant at the 1% level, which shows that the error term in formula (1) has a distinct composite structure, so it is rather effective by using the SFA method than OLS estimates based on the provincial data of 13 years.

Table 1. *Max likelihood estimation (Stage I)*

	Coefficient	Standard Deviation	F-Statistic
β_0	5.666***	0.240	23.598
β_1	-0.426***	0.1061	-4.012
β_2	0.4693***	0.1155	4.064
β_3	0.096***	0.0222	4.323
β_4	0.0299	0.0272	1.101
β_5	-0.0334	-0.044	-0.7710
η_0	-0.9281*	0.4911	-1.890
η_1	-0.4712***	0.0498	-9.469
η_2	-0.5076***	0.0876	-5.793
η_3	-1.1139***	0.1196	-9.301
η_4	0.1929***	0.0344	5.6065
η_5	0.1542***	0.0410	3.7563
η_6	0.0278	0.0409	0.6799
sigma-squared	0.1680***	0.0134	12.533
γ	0.9675***	0.027	35.835

note: * is significant at 10% level; ** is significant at 5% level; *** is significant at 1% level.

(1) From the output elasticity of R&D personnel and R&D expenditure, β_1 =-0.426, β_2 = 0.4693, we can see that domestic invention patent granted decreased by 0.426 with annual R&D capital stock increased by 1%, while domestic invention patent granted increased by 0.4693 with annual R&D staff of full-time equivalents grew 1%, which shows that human resource output elasticity is increasing. China's

regional R&D output growth mainly depended on R&D personnel. This is the case that current R&D personnel configuration relative surplus while relative lack of R &D expenditure. Besides, the sum of R&D funding elasticity and R&D personnel elasticity is 0.0433, less than 1, which means that efficiency will decrease rather than increase with the increase in production factors.

(2) The coefficient of laborer's quality on Chinese regional R&D efficiency is -0.4712, and is significant at the 1% level, indicating that the laborer's quality have an positive effect on China's regional R&D efficiency. The coefficient of government subsidies on Chinese regional R&D efficiency is -0.5076, and is significant at the 1% level, indicating that government financial support have an positive effect on China's regional R&D efficiency. The coefficient of market-oriented index on Chinese regional R&D efficiency is -1.1139, and is significant at the 1% level, indicating that market-oriented index have an positive effect on China's regional R&D efficiency. The coefficient of FDI on Chinese regional R&D efficiency is 0.1929, and is significant at the 1% level, indicating that FDI don't have a positive effect on China's regional R&D efficiency. The coefficient of openness on Chinese regional R & D efficiency is 0.1542, and is significant at the 1% level, indicating that trade don't have a positive effect on China's regional R&D efficiency. The coefficient of industrial structure on Chinese regional R&D efficiency is 0.0278, and is not significant, indicating that industrial structure don't have a positive effect on China's regional R & D efficiency.

(3) As can be seen from Table 2, from 1998 to 2010, the mean of national innovation efficiency is 0.3634, which is higher than the whole industrial R&D efficiency mean (0.16)(Yan and Feng,2005), and also higher than the Chinese high-tech industry R&D efficiency mean(0.258)(Zhu,2006), but lower than the Chinese high-tech industry sub-sector innovation and efficiency mean (0.702) (Han,2010). This suggests that the whole innovative technology efficiency is very low, and there is considerable space(possibility) for improvement. As we can see the trends, the innovation technical efficiency has risen from 0.1812 in 1998 to 0.7074 in 2010, which show the rapid growth trend other than high level of the technical innovation efficiency.

From 1998 to 2010, the top five provinces of an average of 13 years of innovation efficiency is Shanghai, Zhejiang, Guangdong, Tianjin, Hunan, and only the efficiency of Shanghai is over 60%. There are 14 provinces whose innovation efficiency is above the national average level, which account for 46.67%. There are 7 provinces in the eastern region (63.64%) whose innovation efficiency is above the national average level. There are 5 provinces in the central region (62.5%) whose innovation efficiency is above the national average level. And there are only 2 provinces in the western region (18.18%) whose innovation efficiency is above the national average level.

Table 2. *The provincial innovation efficiency of China (R&D Stage)*

Province	Innovation Efficiency													
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	mean
Beijing	0.2853	0.2355	0.2248	0.4346	0.5164	0.5079	0.4286	0.4402	0.5257	0.6094	0.6653	0.8398	0.9187	0.5102
Tianjin	0.2103	0.1226	0.1158	0.2461	0.3915	0.613	0.6972	0.725	0.8379	0.8006	0.7102	0.7855	0.8551	0.5470
Hebei	0.2652	0.2502	0.194	0.2597	0.2913	0.2734	0.2779	0.2707	0.2879	0.3216	0.3962	0.5029	0.5659	0.3198
Sanxi	0.2531	0.2051	0.2464	0.3807	0.3903	0.3449	0.3789	0.2879	0.31	0.4239	0.4418	0.5806	0.6192	0.3741
Neimeng	0.0931	0.1376	0.1001	0.1662	0.2206	0.2039	0.1965	0.199	0.2149	0.2543	0.321	0.3782	0.4878	0.2287
Liaoning	0.305	0.2321	0.2291	0.3382	0.3895	0.3932	0.3905	0.3829	0.4162	0.4718	0.5097	0.6081	0.6736	0.4108
Jilin	0.1941	0.178	0.1834	0.3074	0.5229	0.425	0.4317	0.3791	0.4221	0.4725	0.4905	0.6386	0.7158	0.4124
Heilong	0.2198	0.1663	0.1408	0.1991	0.2629	0.3105	0.3779	0.3924	0.4011	0.5462	0.654	0.7535	0.7853	0.4008
Shanghai	0.1872	0.1411	0.1501	0.3714	0.6195	0.645	0.7408	0.7707	0.8072	0.9099	0.8956	0.8984	0.9396	0.6213
Jiangsu	0.2136	0.1358	0.1498	0.2313	0.3025	0.3054	0.3435	0.3558	0.4545	0.54	0.5621	0.6034	0.6912	0.3761
Zhejiang	0.2715	0.262	0.2124	0.351	0.5387	0.615	0.5905	0.682	0.733	0.791	0.7914	0.877	0.8673	0.5833
Anhui	0.1459	0.101	0.1128	0.1492	0.1544	0.2209	0.2416	0.243	0.3353	0.4536	0.4968	0.7394	0.9215	0.3320
Fujian	0.1814	0.1414	0.0806	0.1519	0.1747	0.2249	0.24	0.223	0.3001	0.3876	0.4667	0.6448	0.7914	0.3083
Jiangxi	0.1043	0.1253	0.0907	0.1493	0.1571	0.1959	0.1949	0.1915	0.2039	0.3228	0.3082	0.4242	0.4915	0.2277
Shandong	0.2575	0.2338	0.204	0.3274	0.318	0.3079	0.3446	0.3475	0.371	0.4478	0.4624	0.5474	0.5409	0.3623
Henan	0.2264	0.181	0.1357	0.21	0.2142	0.238	0.2807	0.2982	0.3024	0.4385	0.4921	0.6382	0.6873	0.3341
Hubei	0.135	0.1502	0.1262	0.2532	0.3704	0.359	0.3949	0.3558	0.4221	0.4778	0.5703	0.7198	0.7692	0.3926
Hunan	0.2637	0.2182	0.165	0.3379	0.3941	0.4669	0.4462	0.4826	0.7137	0.8974	0.8608	0.9056	0.9289	0.5447
Guangdong	0.179	0.1772	0.1442	0.304	0.4901	0.3977	0.4466	0.5349	0.8629	0.9242	0.8871	0.9234	0.8749	0.5497
Guangxi	0.2023	0.1101	0.074	0.1658	0.2207	0.2295	0.274	0.2498	0.2538	0.3729	0.4287	0.5206	0.6275	0.2869
Hainan	0.0741	0.0853	0.0304	0.143	0.1811	0.1599	0.1442	0.1824	0.154	0.242	0.4476	0.4233	0.5121	0.2138
Chongqing	0.0724	0.0498	0.0515	0.1145	0.1191	0.1333	0.1559	0.1933	0.2563	0.3429	0.4088	0.5995	0.674	0.2439
Sichuan	0.1338	0.1492	0.1148	0.1761	0.2432	0.2485	0.2472	0.271	0.3244	0.4147	0.4949	0.6766	0.8302	0.3327
Guizhou	0.1551	0.108	0.1016	0.1572	0.3551	0.3294	0.3937	0.428	0.4625	0.5129	0.6803	0.825	0.775	0.4064
Yunnan	0.2671	0.2239	0.151	0.2961	0.3612	0.4705	0.5	0.5079	0.4831	0.5433	0.6672	0.9149	0.9669	0.4887
Shanxi	0.1264	0.079	0.0732	0.0842	0.1998	0.1929	0.2537	0.2821	0.3166	0.3913	0.5153	0.7686	0.8648	0.3191
Gansu	0.1169	0.0874	0.0965	0.1145	0.1845	0.1548	0.2062	0.2303	0.2588	0.2505	0.357	0.5173	0.6175	0.2456
Qinghai	0.0654	0.0613	0.0497	0.065	0.0816	0.0912	0.1086	0.1033	0.0864	0.1256	0.1553	0.1993	0.2727	0.1127
Ningxia	0.0845	0.0631	0.0729	0.178	0.153	0.145	0.2063	0.1005	0.143	0.1405	0.1678	0.242	0.3302	0.1559
Xinjiang	0.1477	0.0191	0.1783	0.2143	0.2013	0.2374	0.2677	0.2115	0.1864	0.2433	0.3705	0.4706	0.6262	0.2596
Nation	0.1812	0.1477	0.1333	0.2292	0.3007	0.3147	0.34	0.3441	0.3949	0.469	0.5225	0.6389	0.7074	0.3634

Table 3. *Innovation efficiency of China's Eastern, Middle and Western (R&D phase)*

Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	mean
Eastern	0.2209	0.1834	0.1577	0.2871	0.383	0.4039	0.4222	0.4468	0.5228	0.586	0.6177	0.6958	0.7482	0.4366
Middle	0.1928	0.1656	0.1501	0.2484	0.3083	0.3201	0.3434	0.3288	0.3888	0.5041	0.5393	0.675	0.7398	0.3773
Weatern	0.1332	0.099	0.0967	0.1574	0.2127	0.2215	0.2554	0.2524	0.2715	0.3266	0.4152	0.5557	0.643	0.2800
Nation	0.1812	0.1477	0.1333	0.2292	0.3007	0.3147	0.34	0.3441	0.3949	0.469	0.5225	0.6389	0.7074	0.3634

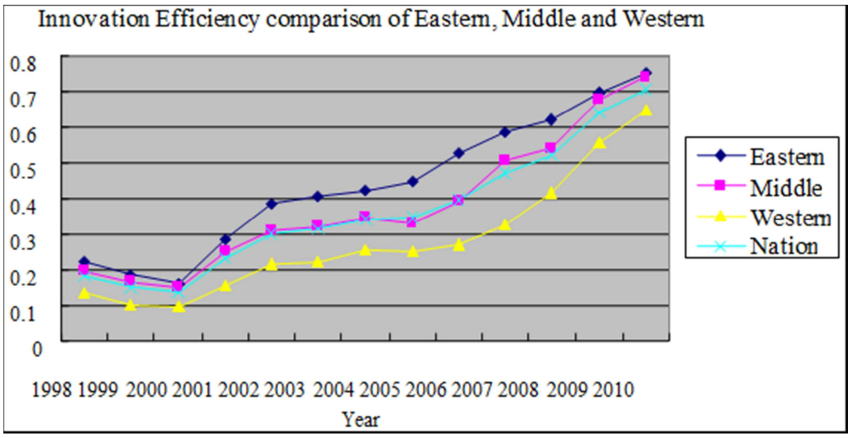

Figure 1. *Innovation Efficiency comparison of Eastern, Middle and Western (R&D stage)*

(4) As can be seen from Table 3 and Figure 1, we can see the regional differences of the average efficiency from 1998 to 2010. The innovation efficiency in Eastern region (TE = 0.4366) > Central Region (TE = 0.3773) > (the national average TE = 0.3634)> Western Region (TE = 0.28). The innovation efficiency in the Eastern region is greater than the Western region and the Central region. And the innovation efficiency in the Central and Western regions is under the national average, indicating that there are significant regional differences of the innovation efficiency.

5.2. Stage II: Commercialization

Table 4. *Max likelihood estimation (Stage II)*

	Coefficient	Standard Deviation	F-Statistic
β_0	1.9558***	0.08206	23.833
β_1	0.0937	0.09071	1.0334
β_2	0.2265**	0.1089	2.0794
β_3	-0.00237	0.01815	-0.1306
β_4	-0.1620***	0.0503	-3.2225
β_5	0.2125***	0.07922	2.6822
η_0	1.4065***	0.3554	3.9580
η_1	-0.2519**	0.1240	-2.0307
η_2	-0.7209***	0.2231	-3.2317
η_3	1.0103***	0.2899	3.4847
η_4	-0.2422***	0.0937	-2.5835
η_5	-0.3165***	0.1138	-2.7806
η_6	0.2216**	0.1119	1.9804
sigma-squared	1.0422***	0.1342	7.7668
γ	0.9998***	0.0003	3100.46

note: * is significant at 10% level; ** is significant at 5% level; *** is significant at 1% level.

As shown from Table 4, γ = 0. 9998, and is significant at the 1% level, which shows that the error term in formula (1) has a distinct composite structure, so it is rather effective by using the SFA method than OLS estimates based on the industry data of 13 years

(1) From the output elasticity of R & D personnel and R & D capital, β_1 =0.0937, β_2 = 0.2265, we can see that technology market turnover increased by 0.0937 with annual R&D capital stock increased by 1%, while technology market turnover increased by 0.2265 with annual R & D staff of full-time equivalents grew 1%, which shows that human resource output elasticity is increasing. China's regional commercialization depended on personnel and capital. This is the case that current R&D personnel configuration relative surplus while relative lack of R&D expenditure. Besides, the sum of R&D funding elasticity and R&D personnel elasticity is 0.3202, less than 1, which mean that efficiency will decrease rather than increase with the increase in production factors.

(2) The coefficient of laborer's quality on Chinese regional commercialization is -0.2512, and is significant at the 5% level, indicating that the laborer's quality have a positive effect on China's regional commercialization. The coefficient of government subsidies on Chinese regional commercialization is -0.7209, and is significant at the 1% level, indicating that government subsidies have a positive effect on China's regional commercialization. The coefficient of market-oriented index on Chinese regional commercialization is 1.0103, and is significant at the 1% level, indicating that market-oriented have a negative effect on China's regional commercialization. The coefficient of FDI on Chinese regional commercialization is -0.2422, and is significant at the 1% level, indicating that FDI have a positive effect on China's regional commercialization. The coefficient of openness on Chinese regional commercialization is -0.3165, and is

significant at the 1% level, indicating that trade have a positive effect on China's regional commercialization. The coefficient of industrial structure on Chinese regional commercialization is 0.2216, and is significant at the 5% level, indicating that industrial structure have a negative effect on China's regional commercialization.

(3) As can be seen from Table 5, the mean of national innovation efficiency is 0.3058 from 1998 to 2010, which is lower than the innovation efficiency (0.3634) of the first stage. This indicates that China's provinces pay more attention to R&D activities than commercialization. This suggests that the whole innovative technology efficiency is very low, and there is considerable space for improvement. As we can see the trends, China's provincial innovation efficiency fell from 0.4342 in 1998 to 0.2703 in 2010, which show a clear downward trend of commercialization.

Table 5. *The provincial innovation efficiency of China (commercialization)*

Province	Innovation Efficiency													
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	mean
Beijing	0.489	0.5791	0.5743	0.5822	0.7944	0.7649	0.8882	0.8988	0.8262	0.8388	0.8944	0.9004	0.9837	0.7703
Tianjin	0.7012	0.6989	0.7624	0.6993	0.6295	0.592	0.5664	0.5528	0.5022	0.4793	0.425	0.4649	0.4987	0.5825
Hebei	0.2915	0.1242	0.1358	0.1	0.0933	0.1067	0.1334	0.1149	0.0916	0.0785	0.0723	0.0787	0.0913	0.1163
Sanxi	0.02	0.05	0.1212	0.0867	0.14	0.098	0.1071	0.1174	0.1474	0.1556	0.1417	0.1378	0.1503	0.1133
Neimeng	0.7236	0.6116	0.4862	0.7174	0.5624	0.5025	0.407	0.3461	0.2359	0.3059	0.4308	0.2724	0.9337	0.5027
Liaoning	0.4859	0.4878	0.5415	0.5547	0.5332	0.4856	0.3673	0.3297	0.2762	0.2842	0.258	0.2614	0.3129	0.3983
Jilin	0.2325	0.254	0.2227	0.198	0.1988	0.1804	0.1857	0.1716	0.1542	0.1386	0.1126	0.1325	0.1039	0.1758
Heilong	0.3362	0.2153	0.2122	0.196	0.174	0.1718	0.1567	0.2875	0.2699	0.2738	0.2505	0.2383	0.3117	0.2380
Shanghai	0.6527	0.8047	0.7901	0.7704	0.7647	0.8385	0.9336	0.842	0.6907	0.6228	0.5029	0.4305	0.382	0.6943
Jiangsu	0.5573	0.5423	0.5073	0.4747	0.4108	0.3484	0.1816	0.1516	0.1308	0.1156	0.1984	0.1938	0.1757	0.3068
Zhejiang	0.9269	0.8944	0.9558	0.8415	0.6459	0.3122	0.2337	0.1819	0.1557	0.1076	0.0812	0.0706	0.0617	0.4207
Anhui	0.2109	0.1924	0.197	0.1711	0.1421	0.1846	0.2022	0.2338	0.2318	0.2109	0.2179	0.2385	0.2428	0.2058
Fujian	0.7883	0.5392	0.43	0.3776	0.2451	0.244	0.1235	0.122	0.1175	0.1269	0.1533	0.1187	0.134	0.2708
Jiangxi	0.3776	0.2976	0.2543	0.276	0.2704	0.2671	0.1801	0.1542	0.0917	0.0951	0.1798	0.2079	0.1979	0.2192
Shandong	0.5607	0.4975	0.4221	0.4657	0.5008	0.4852	0.089	0.1276	0.134	0.114	0.1181	0.1061	0.0882	0.2853
Henan	0.6134	0.5128	0.38	0.3056	0.2442	0.2637	0.2039	0.1855	0.141	0.1169	0.0933	0.105	0.0809	0.2497
Hubei	0.4162	0.452	0.4075	0.4048	0.3769	0.3424	0.256	0.258	0.2525	0.2654	0.26	0.2831	0.3354	0.3316
Hunan	0.9758	0.858	0.8159	0.7133	0.6099	0.5146	0.4689	0.3906	0.3278	0.2639	0.1938	0.1263	0.1134	0.4902
Guangdong	0.5154	0.4788	0.466	0.3739	0.1835	0.2712	0.2017	0.1979	0.2327	0.1621	0.1714	0.154	0.153	0.2740
Guangxi	0.1693	0.3219	0.3629	0.2006	0.3327	0.2854	0.0242	0.0213	0.0469	0.0273	0.054	0.0572	0.0199	0.1480
Hainan	0.801	0.984	0.092	0.1517	0.0262	0.1064	0.0626	0.0587	0.2586	0.0369	0.1477	0.058	0.0075	0.2147
Chongqing	0.4421	0.3926	0.4545	0.5391	0.49	0.2666	0.3313	0.1969	0.2574	0.1378	0.2421	0.1769	0.1173	0.3111
Sichuan	0.1215	0.1251	0.0662	0.0924	0.096	0.0953	0.1072	0.107	0.1283	0.1407	0.1189	0.125	0.1705	0.1149
Guizhou	0.0043	0.0034	0.0741	0.0864	0.056	0.039	0.0181	0.0183	0.0473	0.0368	0.1444	0.2123	0.1253	0.0666
Yunnan	0.7756	0.9876	0.6417	0.7478	0.6007	0.4029	0.1862	0.193	0.0794	0.1422	0.1279	0.117	0.3884	0.4146
Shanxi	0.1081	0.0879	0.1418	0.1253	0.0875	0.1022	0.084	0.1171	0.1383	0.1953	0.2477	0.4365	0.5676	0.1876
Gansu	0.0831	0.0795	0.1474	0.1983	0.2856	0.3734	0.4282	0.4521	0.4268	0.4401	0.4563	0.4778	0.5794	0.3406
Qinghai	0.0547	0.0534	0.125	0.0804	0.1172	0.0961	0.1799	0.3401	0.4275	0.4319	0.5698	0.617	0.6176	0.2854
Ningxia	0.0771	0.1013	0.0819	0.0889	0.1038	0.1103	0.0363	0.0387	0.0441	0.0387	0.0375	0.1205	0.0817	0.0739
Xinjiang	0.5155	0.5688	0.6697	0.7266	0.7213	0.4131	0.3537	0.2796	0.2427	0.0345	0.1132	0.084	0.0832	0.3697
Nation	0.4342	0.4265	0.3847	0.3782	0.3479	0.3088	0.2566	0.2496	0.2369	0.2139	0.2338	0.2334	0.2703	0.3058

Table 6. *Innovation efficiency of China's Eastern, Middle and Western (commercialization)*

Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	mean
Eastern	0.6154	0.6028	0.5161	0.4902	0.4389	0.4141	0.3437	0.3253	0.3106	0.2697	0.2748	0.2579	0.2626	0.3940
Middle	0.3978	0.354	0.3264	0.2939	0.2695	0.2528	0.2201	0.2248	0.202	0.19	0.1812	0.1837	0.192	0.2530
Weatern	0.2795	0.303	0.2956	0.3276	0.3139	0.2443	0.196	0.1918	0.1886	0.1756	0.2311	0.2451	0.335	0.2559
Nation	0.4342	0.4265	0.3847	0.3782	0.3479	0.3088	0.2566	0.2496	0.2369	0.2139	0.2338	0.2334	0.2703	0.3058

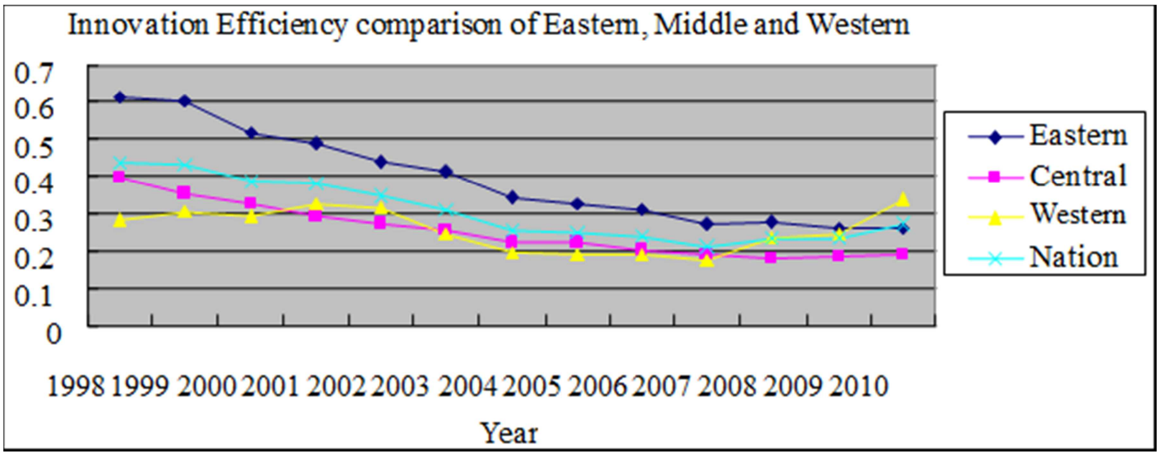

Figure 2. *Innovation Efficiency comparison of Eastern, Middle and Western (commercialization stage)*

(4) As can be seen from Table 6 and Figure 2, whether eastern or central, commercialization efficiency is declining during the period. The western and national commercialization mean meets the minimum in 2007 before a slight rebound. The average commercialization of the Eastern region (TE = 0.394)> (the national average TE = 0.3058)> Western region (TE = 0.2559)> Central region (TE = 0.253). The commercialization of the Middle and Western region is below the national average, and the average efficiency of Western region is slightly higher than the Central region, which shows obvious regional differences of commercialization.

6. Discussion

The role of R&D expenditure and R&D personnel in the two-stage is not the same. R&D expenditure has a negative impact on R&D efficiency, while it has a positive influence on commercialization. The reason may be: R&D innovation efficiency will not sensitive to R & D expenditure than commercialization because basic research will take longer period time and take a slow effect than application. R&D personnel in two stages have a positive effect on R&D efficiency and commercialization. And staff input has higher output elasticity than R&D expenditure. The reason may be: improvement of R&D personnel quality and enhancement of information sources increase the productivity of researchers. Per capita technological opportunities and technology needs of researchers continue to grow. Because of the weak technological base, the lower starting point, the huge gap with foreign technology, so there are large space for technology research after the reform and opening up. Besides, with the rapid economic growth and increasing demand for technology, it will need more R&D personnel. But it will take longer time to train R&D personnel. The growth rate of technology opportunities and needs are faster than R&D personnel, which lead to increase of per capita technical opportunities and improvement of R&D efficiency.

The commercialization efficiency and R&D efficiency in the Eastern region are higher than the Central and Western regions,. which support hypothesis 1. The reasons may be: compared with the Middle and the West, the Eastern region have strong economic strength whose infrastructure, human resources and institutional construction has formed a complete system that promote the innovation efficiency; however, the economic level in the Middle and the West are lower than the East region, weakening its ability in building regional innovation environment, and thus also restricting the effective development of regional innovation activities. This also shows that regional innovation efficiency is relevant to regional economic development level to some extent.

The quality of workers in the two-stage has a significant positive impact on innovation efficiency, which support hypothesis 2A. The discovery is consistent with some scholars (Chi et al,2004; Yu et al,2005). In general, the higher the quality of workers, the stronger of the absorption, digestion and the use and innovation of new technologies capabilities is. And higher level of education can help people make use of innovative resources more rational and effective to further improve the innovation efficiency. Zhou's (2011) study shows that human capital stock was significantly positively correlated with the regional innovation efficiency. Among human capital structure, people who have received university and high school education show a significant promotion to regional innovation efficiency.

Government subsidies have a significant positive impact on regional innovation efficiency, which is consistent with Zhao's (2014) findings and also support hypothesis 2B. Due to uncertainties, spillovers, and market risks, market failures caused by externalities, R&D achievements of enterprises can not be fully occupied, the private rate of return on R&D investment is lower than the social rate of return, which seriously affect the company's R&D investment behavior, directly leading to insufficient investment on business R&D. So it will not achieve socially optimal R&D inputs only relying on market incentives. In this case, the government can make up "market failure" to guide the behavior of corporate innovation directly and indirectly.

Market-oriented degree has a negative effect on commercialization, indicating the development of China's scientific and technological achievements commercialization market is not mature. At present, the government's management of science and technology intermediary organizations lack of legal norms, laws and regulations related to science and technology agency is still basically a blank. Legal status, economic status, management system, operational mechanism of most technology intermediary service organizations is unclear. The quality of service and personnel of part of the science and technology intermediary service is still lower. Most technology intermediary has not created a brand, form service system of specialization and collaboration network. The intermediary organizations served for technology and financial develop slower, so that on one hand the financial sector do not lend out, on the other hand technology companies is serious shortage of funds which can not meet the urgent need for funds.

FDI and regional openness have a negative impact on regional R&D efficiency and have a positive impact on commercialization efficiency, which partly support hypothesis 2D and 2E. This shows that foreign investments are more willing to invest in commercialization with quick return, rather than invest in basic research with huge risk. In foreign trade, it is impossible to achieve advanced and sophisticated technology from abroad through technology trade. Most purchased foreign technologies are backward and outdated and are not helpful for the improvement of regional innovation efficiency.

The ratio of high-tech industry output do not have a positive effect on the regional innovation efficiency, which do not support hypothesis 2F. Relevant literatures have similar findings (Li, 2007; Huang, 2007; Li, 2009). As Huang et al (2007) consider that the innovation efficiency of industry with low technology is higher, while the innovation efficiency of industry with high technology is lower. Does that indicate that constrained environment of high-tech industry restrict the improvement of innovation efficiency? This issue needs to be further in-depth investigation. According to Li(2007)'s research, it can be explained from two aspects: on one hand, due to technical confidentiality, high-tech enterprise are more likely to develop new products, new markets, and not willing to apply patent who will have the risk of disclosure. So there are some flaws by using patent as a indicator in measuring innovation capability of high-tech industries. On the other hand, as seen from the ratio of high-tech industry R&D expenditure and output to manufacturing sector (see Table 7), the ratio of R&D expenditures and R&D staff of China's high-tech industry to manufacturing sector were lower than the proportion of invention patents granted, which to some extant explains the unsatisfactory effect of China's high-tech industry innovation efficiency.

Table 7. *High-tech industry R&D inputs and outputs accounted for the proportion of manufacturing (%)*

	2000	2001	2002	2003	2004	2005	2006	2007	2008
R&D expenditure	34.4	38.1	35.5	32.8	32.7	30.6	29.4	27.1	25.7
R&D personnel FTE	30.9	32.9	31.2	29.7	31.3	31.8	30.4	31.9	30.9
Invention patent granted	23.8	20.1	20.9	22.9	26.5	30.4	28.9	31.5	44.1
New product sales	20.7	32.6	32.8	31.6	32.2	30.1	29	26.7	25.4

7. Conclusion and Suggestion

The paper applies SFA method to analyze regional two-stage innovation efficiency consisting of R&D and commercialization and its influence factors based on panel data in 30 provinces of China from 1998 to 2010. The result shows that: (1) The regional innovation efficiency is low, and commercialization efficiency is lower than R&D efficiency, but both are improving. The output elasticity of R&D personnel is higher than the R&D funds. (2) The commercialization efficiency and R&D efficiency in the Eastern region are higher than the Central and Western regions. The R&D efficiency in the Eastern and Central region is higher than the national average level, while R&D efficiency in the Western region is lower than the national average level. The commercialization efficiency in the Central region is less than the Western region, and both are lower than the national average level. (3) Laborer's quality and government subsidies have significantly positive correlation with R&D efficiency and commercialization. Market competition has significantly positive correlation with R&D efficiency, but has significantly negative correlation with commercialization. FDI and regional opening degree have significantly negative correlation with R&D efficiency, but have positive correlation with commercialization. Industrial structure has significantly negative correlation with commercialization, and has negative correlation with R&D efficiency, but is not significant.

According to above analysis, some suggestions are provided as follow:

Firstly, on one hand, we need to increase regional R&D expenditure, on the other hand we should adjust the R&D expenditure structure. As can be seen from the above analysis, R&D expenditure has a negative impact on patent, while has a positive influence on commercialization, which show that R&D expenditure do not give a enough support to basic research. So in the future we should make feasible structural adjustment of R&D input, and spend more R&D expenditures on basic research. On one hand, government need to rationalize the R&D input structure to ensure the high-efficiency of funding, minimize crowding out business capital; on the other hand, government need to improve the supervision mechanism to ensure the improvement of technological innovation efficiency and quality when funding for science and technology activities.

Secondly, we need to increase investment in education, improve the quality of personnel. Improving the quality of R&D personnel, focusing on training a group of engineers and scientists will help to improve regional technological innovation capability and efficiency, improve the quality of the population to generate more demand for technological innovation, and also help to improve the new product acceptance and consumption capacity. Government should develop and improve the reasonable evaluation and incentive mechanisms of researchers, create a good research environment, fully mobilize the enthusiasm of researchers, and so that researchers can really threw themselves into research work.

Thirdly, we should adopt a policy to guide the FDI to flow to technology, knowledge-intensive industries instead of labor-intensive industries when introduce foreign capital, continue to maintain prosperity and stability during the region's opening up. We should pay attention to that t foreign technology should match the region, manpower, and other factors when develop international trade especially technology trade.

Fourthly, we should pay further attention to commercialization of scientific and technological achievements. We should not only set up official agency who provide support and services for Small-Medium Enterprises' S&T innovation, technology purchase and absorption, industrial structure adjustment to promote the development of SMEs, but also establish profit and private technology intermediary service organizations with reasonable division of labor, multi-level, clear property rights, operating according to market economy to offer a variety of services for different objects. We should increase investment in scientific research and technological services, encourage private capital to enter S&T intermediary organizations, develop all kinds of advisory bodies venture capital funds. We should establish S&T intermediary organizations human resource strategic planning mechanism, improve personnel recruitment, training, evaluation, salary, career planning as well as market-oriented S&T intermediary diverse talent evaluation system.

Lastly, the regional governments should focus on the adjustment of low technological innovation process. Specifically, the Eastern region should not only maintain the research and innovation advantages, but also give further attention to the commercialization. The Central region should concentrate resources to commercialization with the aid of R&D advantages, promote the combination of technological innovation economy, and play the supporting role of technological progress on regional economic growth better. The West region should pay attention to the digestion and absorption of purchased technology, and establish effective mechanisms to protect and promote technological invention and innovation, and develop the appropriate technology actively. The country should give a key support to low innovation efficiency region by encouraging talents and firms to these areas, and increase investment to reduce the gap of technological innovation efficiency between different regions.

References

[1] J. Fagerberg, M. Srholec, National innovation systems, capabilities and economic development[J], Research Policy 37 (2008) 1417-1437.

[2] Freeman, C. H. (1987). Technology policy and economic performance: Lessons from Japan[M]. London: Pinter.

[3] Lundvall Bengt-Ake. National systems of innovation: towards a theory of innovation and interactive learning[M]. London: Pinter, 1992.

[4] Nelson, R. R. (Ed.). (1993). National innovation systems: A comparative study[M]. New York: Oxford University Press.

[5] Cooke, P., Gómez Uranga, M., & Etxebarría, G. (1997). Regional systems of innovation: Institutional and organisational dimensions[J], Research Policy, 26, 474-491.

[6] Cooke, P. (2001). Regional innovation systems, clusters and knowledge economy[J]. Industrial and Corporate Change, 10(4), 945_974.

[7] Buesa, M., Heijs, J., Pellitero, M. M., & Baumert, T. (2006). Regional systems of innovation and the knowledge production function: The Spanish case[J]. Technovation, 26, 463-472.

[8] Guan, J. C., & Liu, S. Z. (2005). Comparing regional innovative capacities of PR China-based on data analysis of the national patents[J]. International Journal of Technology Management, 32, 225-245.

[9] Hilpert, U. (1991). Regional innovation and decentralization: High-tech industry and government policy[M]. London and New York: Routledge

[10] Mihai Talmaciu, Considerations regarding the development of Romanian regional economies through innovation and entrepreneurship[J], Procedia Economics and Finance (2012) 914 – 920

[11] Liu Shunzhong, Guan Jiancheng. The Evaluation on the Innovating Performance of Regional Innovation Systems[J]. Chinese Journal of Management Science, 2002, (1): 75-78. (in Chinese)

[12] Chi Renyong, Tang Gennian, Study on efficiencies of regional technology innovation based on evaluation of inputs and performances[J], Science research Management, 2004, (4): 23- 27 (in Chinese)

[13] Guan Jiancheng, He Ying. The Perfomuance of Chinese Regional Innovation System Evaluation Based on Data Envelopment Analysis [J]. Studies in Science of Science, 2005, (2): 265-272. (in Chinese)

[14] Li Jing, Bai Junhong, Tan Qingmei. Empirical Research on the Regional Innovation Efficiency: Based on the Panel Data of Chinese Provinces and DEA Method[J]. Systems Engineering, 2008, (12): 1-7. (in Chinese)

[15] Zhao zheng, Jiang Xin, Empirical study on Provincial Innovation Efficiency and its Affect factors in China[J], Journal of Beijing Institute of Technology(Social Sciences Edition), 2014(4): 61-66 (in Chinese)

[16] Wu Hecheng, Liu Sifeng, Evaluation on the R&D Relative Efficiency of Different Area s in China Based on Improved DEA Model[J], R&D Management, 2007(2): 108-112 (in Chinese)

[17] Liu Hedong, Research on regional R&D efficiency and its influencing factors ——empirical analysis based on stochastic frontier function[J], Studies in Science of Science, 2011(4): 548-556. (in Chinese)

[18] Shi Ping, Zhang Bingnan, Han Xianfeng, Song Wenfei, R&D Efficiency and Its Influencing Factors of China Region based on SFA method[J], Statistics and Decision, 2011(12): 103-106 (in Chinese)

[19] Cai Xiang, Cui Xiaolan, Xiong Jing, Liu Tongcun, R&D Efficiency and Its Influencing Factors of China Region——A Study Based on the Perspective of"Research Outputs & Achievements Conversion[J], Soft Science, 2013(3): 80-84 (in Chinese)

[20] Liu X L, White S. An exploration into regional variation in innovation activity in China [J]. International Journal of Technology Management, 2001, 21 (1-2): 114-129.

[21] Liu Xielin, Hu Zhijian, The pattern of China regional innovation capability and its implication[J], Studies in Science of Science, 2002(5): 550-556. (in Chinese)

[22] Zhou Li, Wu Yuming, Factor Analysis and Cluster Study on Regional Innovation Capability of China's 31 Provinces——An Alternative to Synthetical Evaluation on Regional Innovation Capability with Factor Analysis[J], China Soft Science, 2006(8): 96-103 (in Chinese)

[23] Zhou Fanqing, Stochastic frontier Analysis on Human Capital, Human Capital Structure and Regional Innovation Efficiency——Empirical Analysis of Chinese Provincial Panel Data[J], Journal of Intelligence, 2011(12): 282-285 (in Chinese)

[24] Hou Peng, Liu Siming, Endogenous Innovation Effort, Knowledge Spillover and Regional Innovation Capacity——Empirical Analysis of Chinese Provincial Panel Data[J], Modern Economic Science, 2013(1): 14-25 (in Chinese)

[25] Li Xibao, An empirical analysis of the effect of institutional factors on regional innovation performance[J]. The Journal of Quantitative & Technical Economics, 2007, 24(8): 13－24 (in Chinese)

[26] Bai Junhong, Jiang Kesheng, Li Jing, Li Jia.Analysis of the Impact of Environment Factors on Regional Innovation Efficiency: Empirical Test Based on the DEA - Tobit Two - step Method[J]. R&D Management, 2009, (2): 96 ~ 102. (in Chinese)

[27] Diao Lilin, Zhang Bei, Ma Yanan, The impact of technological environment on regional technical efficiency based on a stochastic frontier analysis model[J], Science Research Management, 2011(4): 143-151 (in Chinese)

[28] Timothy J.Coelli, D.S.Prasada Rao, Christopher J.O Donnell, An Introduction to Efficiency and Productivity Analysis[M], China Renmin University Press, 2008, 8 (in Chinese)

[29] Aigner D, Lovell, CAK, Schmidt P. Formulation and Estimation of Stochastic Frontier Production Function Models[J]. Journal of Econometrics, 1977, 6(1): 21-37.

[30] Meeusen W, van den Broeck J. Efficiency Estimation from Cobb － Douglas Production Functions With Composed Error[J]. International Economic Review, 1977(18): 435-444.

[31] Battese, E. and Coelli, T. Frontier Production Functions Technical Efficiency and Panel Data with Application to Paddy Famer in India[M] .Journal of Productivity Analysis, 1992, (3): 153-169.

[32] Griliches, Zvi, R &D and Productivit y[M]. Chicago: University of Chicago Press, 1998.

[33] Wu Yanbing, R&D Stock, Knowledge Function and Productive Efficiency[J], China Economic Quarterly, 2006(7): 1129-1156 (in Chinese)

[34] Zhu Pingfang, Xu Weimin, On the Impact of Government's S&T Incentive Policy on the R&D input and its patent output of large and medium-sized Industrial Enterprises in Shanghai[J], Economic Research, 2003(6): 45- 53 (in Chinese)

[35] Griliches, Zvi, Productivity, R &D and Basic Research at the Firm Level in the 1970s'[J], American Economic Review, 1986, 76 (6), 141-154.

[36] Hu, Albert G. Z., Jefferson, G. H. and Qian Jinchang, R&D and Technology Transfer: Firm-Level Evidence from Chinese Industry [J], Review of Economics and Statistics, 2005, 87 (4), 780-786.

[37] Coe, David S. and Elhanan Helpman, International R &D Spillovers[J], European Economic Review, 1995, 39 (5), 859-887.

[38] Jefferson, Gary H., Bai Huamao, Guan Xiaojing and Yu Xiaoyun, R&D Performance in Chinese Industry [J], Economics of Innovation and New Technology, 2004, 13 (1/ 2).

[39] Zhu Youwei, Xu Kangning. The empirical research on R&D efficiency of Chinese high-tech industries[J]. China Industrial Economy, 2006 (11): 38 -45. (in Chinese)

[40] Liang Laixin, Zhang Huanfeng, An empirical study on the R& D inputs performance of high-tech enterprises[J], Journal of Central South University (Social Science Edition), 2005(2): 232-236

[41] Yu Yongze, The empirical research on technical innovation efficiency and its impacts of China ' s high-tech industry: Based on the two stages analysis from the perspective of value chain[J]. Economic Science, 2009(4): 62-74. (in Chinese)

[42] Tang Qingquan, Lu Boke, Yuan Yingxiang, Industrial Firm's Resources Input and Innovation Efficiency[J], The Journal of Quantitative & Technical Economics, 2009(2): 3-17 (in Chinese)

[43] Fan Hua, Zhou Dequn, Regional science and technology innovation efficiency evolution and its affect factors in Chinese provinces[J], Science Research Management, 2012(1): 10-18 (in Chinese)

[44] Zhu Runrun, Research on the relationship between region human capital and innovation capability[D], Yunnan University of Finance and Economics, 2011 (in Chinese)

[45] Zhou Xiaoyan, Ge Jian,Ma Liyi, The Empirical Research on Region Innovation Systems Efficiency-Based on the Panel Data in China[J], Economic Management Journal, 2009,31(3):28-32 (in Chinese)

[46] Fan Gang, Wang Xiaolu, Ma Guangrong, Contribution of Marketization to China's Economic Growth[J], Economic Research, 2011(9):4-16 (in Chinese)

[47] Dang Wenjuan, Kang Jijun, Xu Lei, The Influence of Marketization Degree on Regional Innovation Capability in China- Based on the Perspective of Unbalanced Development[J], Journal of Yunnan Financial and Economic University, 2013(4): 93-99 (in Chinese)

[48] LI Yan-li, ZHAO Da-li, GAO Wei, Study on Market Reform, Knowledge Transfer and Regional Innovation Capacity[J], Soft Science, 2012, 26(4):28-32 (in Chinese)

[49] Jin Huaiyu, Jiam Lirong, China's Regional Innovation Efficiency and Its Influencing Factors Considering the Lag Effect[J], Systems Engineering, 2013 (9): 98-106 (in Chinese)

[50] Connolly M. The Dual Nature of Trade: Measuring Its Impact on Imitation and Growth [J]. Journal of Development Economics, 2003, (72): 31- 55