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# Innovation Efficiency and Impact Factors of China's Strategic Emerging Industries

**[1]Liu Zhiying and [2]Xia Yanmei**

[1]University of Science and Technology of China,
No.96, JinZhai Road Baohe District, Hefei, Anhui, 230026, P.R. China.
[2]University of Science and Technology of China,
No.96, JinZhai Road Baohe District, Hefei, Anhui, 230026, P.R.China.

**Corresponding Author: Liu Zhiying**

**Abstract**

In this article, we select 89 listed companies of China's strategic emerging industries from 2007 to 2010 as a sample, and calculate innovation efficiency of the listed company with method of SFA, then estimate the impact factors of innovation efficiency by Tobit model, including scale and profitability of enterprises, quality of staff and subsidy of government. The result goes that, innovation efficiency of China's strategic emerging industries rose year by year. Scale of company had a significant positive impact on innovation efficiency, so did subsidy, and profitability had a negative impact on innovation efficiency. While, there was no significant relationship between quality of staff and innovation efficiency. Finally, we give some political advice to support the development of strategic emerging industries. The significance of this study probably lies in these points. Firstly, the result confirms that strategic emerging industries in China have achieved a tremendous innovation progress for the past few years, and it prove to be a right choice to cultivate strategic emerging industries as a new economic growth point. Secondly, the government can easily formulate some supporting policies from the aspect of impact factors.

**Keywords:** strategic emerging industries; innovation efficiency; impact factors; SFA; Tobit model.

## INTRODUCTION

After economic crisis, all the countries over the world consider emerging industry as a driving force of economic growth and recovery, China also needs to transform the mode of economic growth, to upgrade industrial structure, and to enhance international competitiveness. In 2010, The state council of China issued a regulation on cultivating and developing strategic emerging industries, and clearly defined energy saving and environmental protection, a new generation of information technology, biology, equipment manufacturing, new energy, new materials and new-energy automobiles as seven major industries to cultivate. Strategic emerging industries will become China's engine industries for economic growth in the future. At present, mainly took some specific industry to discuss the path of technological innovation and impact factors. Professor Du Chuanzhong (2008) regarded information technology industry as a research object, found that innovation diffusion has an obvious correlation with scale of enterprise and market structure. Professor Liu Yong (2011) studied on Taiwan solar energy industry, and discovered that the development of emerging industries would have a huge progress by referring to an industrial plan and formulating technological Integration. Professor Liu Meiping (2012) put forward a symbiosis pattern of technical innovation by analyzing the restricting factors of technology innovation of strategic emerging industries. Xiong Zhengde (2010) stated that macroscopical economic situation has a great influence on the development of strategic emerging industries based on an empirical study, and those emerging industries which are related to low carbon will have bright prospect.

As for the research of innovation efficiency, most scholars start from the aspect of area, industry and enterprise, use the method of DEA or SFA to evaluate innovation efficiency. Nasierowski and Arcelus (2003) Calculated innovation efficiency of 45 countries, found that technology innovation scale and allocation of resources have strong impact on the change of productivity. Akihiro (2008) evaluated research efficiency of pharmaceutical industry in Japan. Diaz-Balteiro Lius (2006) analyzed the relationship between productive efficiency and innovation activity in Spain’s wood-based industry. Xiang Benwu (2011) estimated innovation efficiency of 31 industries, and concluded that there is a great imbalance among difference industries. Ning Zhong and Li Junfeng (2010) compared the innovation efficiency of GEM listed company with main board listed company, and the result goes that there is no significant difference between the two, the scale of listed companies both in GEM and main board is small, and has a significant impact on research efficiency.

In this paper, we collect the panel data of 89 listed companies in strategic emerging industry from 2007 to 2010, use SFA model to calculate innovation efficiency of each listed company and Tobit model for regression analysis of their impact factors. Compared with previous researches, we combined SFA with Tobit model to calculate and evaluate innovation efficiency and impact factors of strategic emerging industries.

The limitation of this research is that the sample size is not big enough, and it may affect the empirical result in some extent. Besides, we need to point out the innovation path and propose more specific and workable advices for the development of strategic emerging industries in further studies.

**Research Method**

Stochastic frontier function model was first proposed by Aigner, Lovell and Schmid, the rationale is to separate the deviation between actual production unit and front into Random error variables and technical inefficiency variables, then, estimate the parameters of random frontier production function.

According to the summaries of Kumbhakar and Lovell, random frontier production function model is generally defined by

$$y_{it} = f(x_{it}, t)\exp(v_{it} - u_{it}) \qquad (1)$$

$y_{it}$ represents the decision unit

The $u_{it}$s are assumed to be non-negative random variables and independently distributed, associated with technical inefficiency of production.

$v_{it}$s are assumed to be random variables, independent of $u_{it}$s.

Technical efficiency is defined by,

$$TE_{it} = E[f(x_{it},t)\exp(v_{it}-u_{it})]/E[f(x_{it},t)\exp(v_{it}) \mid u_{it}=0] = \exp(-u_{it}) \qquad (2)$$

Obviously, when $u_{it} = 0$, $TE_{it} = 1$, the decision unit is technical effective. While $u_{it} < 0$, $TE_{it} < 1$, there exists technical inefficient, log formula (1), then,

$$\ln y_{it} = \ln f(x_{it}, t) + v_{it} - u_{it} \qquad (3)$$

Battese and Coelli (1995) set a variance parameter $\gamma = \sigma_u^2 / \sigma_u^2 + \sigma_v^2$ to estimate the proportion of technical inefficiency part, and $0 \le \gamma \le 1$, if $\gamma$ close to 0 can be accepted, it indicates that the distance between actual output and frontier output all comes from uncontrollable random error variables, at this time OLS method will be proper. As for technical inefficiency $u_{it}$, we use Tobit model for regression analysis.

Tobit model was first proposed by Tobin, Suitable for positive numeric and largely continuous distribution, but contains some results variable whose positive probability value is zero.

Assume the potential variable's regression model is,

$$y_i^* = \beta_0 + x_i\beta + \mu$$
$$y_i = \max(0, y_i^*) \qquad (4)$$

The intercept point is set to zero above, actually the intercept point can be set to any Constant variables, then the log-likelihood function can be described as,

$$\ln L = \sum_{y_i>0} -\frac{1}{2}\left[\ln(2\pi) + \ln\sigma^2 + \frac{(y_i - x_i\beta)^2}{\sigma^2}\right] + \sum_{y_i=0} \ln\left[1 - \Phi\left(\frac{x_i\beta}{\sigma}\right)\right] \qquad (5)$$

The likelihood function is a mix form of discrete distribution and continuous distribution, maximum the likelihood function can achieve estimate values of the parameters. The stochastic frontier function model and Tobit regression model in this article are supposed to be,

$$\ln patent = \beta_0 + \beta_1 \ln K_{it} + \beta_2 \ln L_{it} + \beta_3 t + \frac{1}{2}\beta_4(\ln K_{it})^2 + \frac{1}{2}\beta_5(\ln L_{it})^2 + \frac{1}{2}\beta_6 t^2$$
$$+ \beta_7 \ln K_{it} \ln L_{it} + \beta_8 t \ln K_{it} + \beta_9 t \ln L_{it} + v_{it} - u_{it} \qquad (6)$$

$$m_{it} = \delta_0 + \delta_1 scale + \delta_2 profit + \delta_3 educated + \delta_4 subsidy \qquad (7)$$

$\ln patent$ represents the logarithm form of patent , $i$ and $t$ respectively represent the $i$ th industry and $t$ th year, $\ln K_{it}$ and $\ln L_{it}$ respectively represent the logarithm form of research funds and research personnel full-time equivalent. Besides, $v_{it} \sim N(0, \sigma_v^2)$ and $u_{it} \sim N^+(\mu, \sigma_u^2)$.

## DATA AND VARIABLES

### Data Sources and Processing

The original data used in this paper collected from the web site of the state intellectual property office and annual reports of 89 listed companies. Considering data feasibility and time interval between input and output, we decided to set the time span from 2007 to 2010 and suppose the time interval is one year.

### Input and Output Variables

We select R&D and research personnel of strategic emerging industries' listed companies as input index, refer to Wu Yanbing's data processing method. The formula is defined by,

$$K_{it} = (1 - \delta)K_{i(t-1)} + E_{it} \qquad (8)$$

$K_{it}$ represents the stock capital of the $i$ th place at time $t$, $\delta$ is the depreciation rate, suppose $\delta$ =15%, $E_{it}$ represents actual research and development expenditure of the ith listed company at time $t$.According to Zhu Pingfang and Xu Weimin's price index, we choose year 2007 as base period , then process the nominal R&D expenditure, the formula of capital stock at base period is defined by,

$$K_{i0} = E_{i0} /( g + \delta ) \qquad (9)$$

$K_{i0}$ represents stock capital at base period, $E_{i0}$ represents actual R&D expenditure at base period, $g$ represents the growth rate of actual R&D expenditure during the investigation period, then we can acquire the stock capital of R&D expenditure in each period.

We select applications of invention patent, utility model patent and appearance design patent as innovation output.

**Impact Factors**
Study found that impact of scale on technological innovation is mainly embodied in utilization efficiency of innovation resources. Large enterprises and small and medium-sized enterprises both have advantages and disadvantages in terms of technological innovation, enterprises with large scale often have plenty of innovation resources, such as capital, technology and talent, etc, and they can gain a better scale benefit, but large enterprises' monopoly position in the market inhibits their technical innovation power in a certain extent. While small and medium-sized enterprises have strong innovation consciousness because of competition pressure and relatively flexible organization (Stock G.N., 2002).

Generally, enterprises with good profitability are likely to have strong research and development ability. Furman J.L. and Porter ME, 2002). We defined this variable by net profit divides main business income.

Comparatively speaking, staff with good education background will have high level of insight and research ability (Edler J. and Berger M., 2012.).

As innovation achievement is a kind of public products, government financial aid policy will influence technological innovation, Policy tools consist of government guarantee, discount and loans, tax incentives and public research. In this article, we select subsidies to measure the support of government (Stuart T.E, 2000).

**Empirical Analysis**
We use frontier 4.1 and stata 10 as econometric analysis software, empirical result is shown below:

Table 1 SFA model parameters estimated value

| Variable | Coefficient | standard-error | t-ratio |
|---|---|---|---|
| $\beta_0$ | -39.468*** | 0.995 | -39.647 |
| $\beta_K$ | 1.513*** | 0.498 | 3.039 |
| $\beta_L$ | 7.302*** | 0.928 | 7.864 |
| $\beta_t$ | 7.593*** | 0.986 | 7.700 |
| $\beta_{KK}$ | 0.154* | 0.111 | 1.384 |
| $\beta_{LL}$ | 0.311** | 0.147 | 2.200 |
| $\beta_{tt}$ | -0.165 | 1.117 | -0.140 |
| $\beta_{KL}$ | -0.445*** | 0.175 | -2.540 |
| $\beta_{tK}$ | -0.214 | 0.209 | -1.023 |
| $\beta_{tL}$ | 1.036*** | 0.490 | -2.114 |
| sigma-square | 19.583*** | 5.154 | 3.800 |
| Γ | 0.033*** | 0.006 | 5.768 |
| Mu | -1.597** | 0.925 | -1.727 |
| Eta | 1.597*** | 0.189 | 8.466 |
| log likelihood function | -771.378 | | |
| LR test of the one-sided error | 182.494 | | |

*significant at 0.1,***significant at 0.01, LR obeys mixture of chi-square distribution.

$\gamma$=0.033, and LR test is significant at 0.01, they indicate that Error term in formula (6) has an obvious composite structure. Thus it's necessary to use SFA method.
$\beta_K$=1.513, $\beta_{KK}$=0.154, and respectively significant at 0.01 and 0.1, it demonstrates that there is a significant positive correlation between innovation efficiency and R&D funds.
$\beta_L$=7.302, $\beta_{LL}$=0.311, and respectively significant at 0.01 and 0.05, it shows that labor input has a significant positive impact on innovation efficiency.
$\beta_t$=7.593, significant at 0.01, $\beta_{tt}$=-0.165, not significant, then we can conclude that innovation efficiency of strategic emerging industry increases year by year.

Table 2 Innovation efficiency of strategic emerging industries' listed companies

| Industry | 2007 | 2008 | 2009 | 2010 | AVG |
|---|---|---|---|---|---|
| Energy Saving& Environmental Protection | 0.0260 | 0.2641 | 0.7298 | 0.9363 | 0.4890 |
| Information Technology | 0.0537 | 0.3379 | 0.7727 | 0.9475 | 0.5279 |
| Biology | 0.0535 | 0.3373 | 0.7724 | 0.9474 | 0.5276 |
| Equipment Manufacturing | 0.0604 | 0.3551 | 0.7818 | 0.9498 | 0.5368 |
| New Energy | 0.0119 | 0.1847 | 0.6740 | 0.9211 | 0.4479 |
| New Materials | 0.0338 | 0.2785 | 0.7387 | 0.9387 | 0.4974 |
| New-energy Automobiles | 0.0386 | 0.2498 | 0.6479 | 0.8977 | 0.4585 |
| Strategic Emerging Industry | 0.0397 | 0.2868 | 0.7310 | 0.9341 | 0.4979 |

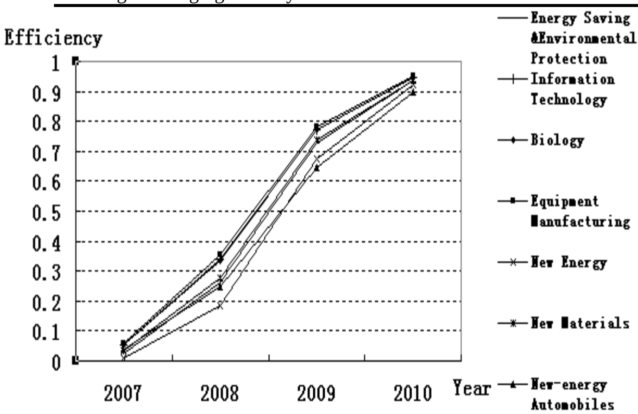


Figure 1: comparison of 7 strategic emerging industries

Figure 1 shows that, Innovation efficiency of strategic emerging industries increased year by year. Because of different conditions in terms of policy support, industrial foundation and market application, segmentation industries' innovation efficiency appears a certain degree of differentiation.

Among them, new energy industry has the lowest innovation efficiency value with 44.794%, and new energy industry is still at the stage of development. Although solar power generation, tidal power generation and geothermal power generation have already begun to take shape in china, design and manufacture of the generator are still behind those countries, such as Denmark, Holland, Britain and America, as well as most of new energy materials in domestic rely on import. In addition, new energy industry is not mature, and cannot match the need of market. New energy vehicle is the direction of transformation and upgrade of global auto industry. Chinese government issued lots of relevant supporting policies, but is not satisfied with its average innovation efficiency. The core technology of new energy industry is lack of competitiveness, especially in terms of battery system integration, large scale production and process design. The Average value of innovation efficiency in energy saving and environmental protection industry is 48.904%, and most enterprises are weak in scientific research.

Besides, technological integration ability of new material industry is not good, processing technology and equipment manufacturing level are low, and production equipments have relied on import for a long term. At this time, government's funds and policies will be a core driving force for the development of energy saving and environmental protection industry. The innovation efficiency values of information technology industry and biological industry are relative high. By the limitation of economic strength and technology accumulation, China's information technology development mainly adopts following strategy. The government attaches great importance to the introduction, digestion, absorption and recreation of information technology, and the input of innovation resources increase year by year. But in the area of high-tech chips, core software, key components and special equipments, instruments and meters, most of intellectual property rights and technology standard are controlled by foreign enterprises. The subjects of technological innovation in biological industry are mainly concentrated upon scientific research institutions and universities, and the proportion of biological enterprises' R&D input is specifically low, they lack effective support from hi-tech achievements.

Innovation efficiency of high-tech equipment manufacturing industry is the highest one, it's up to 53.676%, but the core technology of high-tech equipments highly depends on foreign countries. Statistics state that imports of hi-tech equipment manufacturing industry (except for electronic) was more than 174.6 billion dollars, and the great majority is core parts. In order to further analyze the impact factors of strategic emerging industries' innovation efficiency, we use Tobit model to estimate the influence of scale, profitability, staff quality and government's subsidies. Following result is the estimating value of stata 10.

Table 3 Tobit model regression results

| Variable | Coefficient | Std. Err. | T | P>\|t\| |
|---|---|---|---|---|
| Scale | 0.5072242*** | 0.1384477 | 3.66 | 0.000 |
| Profit | -0.3803834** | 0.1380327 | -2.76 | 0.007 |
| Educated | -0.886799 | 0.1843324 | -0.48 | 0.631 |
| Subsidy | 0.3510568*** | 0.1202234 | 2.92 | 0.004 |
| -cons | 0.1347835*** | 0.0154942 | 8.70 | 0.000 |
| /sigma | 0.1534743 | 0.0091392 | | |
| Log likelihood | 64.195 | | | |
| LR chi2(3) | 30.83 | | | |
| Prob>chi2 | 0.0000 | | | |

*significant at 0.1,***significant at 0.01, LR obeys mixture of chi-square distribution.

Table 3 indicates that both scale of enterprise and government's subsidies have significant positive influence on innovation efficiency of strategic emerging industries, the correlation coefficients are 0.507 and 0.351 respectively. Profitability has an obvious negative influence on innovation efficiency, the correlation coefficient is -0.380. And there is no obvious relationship between staff quality and innovation efficiency. Enterprises with large scale and good operation condition are often conducive to innovation, because they can effectively make use of innovation resources. Besides, organizing and implementing the policy of strategic emerging industry and supervising government subsidy all help to raise innovation efficiency.

**CONCLUSIONS AND COUNTERMEASURES**

Strategic emerging industries will be a common choice to the countries all over the world later in financial crisis, and related researches gain an extensive attention. This paper conducted an empirical research on innovation efficiency and impact factors of strategic emerging industries.

Following parts are the conclusions and countermeasures.

- Input of R&D personnel has a significant positive impact on the output of innovation activities. Different from general technology industries, strategic emerging industries focus on core technological innovation and emphasize international visions and strategic thoughts. Thus, government and enterprises need to cultivate international, strategic and technical talents to accumulate innovation strength for strategic emerging industries. Compared with input of R&D personnel, the correlation between R&D funds and innovation output is not very obvious. In recent years, great enthusiasm was injected into strategic emerging industries. To be specifically, local governments frequently issued relevant development plans and supporting policies, and enterprises set foot in strategic emerging industry one by one. As strategic emerging industries have characteristics of high input resistance and time lag, and the prices of raw materials are relatively high, also research and development funds will not immediately get return, all these factors may lead to the result that R&D funds have no significant impact on innovation output.
    - Innovation efficiency of strategic emerging industries have risen gradually from 2007 to 2010, among them new energy industry innovation efficiency was the minimum one. Due to US sub-prime mortgage crisis and European debt crisis, international economic situation is relatively tough, and China's export is affected in some extent, only by constantly strengthening enterprises' innovation ability, implementing technology breakthrough, and reducing costs, can gain a competitive advantage. Innovation efficiency values of Information technology and high-tech equipment manufacturing industry are relatively high. In the future, information technology industry still needs to break through in terms of web of things and cloud computing application, integrated circuit and high-tech software research as well as network value-added services. High-tech equipment manufacturing industry are required to clear its development direction, mainly choose aviation equipment, satellite and marine equipment as starting points, and concentrates on technology upgrading.
    - Research on impact factors of innovation efficiency indicates that there is an obvious positive correlation between scale of enterprise and innovation efficiency. Research and development activities need a lot of supporting resources and have huge fixed and sunk costs, besides, innovation achievements are often uncertain and risky, and big enterprise is better than small one at bearing innovation risks. But large-scale and collectivization cannot guarantee high innovation ability, reasonable ownership structure and governance mechanism are also needed. Profitability has a significant negative impact on innovation efficiency. It's probably because most enterprises take profit as priority, once the profit is guaranteed, relatively enterprise innovation activities eased up. In this case, government department should strengthen policy guidance, such as tax reduction or exemption for R&D investment and new products.

Government's subsidy has a significant impact on innovation efficiency. Government should give some relevant supporting policies on cultivating and developing emerging industries. Such as offering some preferential tax or giving direct subsidies to comprehensive utilization of resources, technological research and development, equipment investment and technology transformation.

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