

Research on Innovation Input-Output Efficiency Evaluation of Private Listed Companies in Liaoning Province

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Abstract. In the market economy environment, the level of innovation and development of the private listed companies reflect the local economic development potential to a large extent. Liaoning Province is one of the earliest coastal provinces in China, which is the only coastal and boundary provinces in Northeast China. The innovation ability of private listed companies has greatly promoted and improved the regional economic development. In this paper, the BCC model of data envelopment analysis is used to evaluate the efficiency of input and output of 26 private listed companies in Liaoning Province. The main conclusions are followings. Firstly, the innovation input and output of Liaoning private listed companies is not high in the overall, which did not make the investment resources to maximize the benefits. Secondly, the main factors that resulted a lower output efficiency included corporations putting in too much funds in projects and a diminishing scale returns. Thirdly, innovation efficiency achieving the best DEA was the middle of the scale of non-manufacturing enterprises, these enterprises hadn't much investments in innovation, but its output benefits were more significant. Finally, in order to improve the efficiency of private investment in listed companies. It put forward countermeasures including private listed companies in Liaoning Province should increase investments in innovation activities, create a good atmosphere of scientific and technological innovation and stimulate the innovative thinking of scientific research personnel.

1. Introduction

With the rapid development of economic society and technology, social production and accessible resources methods are affected by science and technology. In recent years, the academic community studying technological innovation from a number of angles, multiple levels, especially innovation and output efficiency of the research results are quite rich. For example, Lv Tao Geng used Suzhou manufacturing industry to be a research object[1], and analyzed its the scientific and technological innovation input-output efficiency from the perspective of government investment. Cui Junfu referred and improved the framework of scientific and technological innovation that built by the Rand Corporation National Defense Research Center and the World Economic Forum. It analyzed the world's technological innovation strength decomposition[2], including China, the United States, Japan and the European Union. Based on the model of influencing factors of technological innovation of SMEs and the model of "growth-innovation", Chen xiaohong analyzed the relationship between the technological innovation ability and the growth of 126 small and medium-sized listed companies in China[3]; Yanyan Retrospectively analyzed the efficiency of independent innovation of high-tech enterprises in Zhejiang Province from two aspects: industry and ownership. It showed that the output efficiency of the overall R&D expenditure of high-tech enterprises in Zhejiang Province was higher than that of scientific research personnel[4]. Private listed companies had innovative conditions and



development space as part of the innovation system. After several years of accumulation and development in the innovation system, innovation of private listed companies has been very good foundation under the premise of the country's innovation-driven development strategy in Liaoning Province. These enterprises innovation achievements continue to emerge new technology. From the existing scholars' research, there is not much research on the efficiency of input and output of enterprises of Liaoning Province. Wu Wei studied open technology innovation model of small and medium-sized enterprises taking Liaoning Province as example[5]. In the evaluation index system of the original innovation ability, Cui Chunyan evaluated the technological innovation ability of the small and medium-sized enterprises of Liaoning Province according to the characteristics of technological innovation capability[6]. In the existing research, it has not been found that the input-output efficiency of private listed companies of Liaoning Province from the perspective of innovation output. Based on the development status of private enterprises in Liaoning Province in recent years, the efficiency of innovation input-output was evaluated by DEA method, and provided practical reference information for innovation input-output efficiency and better served for economic development.

2. The development of private listed companies in Liaoning Province

Private enterprises which facing the reform and opening tendency with flexible management mechanism, market competitiveness and adaptability are developing. Private enterprises in Liaoning Province is not only an important engine of economic development but the main way of absorbing social employment. At present, changing the inactive status of private enterprises development is to narrow the gap which refers to the number of enterprises, the total economy and the quality of development between Liaoning and developed provinces. The government needs to adopt market access, open up the financing channels and so on, supporting the development of private economy. From the economic institutions in Liaoning Province, the state-owned enterprises accounting for the main part is the pillar of the old industrial base, it is precisely that this mechanism to a certain extent limits the development of private enterprises, so it is necessary to resolutely break the institutional mechanisms obstacles in Liaoning Province, forming a market structure that is docked with market completely and full of vitality. Stimulating the vitality of the main market constantly and actively expanding the private enterprise economy are essential to get new structural advantages with an open spirit, advancing with the times, to seize the development opportunities. In 2016 China's top 500 private enterprises list(Liaoning Province), Dalian Wanda, Yida Group, Shenyang ambitious and other seven companies on the list, it was more than 2015. Dalian Wanda ranked sixth by 292.2 billion turnover, which was also ranked first in Liaoning Province. In addition to Huanjia Group, the remaining six were in top 500 list, Dalian Wanda rose to number 1 from the previous year's 7 position, Yida Group, Tong Yi Industrial and Shenyang dropped 18, 8 and 108, while Panjin North Asphalt, Jinlian Holdings were up 63 and 45 respectively[7].

3. DEA model

There are many types of DEA models, the paper mainly focuses on the CCR model and BCC model. The main difference between the two is application premise, CCR model assumes that the scale of the same remuneration, BCC model assumptions variable scale. Assuming that there are t piece of evaluated equal parts, called the decision unit DMU, each decision unit has a number of input variables and lots of output variables. For example, x_{ij} is the input of the number j DMU to the number i input, $x_{ij} > 0$; y_{rj} represents the output of the number j DMU to the number r output, and each DMU has a corresponding efficiency evaluation index.

$$h_j = \frac{u^T y_j}{v^T x_j} = \frac{\sum_{r=1}^n u_r y_{rj}}{\sum_{i=1}^m v_i x_{ij}}, j = 1, 2, \dots, t$$

Among, $x_j = (x_{1j}, \dots, x_{mj})^T$, $y_j = (y_{1j}, \dots, y_{nj})^T$, $j = 1, 2, \dots, t$

The weight coefficient can be appropriately selected to satisfy: $h_j \leq 1$, $j = 1, 2, \dots, t$.

After get the number of non - Archimedes infinite ε , the input and output of the relaxation variable S^- 、 S^+

The BCC model for the t_0 decision-making unit is as follows:

$$\min[\theta - \varepsilon(e^T S^- + e^T S^+)]$$

$$\begin{cases} \sum_{j=1}^n \gamma_j X_j + S^- = \theta X_{0j} \\ \sum_{j=1}^n \gamma_j Y_j - S^+ = Y_{j0} \\ \sum_{j=1}^n \gamma_j = 1 \\ \gamma_j \geq 0 \quad j = 1, 2, \dots, n \\ S^+ \geq 0 \quad S^- \geq 0 \end{cases}$$

4. Innovation input-output efficiency evaluation

4.1. The establishment of index system

Through the calculation method of DEA, the innovation input-output efficiency of private listed companies in Liaoning Province is analyzed from the aspects of input and output, the indicators are input index and output index. On the basis of the relevant research, this paper designs two input indicators and three output indicators according to the actual situation of the innovation subject in Liaoning Province and follow the scientific, normative, reliability and data availability.

4.1.1. Input indicators

In the innovation activities of innovation, the investment of R&D capital and human resources is the foundation of innovation. The two are complementary to each other. This paper chose R&D investment as the measure of R&D capital of innovation, showing the innovation investment of enterprises intuitively and accurately; Taking into account the different circumstances of each enterprise, the paper selected the proportion of R&D personnel to measure the status of human resources investment, not the number of R&D personnel to measure. They are fair and consistent.

4.1.2. Output indicators

Academia are still controversial about output indicators of innovation activities. It has not yet formed a unified system, After reference to the study of other literature, this paper chose three indexes of invention authorized, net profit growth rate and return on net assets. The number of invention authorized, rather than the number of patent licenses, is taken into account that the design and utility model does not involve core innovation in practice; The net profit growth rate of this paper is the net profit growth rate attributable to the shareholders of the listed company embodied in the annual report of the listed company. The output is measured from the perspective of the related rights and interests of the shareholders, because in the innovation activities of the enterprises, Shareholders also provide a huge support; Return on net assets is the ratio of net profit to average net assets, reflecting the level of remuneration derived from owners' equity.

Table 1. input-output indicators

Level 1	Level 2	Variable
Input	R & D investment(ten thousand)	X_1
	R & D personnel accounted	X_2

Output	Authorization Quantity	Y_1
	Net profit growth	Y_2
	Return on net assets	Y_3

4.2. Data sources and statistics

With the country creating an innovative atmosphere, this paper mainly analyzed the investment and output efficiency of private listed companies in Liaoning Province, and understands whether the innovation efficiency of private listed companies in Liaoning Province has produced significant benefits in recent years. Therefore, the data source of this article was mainly listed in the annual report of the listed companies and Guotai Junan database, the enterprise is selected in the Shenzhen Stock Exchange GEM, Shanghai and Shenzhen listed private companies, and registered address belongs to Liaoning Province. The company listed on Shenzhen Stock Exchange GEM has 12, selecting 10 of them; private companies listed on the Shanghai and Shenzhen motherboard have more than 30, selecting 16 of them. Eventually collecting 26 listed companies data[8].

4.3. Evaluation methods and results

According to the economic analysis, the innovation projects and activities carried out by enterprises are variable in the scale of remuneration. With the innovative characteristics, innovation is increasingly becoming an important part of the core competitiveness of enterprises and can obtain the largest output with minimal investment. In this paper, the software deap 2.1 is used to analyze the data, from the scale of compensation and output to the main point of view. In the processing of data, the requirements of the data can not be negative, but indicators of net profit growth rate and return on net assets are involved in negative growth, so the two parts should be standardized using the minimum value.

4.3.1. Technical efficiency evaluation

In data envelopment analysis, pure technical efficiency refers to the distance between the efficiency of each decision unit and the frontier of production when the scale pay is variable; Scale efficiency refers to the distance between the frontier and the scale when the scale efficiency is variable, the technical efficiency can be expressed by the product of the two.

As what can be learned from the calculation, the average technical efficiency is 0.375, the average pure technical efficiency is 0.865, the average scale efficiency is 0.408. Technical efficiency as a whole is not high, only five listed companies are DEA best, namely: Northeast Electric Development Co., Ltd., Dalian Tianbao Green Food Co., Ltd., Shenyang Caihua Gold and Silver Jewelry Co., Ltd., Dalian Dayang Genesis Co., Ltd., Songliao Automobile Co., Ltd., The five listed companies are effective because their capital and human resources are not particularly high but the maximum extent of the resource efficiency that bringing the benefits are relatively high.

From the point of view of the scale of pay, in addition to the five DEA best companies, the rest are drs. That is, the scale returns is diminishing, which means 21 listed companies invested too much. If they continue to increase investment, the scale efficiency will reduce. The main factor affecting the efficiency of technology is the lower scale efficiency from the results obtained by the analysis. From the collection of data, the 21 listed companies in the capital and staff investment is relatively high. On the one hand, it is the need for research, whose projects need some funds and personnel to support; on the other hand, it is the cycle from innovation to production is slightly longer. With the economic environment continues to change, the scale of pay is not obvious. Such as Shenyang Xin Song Robot Automation Co.,Ltd., the company's R&D funds reached 84,193,900\$. R&D personnel is accounted for 65.65%, more than half of the staff have engaged in research and development work, but the output efficiency is not high.

4.3.2. Input and output redundancy analysis

From the analysis of the results of relaxation variables, if the input relaxation variable is 0, then the part of the input does not need to change, otherwise if the variable is not 0, indicating that the investment is too much, the input should be reduced. According the analysis of the calculation, we can see that the R&D expenditure of the average relaxation rate is 2511.306, R&D personnel accounted for the average is 0.093, showing that private enterprises in Liaoning Province mainly focus on investment, in addition to 5 DEA best companies, the rest are put into the excess capital. Dalian Tianxin Entertainment Co., Ltd. has reached the highest level in both cash and R&D personnel. Liaoning Aoke Chemical Co., Ltd. and Liaoning Hefeng Animal Husbandry Co., Ltd. In the proportion of R & D personnel did not exist in the excess situation, but there is excess in R&D funding; In terms of R&D personnel, in addition that Shenyang Xin Song Robot Automation Co., Ltd. and Liaoning Aoke Chemical Co., Ltd. is more serious, the difference of rest business is not particularly large.

If the slack variable is zero, it means that there is no shortage of innovation output. The number of authorized inventions are not insufficient, only Liaoning Aoke Chemical Co., Ltd. has insufficient output in net profit growth rate; 16 listed companies fall into the excess situation in net assets yield.

Overall, the redundant innovation input phenomenon is more serious currently. 26 private listed companies in Liaoning Province should adjust the input side to achieve maximum efficiency of resources and to promote the ability to innovate; There is the phenomenon of diminishing returns to scale in the majority of enterprises. Continuing to increase investment, it doesn't bring a significant increase in innovation output. They should optimize the existing scale of investment. Reduce capital and personnel appropriately so as to make resources be truly used in excellence science and technology innovation, focusing on improving research and development efficiency and ability.

4.3.3. Valid values of each variable

In the calculation of DEA, the use of software can be drawn to achieve the revision that needs each decision-making unit to adjust to obtain optimal efficiency. In the analysis of this paper, the calculation method is: input effective target value = original value + input relaxation value; output effective target value = output the original value + output redundancy. On this basis, combined with the data, we can calculate the effective target value of each decision unit. Δx means that if the output is kept constant, it is necessary to increase the absolute input amount to achieve the relative efficiency of the production front; Δy refers the absolute amount of output to achieve the relative efficiency of the production frontier in the case of the existing investment. Resulted in the analysis, in addition to the above DEA effective five listed companies, the remaining of the enterprises need to make modification. The scale of returns in the analysis are decreasing, 21 listed companies are showing too much investment phenomenon, so it doesn't need to continue to increase investment in innovation, but to reduce investment, especially to reduce the amount of investment; As we all know, innovation has a cyclical, some results of innovation is long, so the efficiency of the analysis is not high. Along with the accumulation of research and development process, innovation efficiency will gradually increase. This also requires all enterprises to adjust their own technology management system to further improve the efficiency of innovation.

5. Suggestions for improvement

5.1. Improving the marginal efficiency of R&D funds

Private enterprises in Liaoning province should reflect on the existing investment system, the existence of funds and personnel "misplaced" phenomenon[9]. For the investment in R&D funds, listed companies should be gradually according to the progress of R&D projects allocated funds not be issued at the time of the launch of all funds. But the specific funds could be used by the innovation team to master, give its innovation and autonomy, then stimulate their enthusiasm for innovation.

5.2. People-oriented, improving the development of research technology

Human resources as a business-specific resources, business innovation activities must rely on a special human capital professionals. In order to maximize the utilization of human resources, enterprises should develop long-term personnel training program, the distribution and use of talent to be scientific and systematic. Private enterprises in Liaoning Province would make efforts to retain high-quality talent holding on the advantages of local colleges and universities. Establishing a good incentive mechanism can use cultural incentives, training incentives, material incentives, etc., to meet the all-round demand of scientific and technological personnel in many ways, and improve the enterprise's innovation and efficiency[10].

5.3. Playing the advantages of manufacturing in Liaoning Province

In the field of industrial robots, Liaoning Province has two leading enterprises of the robot and Shenyang machine tools, and in the field of cloud computing also has a indispensably Neusoft Group, in the previous analysis, Zhiyun shares, Blue Ying equipment in the field of automation equipment have accumulated years of technical experience; Rongke technology is also planing to transform into the wisdom of medicalation Liaoning Province should derive more "industrial 4.0" enterprises and form industrial clusters in mature areas on an existing technical basis, getting out of the old industrial development problems, and embrace the "Industrial 4.0" era.

5.4. The government establishing a fair competitive environment and creating a good atmosphere

The government should strengthen the sense of service, establish a fair competitive environment for the innovation of private enterprises, severely punish the illegal profits through the improper means, break the various administrative monopoly power, and further promote the development of enterprise innovation. The government should continue to support and guide the innovation activities of enterprises and strengthen market competitiveness and promote the healthy development of enterprises.

Acknowledgment

This thesis is sponsored by Liaoning province social sciences project, Project number:L16AGL013. Liaoning education department Project, Project number: W2015317. Liaoning province social sciences project, Project number: L16AJY012.

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