

Study on Financing Efficiency of Listed Technology SMEs Based on DEA Method

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ABSTRACT

The data envelopment analysis (DEA) method is employed in this paper to analyze the financing efficiency of 706 technology small and medium-sized enterprises (SMEs) listed on the SME Board and the Growth Enterprise Market (GEM). The empirical results show that the average value of TE in the first three quarters of 2019 is 0.728, which is a decrease from 0.768 in 2018. The average value of PTE and SE are 0.936 and 0.777 in the first three quarters of 2019, and are 0.923 and 0.823 in 2018. The financing efficiency of the selected companies is close to the high level in terms of both proportion and average value. The comprehensive technical inefficiency is mainly caused by the scale inefficiency, and the decrease of TE is also caused by the decrease of SE. This result means the system and management of technology SMEs should be affirmed, but it is necessary to better grasp the scale and match the source and use of funds, in which both companies and the government need to make efforts.

Keywords: *financing efficiency, technology SMEs, data envelopment analysis (DEA)*

1. INTRODUCTION

Small and medium-sized enterprises (SMEs) are an important part of China's economic structure. They play an important role in promoting economic development, easing employment pressure, optimizing economic structure and promoting social stability. As the main force of high-tech industry, technology SMEs have made some progress in recent years. According to the website of the Torch High Technology Industry Development Center of the Ministry of Science and Technology, as of February 2020, about 297,096 SMEs have been announced to be in the national technology SMEs project. These companies, which are still in the stage of development and growth, are generally relatively small but have great potential. The number of companies in each region is shown in Appendix.

The document [2017]No.115 issued in May 2017, *Evaluation Methods for Technology SMEs*, has made a clear definition for technology SMEs and standardized supervision and subsidies for these companies. Despite enjoying tax incentives and financial subsidies, technology SMEs still face the problem of insufficient funds. Their "high-tech, high-risk, high-return" characteristics make it difficult for them to find suitable funds. Therefore, it is necessary to study the financing efficiency of technology SMEs.

There are many research results on financing efficiency with enterprises in China. Zeng Kanglin (1993) [1] used the concept of "financing efficiency" for the first time when analyzing the comparison between direct financing

and indirect financing, and gave 7 factors that affect financing efficiency and cost.

Since 2008, the state has emphasized the importance of SMEs development, which has stimulated many studies on SMEs financing. What's more, since 2013, it has been difficult for technology SMEs to obtain appropriate financing which become a social focus. Scholars have conducted a lot of works on the financing difficulties and solutions. Zeng Jianghong and Chen Diyu (2008) [2] used the DEA model to evaluate the financing efficiency from the savings of debt financing costs and the use of the obtained funds. Fang Xianming and Wu Yueyang (2015) [3] used the DEA model to study the financing efficiency of SMEs in the NEEQ market, and Xiu Guoyi and Li Yizhe (2016) [4] used the DEA-Malmquist model to make a further research of technology SMEs in the NEEQ market. Wang Xiaoning et al. (2016) [5] and Shen Chen (2017) [6] used the three-stage DEA model for research, but Shen Chen's research focused on private placement. Song Guanghui et al. (2017) [7] used the two-stage DEA model to study the financing efficiency of technology SMEs. Wu Yangfen and Zeng fanhua (2019) [8] used DEA to compare the NEEQ companies by different industries and also compared their financing efficiency before and after listing.

In summary, data envelopment analysis (DEA) is a common research method, which will also be used in this paper. The contribution of this paper lies in the selection of technology-based companies listed on the SME Board and the Growth Enterprise Market (GEM), and a staged evaluation of their financing efficiency.

This paper will be divided into four parts. First, introduce the background. Then, introduce the data and methodology. Third, give the empirical results and analysis. Finally, give suggestions to improve the financing efficiency of technology SMEs.

2. METHODOLOGY AND DATA

2.1. Methodology

Data envelopment analysis (DEA), developed by Charnes et al. in 1978, is a nonparametric method in operations research and economics for the estimation of production frontiers. It is used to empirically measure the efficiency of decision making units (DMUs). A technology SME can also be called a DMU here is considered to be technically efficient if it has the ability to operate on the boundary of its production set. In 1971 Boles developed the formal linear programming problem with multiple outputs identical to the constant returns to scale (CRS) model in Charnes' work, where named the technique data envelopment analysis (the CCR model). Then, in 1984, Banker et al. Introduced a DEA estimator (the BCC model) that allowed for variable returns to scale (VRS).

It is customary to use technical efficiency (TE) to represent "crste", which means the technical efficiency from CRS DEA. Pure technical efficiency (PTE) can represent "vrste", which means the technical efficiency from VRS DEA. Scale efficiency (SE) can represent "scale", which can be calculated as $crste / vrste$. All the efficiency value is between 0 and 1. The situation of one input and one output can be simply shown with the figure below.

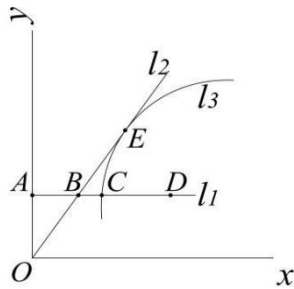


Figure 1 one input and one output

l_2 is the production frontier with CRS, which represents the maximum output that can be obtained under the current established input level. All companies produce on or below l_2 . There is a equal production line l_1 . Suppose a SME produces at point D , its TE is known to be:

$$TE = AB / AD \tag{1}$$

Under the assumption of VRS, the production frontier is l_3 . PTE is a measure of the distance between the current production point and the production frontier with VRS, while SE is a measure of the distance between the

production frontier with CRS and VRS. PTE and SE can be expressed as:

$$PTE = AC / AD \tag{2}$$

$$SE = TE / PTE = AB / AC \tag{3}$$

So the production is scale efficient at point E where $SE = 1$ but inefficient at point D where $SE < 1$.

For a given input and output (x_0, y_0) , the input-oriented BCC model with VRS can be written as follows:

$$\begin{aligned} \theta(x_0, y_0) = \min \theta \\ \left\{ \begin{array}{l} \theta x_0 - \sum_{i=1}^I \lambda_i X_i \geq 0 \\ \sum_{i=1}^I \lambda_i Y_i \geq y_0 \\ \lambda_i \geq 0 \\ \sum_{i=1}^I \lambda_i = 1 \\ \theta > 0 \\ i = 1, \dots, I \end{array} \right. \tag{4} \end{aligned}$$

Where x and y are the input and output while X and Y are the input and output vectors and feasibility implies that the technology SMEs under consideration can obtain output quantities given the input quantities. In addition, there are I DMUs in total, and each DMU can be called i . λ is the decision vector. The result of the obtained TE is θ .

According to Wu Yangfen and Zeng fanhua (2019) [8], in general, the division of efficiency is shown in Table 1.

Table 1 The division of efficiency

$0 \leq \theta < 0.5$	Low efficiency level. The financing is poor, and funds cannot be effectively used.
$0.5 \leq \theta < 0.8$	Medium efficiency level. The utilization of funds has improved, but there is still a need to adjust between funds and scale.
$0.8 \leq \theta < 1$	High efficiency level. Although the optimal financing efficiency has not been reached, the funds have been used reasonably.
$\theta = 1$	Best efficiency. Financing is in the best state of efficiency, reaching Pareto optimality, and optimal matching of scale and returns.

If $TE = 1$, the evaluated financing is comprehensive technical efficient. At this time, PTE and SE are the best. If $TE \neq 1$, it means that the current return on the scale of funds has not fully played its role, and the absorbed funds are redundant. Companies should pay more attention to the economic benefits of their financing scale and rationally adjust the scale.

In this paper, the input-oriented BCC model is selected and the software DEAP2.1 is used for analysis.

2.2. Data

In this paper, 706 listed technology-based companies on the SME board and GEM are selected as samples to analyze their financing efficiency in 2018 and the first three quarters of 2019. According to the annual report of 2018, companies with proportion of R&D personnel for 10% or more and R&D investment accounting for 4% or more of operating revenue are selected refer to the document *Evaluation Methods for Technology SMEs*. It should be noted that, few listed companies can meet all the requirements of the document, and considering the availability of data, the selected companies are not the technology SMEs that are strictly specified in the document.

Considering the indicators, the DEA formulation is defined by using subtotal of cash inflow from financing activities, debt-equity ratio and total assets as inputs, and return on equity (ROE) and total asset turnover rate as outputs. The data were extracted from Wind database.

Table 2 Inputs and outputs

Input	Subtotal of cash inflow from financing activities
	Debt-equity ratio
	Total assets
Output	Return on equity (ROE)
	Total asset turnover rate

The subtotal of cash inflow from financing activities includes cash received from absorbing equity investment, cash received from obtaining loans, cash received from issuing bonds and cash received from other financing situations, which directly reflects the situation that companies obtain high liquidity assets through financing. The debt equity ratio reflects the capital structure, which can show the utilization of financial leverage and reflect the choice of financing methods. The total assets reflect how much resources a company controls to carry out production and business activities. As a company expands the scale of debt financing or equity financing, the scale of assets will also increase. Therefore, changes in total assets reflect the financing scale.

The return on equity (ROE) is the most important indicator of corporate profitability. It reflects the overall use of net assets, that is, the ability of companies to integrate funds into output. The higher the ROE, the stronger the corporate profitability. The total asset turnover rate reflects the turnover speed of total assets from input to output, and reflects the management quality and utilization efficiency of assets. The faster the turnover, the higher the efficiency.

Table 3 Descriptive statistics of the employed inputs and outputs

Descriptive statistics	2018					2019 Q1~Q3				
	Max	Min	Median	Mean	Std	Max	Min	Median	Mean	Std
Subtotal of cash inflow from financing activities (RMB 00'M)	670.76	0	3.63	10.70	34.51	711.10	-0.01	2.47	8.00	30.26
Debt-equity ratio (%)	749.04	4.14	52.97	70.01	65.74	726.10	3.55	53.68	70.49	69.93
Total assets (RMB 00'M)	1945.71	3.55	25.39	47.42	99.12	1982.26	3.74	27.27	50.77	108.02
Return on equity(ROE) (%)	45.80	-127.64	6.77	3.88	17.88	44.87	-76.77	4.68	5.36	7.90
Total asset turnover rate	2.84	0.03	0.48	0.51	0.25	1.46	0.02	0.33	0.35	0.18

In 2018, the average proportion of R&D personnel for 25.68%, with a maximum of 93.67%, and the average R&D investment accounted for 8.47% of the operating revenue, with a maximum of 54.65%. It can be seen that the selected companies have the characteristics of "high-tech". The debt-equity ratio was about 70% on average. In 2018, the average return on equity reached 3.88%, with a range of 173.44%, and the average total assets turnover rate was 0.51. In the first three quarters of 2019, they reached 5.36%, 121.64%, and 0.35, which shows that these companies have "high-risk" and "high-return". In 2018, the subtotal of cash inflow from financing activities averaged 1.07 billion yuan, with a range of 67.076 billion yuan, while the total assets averaged 4.742 billion yuan. In the first three quarters of 2019, they were 0.8 billion yuan, 71.111 billion yuan, and 5.077 billion yuan. The average

subtotal of cash inflow from financing activities has reached more than 15% of the total assets, showing the demand for funds is large while financing needs of these companies vary widely.

The DEA model requires no data gaps, so companies with data gaps are eliminated. In addition, the DEA model requires that the inputs and outputs are positive values. The large differences in the numbers may reduce the accuracy of the results, and different data units will affect the results. Therefore, the inputs and outputs are Standardized as follows.

$$x^* = 0.1 + \frac{x - \min(x)}{\max(x) - \min(x)} \times 0.9 \tag{5}$$

Where x^* is the inputs and outputs after standardized processing, and x is the original value.

3. EMPIRICAL RESULTS

Table 4 presents the estimated efficiency results produced by the input-oriented DEA model under the VRS assumption. As can be seen from Equation 3, TE is determined by both PTE and SE. Among them, PTE focuses on reflecting the distance between the current financing efficiency and the production frontier with VRS, while TE also includes the effect of scale. SE explains the impact of expansion or contraction of production scale on financing efficiency.

In 2018, 6 selected technology SMEs are comprehensive technical efficient. They are located on the production frontier, and the output is the maximum at the current input. They can make good use of the funds they absorb while have a good grasp of the scale. 49.43% of the TE values are above 0.8, which is at a high efficiency level. This is a high proportion, reflecting that half of the selected companies have reached a good level in fund utilization and resource allocation. In the first three quarters of 2019, 10 companies achieved comprehensive technical efficiency, but only 20.83% of the TE values were above 0.8, which shows that the overall financing efficiency has decreased compared to 2018.

However, in 2018, 50 companies reached pure technical efficiency, and 90.22% of them were within the high efficiency level; 6 companies are scale efficient, and 79.89% reached high efficiency level. The values for the first three quarters of 2019 were 64, 92.64%, 10, 31.45%.

It can be seen that the system and management in the financing process are affirmed, but the scale matching of fund absorption and utilization is relatively poor. That means the inefficiency of TE is mainly caused by the inefficiency of SE.

The same conclusion can be drawn from the mean value. Comparing the two periods, the average TE values of the 706 selected companies are 0.768 and 0.728, which means that the efficiency of technology SMEs is moderately high. If good guidance and assistance is provided, it is possible to greatly improve the financing efficiency. The average value of PTE is 0.923, 0.936, and the average value of SE is 0.832, 0.777, which are better than TE, indicating that the system and management in financing have corrected the scale of some inefficient companies. Once again, although the SE is not low, the main reason for the comprehensive inefficiency is inefficiency of scale. The decline in financing efficiency in the first three quarters of 2019 was also caused by the decline in SE.

As far as economies of scale are concerned, almost all companies are in a state of increasing returns to scale, and appropriate expansion of financing and production scale is necessary. This reflects the development potential of technology SMEs.

In summary, the financing efficiency of technology SMEs is not at a poor level, but there is an urgent need to address the issue of scale, which can make financing efficiency enter and stay in the effective range in the future.

Table 4 Efficiency estimation results

2018		TE (crste)		PTE (vrste)		SE (scale)	
		Number of companies	Proportion (%)	Number of companies	Proportion (%)	Number of companies	Proportion (%)
Inefficiency	$0 \leq \theta < 0.5$	32	4.53	10	1.42	12	1.70
	$0.5 \leq \theta < 0.8$	325	46.03	59	8.36	130	18.41
	$0.8 \leq \theta < 1$	343	48.58	587	83.14	558	79.04
Efficiency	$\theta = 1$	6	0.85	50	7.08	6	0.85
Mean		0.768		0.923		0.832	
2019 Q1~Q3		TE (crste)		PTE (vrste)		SE (scale)	
		Number of companies	Proportion (%)	Number of companies	Proportion (%)	Number of companies	Proportion (%)
Inefficiency	$0 \leq \theta < 0.5$	19	2.69	6	0.85	3	0.42
	$0.5 \leq \theta < 0.8$	540	76.49	46	6.52	481	68.13
	$0.8 \leq \theta < 1$	137	19.41	590	83.57	212	30.03
Efficiency	$\theta = 1$	10	1.42	64	9.07	10	1.42
Mean		0.728		0.936		0.777	

Table 5 Economies of scale

Economies of scale	2018		2019 Q1~Q3	
	Number of companies	Proportion (%)	Number of companies	Proportion (%)
Increasing	698	98.87	694	98.30
Decreasing	2	0.28	2	0.28
Constant	6	0.85	10	1.42

4. SUGGESTIONS

Based on the analysis of the empirical results, the following suggestions are given to improve the financing efficiency of technology SMEs.

On the one hand, companies should improve financing capabilities, including improving financing systems and management. The first is to improve the capital operation capacity, find the proper use of the absorbed funds, clarify the professional development of the main business, and conduct feasibility studies on the proposed investment projects in advance to avoid idle or waste of funds. In addition, the company should optimize the capital structure and make a good choice of financing methods. The method like properly expanding the debt financing ratio, improving the company's internal governance mechanism, appropriately diversifying its equity to reduce the company's equity concentration, and increasing the proportion of circulating shareholders especially institutional investors can all be considered.

On the other hand, companies should find ways to optimize scale efficiency in financing. This needs to be done from both inside and outside. First of all, companies need to make good estimates, that is, they need to know how much fund they need and how much value they can create, so that they can better negotiate with the capital providers. Some technology SMEs focus on R&D and are not good at expanding production and operations. This has caused problems such as a low conversion rate of scientific research works, weak product competitiveness, or difficult adjustment of the domestic industrial structure. At the same time, some companies encountered bottlenecks in R&D. They lacked high-tech talents but were stubbornly expanding their investments. This led to excessive borrowing, which caused waste of funds and accumulated debt risks. The government and scientific research institutions can give guidance at this time to control the quality and quantity of technology SMEs financing, so as to improve the matching of funds and thus improve the scale efficiency.

What's more, as has been emphasized in recent years, opening up financing channels for technology SMEs is also the focus of government work. Through tax incentives, financial subsidies, the establishment of incentive standards and equity trading centers, and encouragement of banks and other financial institutions to launch

innovative loan products, all efforts are being made by the government to solve the problem of lack of suitable funding sources for technology SMEs. One of the financial innovation is the investment-loan linkage mode tailored for technology SMEs. The pilot of this model has been proposed by the original China Banking Regulatory Commission (CBRC), the Ministry of Science and Technology (MOST) and the People's Bank of China (PBC) in 2016. Through the mode of cooperation between financial institutions and companies or the establishment of industrial development fund, equity investment and loan provision are combined to solve the financing problem, while strengthening risk management and control, sufficient funds are prepared for these companies, and finally a win-win situation will be achieved.

5. CONCLUSION

After summarizing the research results of scholars, the input-oriented DEA model under the VRS assumption is employed in this paper to analyze the financing efficiency of 706 technology SMEs which is selected refer to the document *Evaluation Methods for Technology SMEs*.

The empirical results show that only a few companies are comprehensive technical efficient, which means they can make good use of the funds they absorb while have a good grasp of the scale. But in 2018, 49.43% of the company's TE value reached a high level, compared with 20.83% in the first three quarters of 2019. The mean value of PTE in both periods is about 0.93, which indicates that the system and management in the financing process are good, but the scale matching of fund absorption and utilization is relatively poor. It can be inferred that the inefficiency of TE is mainly caused by the inefficiency of SE. In addition, with the rise of PTE and the decline of SE, it is easy to see that the decline of TE in the first three quarters of 2019 compared with 2018 is caused by the decline of SE. As far as economies of scale are concerned, almost all companies are in a state of increasing returns to scale, so appropriate expansion of financing and production scale is necessary. To improve the efficiency of financing, both the company and the government need to make some efforts.

However, it should be noted that the selected companies are not the technology SMEs that are strictly specified in the document while the indicator and the model can be better designed.

APPENDIX

The number of announced technology SMEs in each region

Region	Beijing	Tianjin	Hebei	Shanxi	Inner Mongolia	Liaoning	Dalian, Liaoning	Jilin
Total	14760	11759	6055	7872	584	4592	3280	1939
Heilongjiang	Shanghai	Jiangsu	Zhejiang	Ningbo, Zhejiang	Anhui	Fujian	Xiamen, Fujian	Jiangxi
3866	14886	41508	17084	4037	9391	5351	2801	8889
Henan	Shandnog	Qingdao,	Hubei	Hunan	Guangdong	Shenzhen,	Guangxi	Hainan

		Shandong				Guangdong		
13965	12587	4687	7270	5853	39609	17071	2381	533
Chongqing	Sichuan	Guizhou	Yunnan	Tibet	Shaanxi	Qinghai	Ningxia	Xinjiang
1882	16199	1149	2211	221	9655	364	619	895

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