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Research on the Impact of Financial Flexible Reserve on the Innovation Performance of Listed Enterprises: Based on the Three-stage DEA and Threshold Model

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Abstract: ***The three-stage DEA model was used to test the innovation efficiency of 255 listed companies in China in 2015-2020, so as to obtain the relatively real innovation efficiency value after excluding environmental factors and statistical noise, and establish a threshold regression model to test the action mechanism of financial flexible reserve on the innovation efficiency of enterprises. Empirical results found: first, whether the whole sample of enterprises or different property rights enterprises, its adjusted innovation efficiency value has relatively decreased, and the adjusted efficiency value of non-state-owned enterprises is slightly higher than state-owned enterprises, prove that enterprise innovation under the influence of the environment presents the illusion of inflated efficiency, pure technical efficiency is underestimated, and scale efficiency is seriously overestimated. Second, In the second stage of SFA regression results, it was found that cash holding had a negative impact on all the four input relaxation variables, which was conducive to enterprise innovation. On the contrary, the enterprise size had a positive impact on all the four input relaxation variables. Thirdly, Financial flexible reserve has a double threshold effect on the innovation efficiency of enterprises, and with the increase of the strength of the financial flexible reserve range, its positive effect on the innovation efficiency of enterprises is also gradually weakened.***

Keywords: Three-stage DEA model, Innovation efficiency, Financial flexible reserve, Threshold model**.**

1. Introduction

In June 2021, the Strategic Research Institute released the National Innovation Index Report 2020, saying that China's research and development expenditure accounts for 17.5% of the world, ranking second in the world, while innovation ranks 15th in performance, due to China's low labor productivity and comprehensive energy consumption output rate. With the policy support of the innovation-driven development strategy, Chinese enterprises will actively change from traditional scale-speed to quality-efficiency innovation. In the real world, due to information asymmetry and moral risks, enterprises cannot obtain resources and effectively allocate them in the innovation process. At the same time, at the same time, enterprise research and development innovation has the characteristics of long duration and high risk. When enterprises are faced with market, organization, environment and other uncertainties, it needs to make rapid strategic adjustment through the enterprise financial resource allocation and financial resource acquisition ability. What is the state of Chinese innovation efficiency under the background of innovation-driven strategy? Is it normal, or is it inflated or falsely low? Is this phenomenon caused by management problems or environmental uncertainties? What role does the effect of financial flexible reserve have on enterprise innovation performance? These problems are of great significance to improve the ability of enterprises to deal with uncertainty and promote their innovation ability. To this end, this paper mainly carries out the following studies: First, use the three-stage DEA model to measure the actual technological innovation efficiency of enterprises, and analyze the impact of environmental factors through SFA; Second, find the optimal interval of financial flexibility through the threshold regression model, improve the prevention and resistance ability of enterprises in the crisis period, and promote the innovation efficiency of enterprises.

2. Literature Review

2.1 Research on Enterprise Innovation Efficiency

If the research of enterprise innovation is analyzed with the original innovation input-output value, the results will be untrue, because the original innovation data is not the data of each enterprise in the same environment. Therefore, some scholars use DEA method to test from two different perspectives of macro and micro to test the relatively real innovation efficiency of enterprises: From the macro level, generally taking provinces and cities as the decision-making unit, Yang and Wei[1] use the ultra-efficiency DEA and Malmquist index to detect the scientific and technology research and development efficiency of the four national urban clusters in three years; Huang and Yao[2] measured the innovation efficiency of 30 provinces in China for six years through the ultra-efficiency DEA model and the improved gravity model; Huang and Jin[3] used the window DEA model to measure the green innovation efficiency in 30 Chinese provinces for 20 years. From the micro level, generally with enterprises as the decision-making unit, its relatively less research literature. Guo et al[4], with Chinese listed companies from 2008-2017, calculated the adjusted enterprise innovation investment and innovation efficiency value based on the three-stage DEA model, and then tested the impact of equity structure on the innovation efficiency through the Tobit model; Zhu et al[5] took China's manufacturing industry from 2005-2015, examined the influence of tax incentives and enterprise innovation efficiency through the random frontier model SFA, and found the optimal incentive interval of tax incentives by the

threshold regression model; Zhao[6] takes the strategic emerging enterprises from 2017-2019 as the main body, measures the technological innovation efficiency of the subject and conducts Malmquist index analysis.

2.2 The Relationship between Financial Flexibility and Enterprise Innovation

There are some problems in the process of innovation: First, the enterprise innovation activities in the development state have not created value so that it does not guarantee the role, and the confidentiality of the innovation behavior and technical level differences make it difficult for enterprises to obtain external financing or bear higher costs; Second, Due to the characteristics of long duration and high risk, innovation activities have strong financial risks in the enterprise operation and development[7]; Third, Due to market, technology and organization uncertainties, corporate innovation activities require flexible strategic adjustment capabilities[8]; Most scholars believe that the prevention and utilization attributes of financial flexibility can help enterprises to carry out innovative activities for the following reasons: First of all, enterprises are faced with the problem of external financing difficulties in the process of innovation, while financial flexibility can provide strong internal financial support for enterprises by controlling their own costs, optimizing resource allocation and coordinating financing problems; Secondly, financial flexibility refers to the flexible mobile financial resources reserve that can be used in time. Enough financial resources can be recombined and configured after some risks, so as to enhance the risk control ability of enterprises; Finally, the flexible financial resource allocation ability and strong financial resource acquisition ability of financial flexibility make the enterprise innovation to quickly make strategic adjustments in the face of uncertainty; Therefore, according to the above analysis, the financial flexible reserve can have an impact on enterprise innovation from a financial perspective.

In the past, there are relatively few documents on the relationship between financial flexibility and enterprise innovation, and scholars have different conclusions on the impact of financial flexibility on enterprise innovation. First of all, financial flexibility plays a positive role in promoting enterprise innovation. Xu and Feng[9] said that the combined financial flexibility policy has a positive impact on R&D investment; Zhang and Zhang[10] research found that enterprise financial flexibility has a positive role in promoting innovation investment, and regional financial development can further promote the positive effect of both; He and Wang[11] believe that financial flexibility has an important impact on R&D investment, and that cash holding can promote R&D investment and thus affect the R&D level. Secondly, Hao and Yuan[12] proposed that the relationship between financial flexibility and enterprise innovation is inverted, and the appropriate financial flexibility will improve the level of enterprise innovation investment; Finally, Gao and He[13] show that although financial flexibility has a positive effect on enterprise innovation, different types of financial flexibility has a lagging impact on enterprise innovation.

2.3 Literature Summary

In summary, On the one hand, the previous scholars from the micro perspective of enterprise innovation efficiency literature is less, and measure the method of DEA or SFA method, the environmental factors and statistical noise still affect this method makes the result is not true, so this paper adopts three-stage DEA method to calculate environmental factors and statistical noise after the real enterprise innovation efficiency; On the other hand, most scholars study the relationship between financial flexibility and enterprise innovation is mainly from the perspective of financing analysis, in fact, financial flexibility can not only coordinate financing problems can also play a role in risk prevention and continuous strategic adjustment, so this paper from the perspective of financial flexibility to study the influence of financial flexible reserve on enterprise innovation efficiency, and put forward the corresponding countermeasures and suggestions.

3. Research Design

3.1 Three-stage DEA Model theory

Although the first-stage and two-stage DEA analysis methods adopted by previous scholars can solve the problem that the traditional DEA decision units are in a heterogeneous environment, they still have some defects. If the impact of statistical noise is not considered in the first stage and the influence of the efficiency of non-effective decision unit, In the second stage, the impact of insufficient output (or excess investment) was not considered, resulting in biased results. Therefore, the three-stage combinatorial efficiency measurement model will be more fair and reasonable relative to the one-stage and two-stage analyses[14]. There are two main categories of existing three-stage models, one is the DEA-Tobit-DEA model that exclonly out the environmental factors, the other is the DEA-SFA-DEA model considering both environmental factors and random interference. If the problem of breaking through the maximum mandatory positive adjustment is considered, the RAM model in DEA is the three-stage RAM-Tobit-RAM and RAM-SFA-RAM, the latter model was chosen if the effects of both environmental factors and random interference are needed[15]. If the innovation process is considered as a dynamic process, the SBM model in DEA is the three-stage SBM-Tobit-SBM and SBM-SFA-SBM[16]. In this paper, the three-stage DEA-SFA-DEA model is selected, considering the positive value of the decision unit in the same operating environment and excluding the effects of environmental factors and random interference.

In 2002, Fried[17] proposed a three-stage DEA model that the key is to how to remove environmental factors and statistical noise from the original input values. The model is divided into three stages. The first stage uses the traditional DEA method to find out the initial efficiency value and the relaxation change of each input, different directions and models are selected according to the specific analysis purposes. The DEA model can be divided into input oriented and output oriented, mainly CCR model[18] and BCC model[19], the CCR model

is selected when the variable is assumed to be the scale reward invariant and the BCC model when the scale reward is variable. Most scholars choose the input-oriented BCC model. The second stage[20] is to build an SFA regression model for input relaxation variables and decompose the input relaxation variables into functions of three explanatory variables: management effect, environmental effect and noise effect, so as to obtain the input variable data of each enterprise at the same environmental level. The third stage is to calculate the efficiency value of each enterprise again for the original and adjusted input data again. At this time, the efficiency value is closer to the reality than that of the first stage, that is, the efficiency value after excluding environmental and random factors. This paper selects the three-stage DEA model to find the real enterprise innovation efficiency after eliminating environmental factors and statistical noise.

3.2 Three-stage DEA Model Variable

According to the research and development stage and value creation stage to measure innovation input variables, human and financial investment are measured by R&D personnel input and R&D investment respectively, and human and financial input in the value creation stage are measured by labor capital investment and production capital investment respectively[21]. Innovation output variables are also measured based on the technology production brought by the research and development stage, and the profit production brought by the value creation stage. Among them, the innovation output index lags behind the innovation input index. Environmental variables mean that the decision-making unit cannot affect or control itself, but the efficiency of the decision-making unit is affected by it. Therefore, in this paper, the number of establishment years, enterprise scale, equity concentration degree and cash holding are selected as the environmental impact factors. The three-stage input-output indicators are shown in Table 1.

Table 1: Input-output indicators

Benchmark layer		Index layer	Variable symbol	Variable definition
Input variable	Research input	R & D funding	rd	research input
		R & D staff input	rdl	research staff
	Production input	Labor capital input	l	Total number of employees in the company's annual report
		Production capital input	k	Net fixed assets
Output variable	Technology output	Number of patent applications	inov	Number of patent applications
	profit output	Main business income	rev	Main business income
Environment variable	Established years	Enterprise registration is up to the reporting period	registime	Established years
	Firm size	Total assets of the enterprise	Size	enterprise scale
	Equity concentration	The largest shareholder ratio	Sh1	The largest shareholder ratio
	Cash hold	Businesses hold cash	cash	Closing balance of cash and cash equivalents

3.3 Threshold Regression Model and its Variables

After the calculation excluding environmental factors and statistical noise enterprise real innovation efficiency, further analyze the influence of enterprise internal factors on enterprise innovation efficiency, because financial flexible reserve can help enterprises in trapped adjustment to maintain enterprise normal operation, so this paper will study the mechanism between financial flexible reserve and enterprise innovation efficiency. This paper believes that the financial flexible reserve is not the more the better, but the best reserve in a certain interval, making it presents a non-linear relationship, and the threshold regression model can find a threshold variable to make the function form change. Therefore, after calculating the real innovation efficiency of enterprises, this paper will use the threshold regression model to find out the best financial flexible reserve and verify its action mechanism on the enterprise innovation efficiency.

3.3.1 The explained variable

Enterprise innovation efficiency(Rd): Most scholars choose the Malmquist index (MA index) to represent the enterprise innovation efficiency in the measurement of enterprise or industrial efficiency, referring to previous studies, this paper calculates the adjusted input and output through the Malmquist index method, and expresses the final TFP (total factor productivity) as the explained variables, so as to better analyze the total factor R&D efficiency of each enterprise.

3.3.2 Explanatory variable

Financial flexible reserve(FF): Based on Xia Xiufang and Wang Di, the sum of cash flexibility (cf) and debt flexibility (df) is used to measure it, including cash flexibility = enterprise cash ratio - industry cash ratio, cash ratio = (monetary funds + trading financial assets) / total assets, debt flexibility =MAX {0, industry liability flexibility-enterprise liability flexibility}, liabilities flexibility = Total liabilities / total assets.

3.3.3 Control variable

1) Profitability: As indicated in return on equity (Roa), as an important source of enterprise innovation, the higher the operating benefits, the more sufficient funds it can provide to promote the innovation and development of enterprises.

2) Development ability: In the operating revenue growth rate (Oigr). According to the Boston matrix, there can be four stages of enterprises. Enterprise development ability is different in different stages, and the stronger the development ability will have a greater positive impact on enterprise innovation efficiency.

3) Financial relative indicators of the company: Represents as Tobin Q value (Sg). It can measure the market value of an asset, when Tobin Q is greater than 1, companies tend to expand investment, but on the contrary; so the indicator affects corporate investment in innovation activities.

4) Equity Concentration Level (Sh1): Measured by the proportion of the largest shareholder, the larger the value indicates the higher equity concentration, which affects the investment decision of enterprises.

5) Years of Establishment (Age): Calculated from the enterprise registration time to the reporting period, the longer the establishment time is established, with the accumulation of funds, the standard of the company operation and the attraction of talents gradually sufficient conditions, it is more conducive to the innovation of enterprises.

6) Enterprise Size (Size): Measured by the total assets of enterprises, the size of enterprise scale is an important influencing factor of enterprise innovation investment. Some scholars say that large-scale enterprises will have more capabilities and resources to carry out enterprise innovation projects than small-scale enterprises.

7) Property Property (Soe): As a virtual variable, the SOE value is 0, and the non-SOE value is 1, under different property rights properties, the advantages and disadvantages of each enterprise are different, leading to significant differences on the innovation efficiency of enterprises. The threshold regression model variables are shown in Table 2.

Table 2: Threshold regression model variables

Type of variable	Variable definition	Variable symbol	Measure the index
Explained variable	Enterprise innovation efficiency	Rd	Real efficiency after excluding environmental factors and statistical noise
Explanatory variable	Financial flexible reserve	FF	Cash flexibility and debt flexibility in the sum of the year
Control variable	profitability	Roa	Return on equity
	Development ability	Oigr	Increase rate of business revenue
	Financial relative indicators of the company	Sg	Tobin Q value
	Equity concentration	Sh1	The largest shareholder ratio
	Established years	Age	Enterprise registration time to the reporting period
	enterprise scale	Size	Total assets of the enterprise
	Property nature	Soe	State-owned enterprises take 0, non-state-owned enterprises take 1

3.4 Data Sources

This paper targets Shenzhen-Shanghai A-shares and SME-sized board listed companies from 2015 to 2020, and the relevant data are from Wind Wind and National Tai'an CSMAR database. In order to ensure the reasonable and reliability of the data, this paper chooses enterprises that have a long time to carry out innovation activities and have more complete R&D information disclosure. Therefore, the policy of additional deduction of R&D expenses was proposed in 2015 to explore the impact of this policy on enterprise innovation activities. At the same time, this paper will eliminate the enterprises with negative profit for three consecutive years, and incomplete data from ST, PT and major variables. Because the R&D investment lags behind, the innovation output data in the sample will lag behind the first phase of the innovation investment. Finally, 1275 (255*5) samples of the balanced panel were obtained. In the threshold regression model, the TFP value was benchmarked by using the hyperefficiency index, so the sample size was 1020 (255*4).

4. Analysis of the Research Results

4.1 Three-stage DEA Efficiency Measurement Results

4.1.1 Phase 1 Traditional DEA results

The DEAP2.1 software selects the BCC model with variable scale remuneration to obtain the unadjusted innovation efficiency values and input relaxation variables for all enterprises from 2015 to 2020. Considering that the large number of sample enterprises listed is too long, this paper only lists the average innovation efficiency of the whole sample of enterprises, state-owned enterprises and non-state-owned enterprises over the years.

As shown in Table 3, the efficiency value obtained through the BCC model is comprehensive technical efficiency(TE), which can reflect the ability of enterprises to resource allocation, and can be subdivided into pure technical efficiency(PTE) and scale efficiency(SE). From 2015 to 2019, the average comprehensive technical efficiency of the whole sample of enterprises was below 0.45, and the number of enterprises at the forefront of efficiency was 23,17,19,18 and 22 respectively, which reflected the development trend of falling first and then rising, which shows that the innovation performance of most listed enterprises in China is low, and there is still a long distance from the forefront of efficiency.

Among them, the high scale efficiency reaches more than 0.78, while the pure technical efficiency is very low below 0.48, which shows that the reason for the low comprehensive technical efficiency of the whole sample of enterprises is that the production technology is relatively backward. Secondly, in 2015-2019, the average comprehensive technical efficiency of state-owned enterprises and non-state-owned enterprises is below 0.57 and 0.51 respectively, and the innovation efficiency of state-owned enterprises is slightly higher than that of non-state-owned enterprises. The two types of enterprises are at 0.8, while the pure technical efficiency is between 0.5-0.6, which shows that the scale efficiency and pure technical efficiency need to be improved, and the greater impact on the comprehensive technical efficiency is pure technical factors. The efficiency values of this stage include the impact of statistical noise and environmental factors, therefore, this paper will adopt SFA method to separate the management efficiency, statistical noise and environmental factors affecting enterprise performance, so as to obtain the actual innovation efficiency value of the enterprise.

Table 3: Average innovation efficiency of listed companies over the years

year	Full sample enterprise			state-owned enterprises			Non-state-owned enterprises		
	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE
2015	0.383	0.474	0.806	0.456	0.549	0.836	0.488	0.598	0.817
2016	0.378	0.485	0.788	0.463	0.565	0.831	0.516	0.618	0.836
2017	0.361	0.456	0.796	0.571	0.664	0.862	0.517	0.613	0.844
2018	0.367	0.465	0.799	0.526	0.598	0.884	0.491	0.599	0.822
2019	0.411	0.489	0.839	0.504	0.589	0.862	0.481	0.579	0.837

4.1.2 Phase II SFA regression results

In this paper, the input relaxation variables obtained in the first stage were used as the dependent variable of the second stage regression. Because the main effect of the environmental variable is the influence on the dependent variable, so the environmental variables were standardized as the independent variable of the second stage regression, and the SFA regression results were obtained using Frontier4.1 software.

The regression results are shown in Table 4, and the one-sided generalized likelihood ratio LR is far greater than the standard values of the mixed chi-square test, indicating that the SFA regression model is appropriate through the test and model design. Next, the impact of the various environmental factors on the innovation efficiency was analyzed. First of all, the scale of the enterprise has a significant positive impact on the R&D investment, R&D personnel, labor capital investment and productive capital investment relaxation variables, that is, the larger the enterprise scale, the greater the redundancy of R&D funds, R&D personnel, total workers and fixed asset investment, and the more conducive to the enterprise technological innovation. From the perspective of internal control, when the scale of enterprises is larger, the flow of funds and the use of management and supervision is more likely to make mistakes, resulting in inefficiency. Second, cash holding is contrary to the size of the enterprise, which has a significant negative impact on the four relaxation variables, that is, the more cash holding of the enterprise, the smaller the research and development investment and production investment, it indicates that cash holding is conducive to the effective allocation of R&D resources. This may be because cash holding can improve the ability of enterprises to resist risks and ensure the continuous development of innovation activities. Third, the number of enterprises has a significant positive impact on labor capital investment, while it has a negative impact on R&D investment, R&D personnel and productive capital investment. Generally speaking, the longer the enterprise is established, the more the investment in innovation, the more the research and development experience, the higher the resource utilization efficiency. Fourth, the equity concentration is exactly the opposite to the life of the enterprise, which is significantly negatively correlated to the labor capital investment, and positively correlated with the other three investment relaxation variables. Equity concentration means the high proportion of the largest shareholder holding the company. On the one hand, in order to expand the operation, the company will increase the total number of workers to obtain demographic dividend. On the other hand, shareholders' too strict monitoring of managers will make managers reduce their investment in high-risk and make full use of resources for R&D and innovation activities.

Table 4: The SFA regression results

Variable	Research input slack variable	Research staff slack variable	Labor capital input slack variable	Production capital investment relaxation variable
Con_	-2.87*108	-3.68*102	-1.23*103	-4.10*109
Enterprise years	-3.58*107	-0.22*102	3.25*102	-4.99*108
Enterprise scale	5.88*108	4.09*103	2.03*104	1.71*1010
Equity concentration	1.38*108	0.85*102	-1.09*102	5.11*108
Cash hold	-5.24*108	-3.60*103	-1.77*104	-1.32*1010
sigma	4.29*1017	4.56*106	1.22*108	7.76*1019
gamma	0.9081	0.8898	0.9576	0.9121
LR	1.31*103	1.21*103	2.06*103	1.34*103

4.1.3 DEA results adjusted for Phase III inputs

New input data were removed from environmental factors and statistical noise in the original input variables, and the original output value was kept unchanged. DEAP4.1 software was used to select the BCC model to calculate the adjusted efficiency value of each enterprise over the years.

As shown in Table 5, we can first know that the comprehensive technical efficiency value of the whole sample of enterprises from 2015 to 2019 was below 0.25, and the number of enterprises in the forefront of efficiency was 5,9,11,12 and 7, respectively. Compared with the efficiency value and frontier number of enterprises when not adjusted, which shows that the sample enterprises will show the false appearance of inflated efficiency under the influence of environment and random factors. Different from the first stage DEA results, the pure technology efficiency of the whole sample of enterprises is above 0.9, scale efficiency is below 0.22, which shows on the one hand that the pure technology inefficiency is indeed affected by the external environment and random factors, and not caused by the enterprise own technology management level, on the other hand shows that the scale efficiency under the influence of external environment is artificially high, enterprises can achieve efficiency by expanding scale. Secondly, compared with the efficiency value of the first stage, the comprehensive technical efficiency of state-owned enterprises is slightly lower than that of non-state-owned enterprises in the years. This result is consistent with the view that non-state-owned enterprises make their innovation efficiency higher than state-owned enterprises due to strong flexibility and good incentive effect. The efficiency value of both types of enterprises is affected by the adverse environment, both of which are greatly improved in pure technical efficiency and greatly reduced in scale efficiency. Overall, the results of phase 3 DEA innovation efficiency are contrary to Phase I DEA results, indicating that disturbed by adverse environmental factors, pure technical efficiency is underestimated, while scale efficiency is severely overestimated, resulting in an overestimation of comprehensive technical efficiency.

Table 5: Adjusted enterprise innovation efficiency over the years

year	Full sample enterprise			state-owned enterprises			Non-state-owned enterprises		
	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE
2015	0.201	0.924	0.223	0.252	0.933	0.273	0.354	0.933	0.378
2016	0.244	0.928	0.269	0.304	0.928	0.33	0.346	0.928	0.373
2017	0.250	0.904	0.282	0.328	0.926	0.355	0.369	0.917	0.405
2018	0.255	0.915	0.285	0.34	0.929	0.366	0.362	0.911	0.4
2019	0.228	0.911	0.256	0.318	0.925	0.344	0.366	0.906	0.409

4.2 Threshold Regression Results

Based on the condition of enterprise innovation efficiency, this paper tests the impact of financial flexible reserve on enterprise innovation efficiency through the threshold regression model, because the data can divide each threshold variable according to its own unique nature. In this paper, single threshold and double threshold model are according to Hansen threshold panel model, such as formula (1) and (2):

$$Rd= \alpha_0 + \alpha_1 Ff^*(\omega_{it} \le \gamma)+ \alpha_2 Ff^*(\omega_{it} > \gamma)+ \alpha_3 controls_{it} + \varepsilon_{it} \quad (1)$$

$$Rd= \beta_0 + \beta_1 Ff^*(\omega_{it} \le \gamma)+ \beta_2 Ff^*(\gamma_1 < \omega_{it} \le \gamma_2)+ \beta_3 Ff^*(\omega_{it} > \gamma_2)+ \beta_4 controls_{it} + \varepsilon_{it} \quad (2)$$

In the formula, Rd indicates the enterprise innovation efficiency value, Ff indicates the financial flexible reserve, Controls represents the various control variables; γ , γ_1 , γ_2 are the threshold value, the ω_{it} is the threshold variable, I(*) is a schematic function，If the condition is met, the value is 1, and vice versa, 0, ε_{it} is a random interference term.

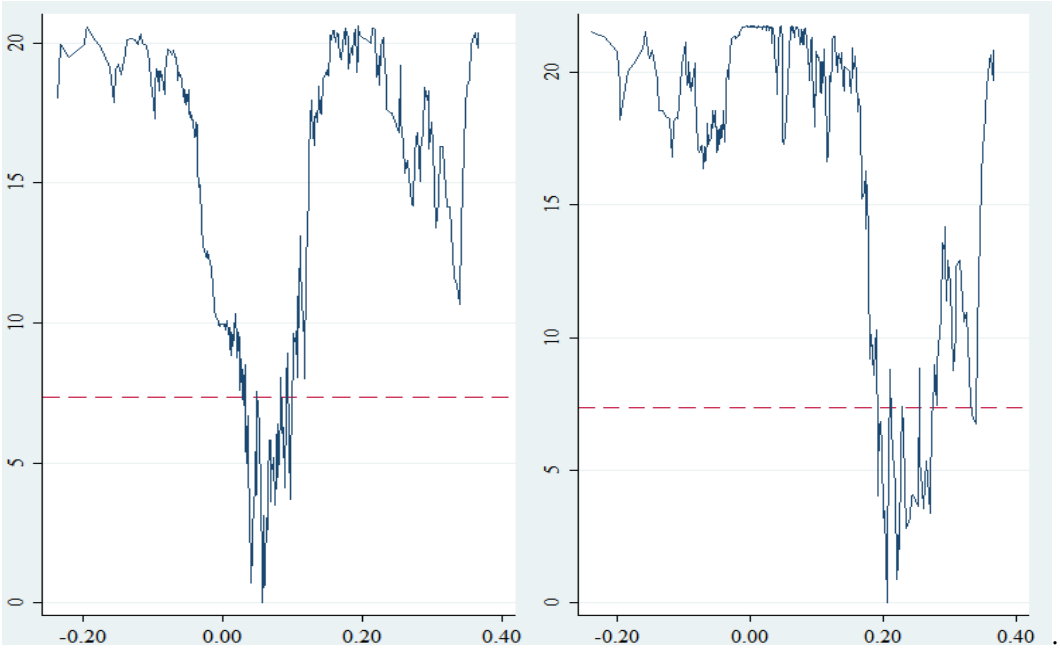
4.2.1 The threshold effect test of financial flexible reserve on enterprise innovation efficiency

The existence test of Table 6 shows that there is a double threshold effect of the impact of financial flexible reserve on enterprise innovation efficiency; the first threshold value are 0.0571 and 0.2060, respectively, and are significant at least 5%. With the two threshold values, the financial flexible reserve is divided into three dimensions: high school and low school, Highly Financial Flexible Reserve (X 0.0571), Medium Financial Flexible Reserve (0.0571<X 0.2060), and Low Financial Flexible Reserve (X>0.2060). Through the authenticity test of Figure 1, the threshold value is found, financial flexible reserve has threshold effect on enterprise innovation efficiency.

Table 6: Self-sampling test, Threshold values, and Confidence intervals

Threshold model	Estimated value	95%confidence interval	F value	P value	1%	5%	10%
Single threshold value	0.0571	(0.0532-0.0581)	50.43***	0.0000	16.1025	11.3130	10.1993
Double threshold value	0.2060	(0.1966-0.2064)	20.79**	0.0033	16.6067	14.5769	11.8210

* p<0.05, ** p<0.01, *** p<0.001.



A) First Threshold B) Second Threshold

Figure 1: Threshold authenticity Test

4.2.2 Estimation results of the threshold effect of financial flexible reserve on enterprise innovation efficiency

From Table 7 second column threshold regression results, on a whole, in three different financial flexibility dimensions, financial flexible reserve impact on enterprise innovation efficiency is 10%, the moderate and high financial flexibility are significant at the level of 1% positive, which shows that the prevention and utilization of financial flexibility has performance in front of opportunities and challenges to improve enterprise flexible strategic adjustment ability and resource acquisition ability, so as to truly improve the enterprise innovation efficiency. From three aspects of different dimensions, financial flexible reserve has a threshold effect on enterprise innovation efficiency. When the financial flexible reserve is in the high and low range, its influence coefficient is 9.2660,3.9930 and 1.2780 respectively, which means that with the increase of range strength, the impact of financial flexible reserve on enterprise innovation efficiency is gradually weakened. Among them, when the interval strength is lower than 0.0571, financial flexible reserve has the biggest effect on enterprise innovation efficiency, so financial flexible reserve has a positive effect on enterprise innovation efficiency, but this effect will gradually weaken with the increase of interval intensity.

In the threshold regression results, only the Tobin Q value and years of establishment had a significant impact on the enterprise innovation efficiency by each explanatory variable, with the coefficients of 0.1520 and 0.0931, respectively, and were significantly positive at the 10% and 5% levels, this means that when an enterprise has strong development ability, sufficient funds or increased market share can provide good preconditions for enterprises to carry out innovation activities. When the enterprise is established for a long time, its mature corporate governance ability, capital accumulation and rich resources other conditions also provide conditions for the improvement of enterprise innovation efficiency.

Table 7: Threshold model regression results

	Threshold Return	Fixed Effect	Tobit Return
roa	0.5560	0.7010	-0.5600
	(0.8630)	(0.8080)	(0.4820)
oigr	0.1970	0.1760	0.2210*
	(0.1790)	(0.1940)	(0.1050)
sg	0.1520*	0.1790**	0.1260*
	(0.0731)	(0.0686)	(0.0549)
age	0.0931**	0.0833***	-0.0007
	(0.0290)	(0.0239)	(0.0064)
size	0.1290	0.1820	0.1770***
	(0.1460)	(0.1010)	(0.0512)
Sh1	-0.0006	-0.0027	0.0017
	(0.0135)	(0.0131)	(0.0021)
cash	-0.0887	-0.0696	-0.1090*
	(0.0798)	(0.0863)	(0.0422)
Ff		3.7360***	1.1340***
		(0.5270)	(0.2410)
Ff (X ≤ 0.0571)	9.2660***		
	(1.0590)		
Ff (0.0571 < X ≤ 0.2060)	3.9930***		
	(0.7330)		
Ff (X > 0.2060)	1.2780*		
	(0.5790)		
cons	-1.9840	-3.5960	-0.9170
	(3.1790)	(2.1990)	(0.6970)
N	1020	1020	1020

4.2.3 Robustness Test

To ensure robust and reliability of the conclusions of this paper, it will be tested in multiple ways. First, this paper uses a panel fixed effect model for regression, and the results are shown in the third column in Table 7, and the impact of financial flexible reserves on enterprise innovation efficiency is significantly positive at the level of 1%, thus demonstrating the reliability of the conclusions of this paper. Secondly,

considering that the dependent variable is greater than zero, the restricted regression model, namely the Tobit model, was used to test, and the results are shown in the Tobit regression in the fourth column of Table 7, and the conclusion still holds, indicating that the above conclusion is robust.

5. Conclusion and Suggestion

5.1 Conclusion

This paper targets Shenzhen-Shanghai A-shares and small and medium-sized board listed companies from 2015 to 2020, uses the three-stage DEA model to empirically test the real innovation efficiency value after excluding environmental factors and statistical noise, and deeply analyzes the differential impact of environmental variables on innovation input, and finally draws the following conclusions: First of all, through the comparison of the first stage and the third stage DEA results found that the adjusted comprehensive technical efficiency than before the adjusted efficiency value decreased, and the adjusted comprehensive efficiency value is mainly low scale efficiency, and pure technical efficiency is higher than 0.9, which shows that environmental factors lead to inflated efficiency, make pure technical efficiency is underestimated, and scale efficiency is seriously overestimated. The comprehensive technical efficiency of SOEs and non-SOEs has also decreased compared with the adjustment, and the efficiency value of non-SOEs is slightly higher than that of SOEs. Second, the environmental factors have a significant impact on the innovation efficiency of the enterprise. Cash holding has a negative impact on all four input relaxation variables, while the enterprise size instead has a positive impact on all four input relaxation variables. The life of the enterprise has a positive impact on the R&D investment, R&D personnel and productive capital investment relaxation variables, while it has a negative impact on the labor capital investment relaxation variables, and the equity concentration is the opposite. Third, financial flexible reserve has a significant positive impact on enterprise innovation performance and dual threshold effect, but with the increase of interval strength, the effect on financial innovation efficiency is gradually weakened, and the interval strength is below 0.0571, financial flexible reserve innovation efficiency is the greatest; the Q value and years of establishment have a significant positive impact on enterprise innovation efficiency.

5.2 Suggestion

According to the above conclusions, relevant countermeasures and suggestions from enterprises and government:

5.2.1 Enterprises should improve the innovation efficiency with moderate financial flexibility

This paper analyzes the impact of financial flexibility on the enterprise innovation efficiency from three aspects, so it makes relevant suggestions on how to coordinate the financing problems, improve the ability of strategic adjustment and prevent risks. First of all, enterprises should do a good job in information disclosure, attract the interest of external investors, and strengthen the contact with financial institutions, guarantee institutions and other departments, so as to reduce external financing difficulties and improve the flexibility of corporate liabilities. Secondly, enterprises should increase the proportion of capital accumulation and increase the level of cash holding, so as to improve the cash flexibility of enterprises. Thirdly, Establish the flexibility of enterprise financial measurement and early warning mechanism, in order to reduce the loss caused by the failure to prevent risks. Finally, enterprises should scientifically reserve financial flexibility, find the optimal reserve amount, in order to achieve the best state of financial flexibility, so as to promote enterprise innovation.

5.2.2 Government should provide a good financing environment and institutional environment for enterprise innovation

First of all, for the bottleneck of the capital supply of financial institutions and the financing needs of enterprises, the government should encourage the establishment of financial service institutions, to provide enterprises with scientific and technological financing guarantee, intellectual property pledge and other services, to ease the difficulty of enterprise loans, and to provide good financing conditions for enterprise innovation. Secondly, the government should establish a sound intellectual property protection regulations and strengthen the supervision of intellectual property rights to provide a good institutional environment for innovation for enterprises.

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