Research on the Influence of R&D Models on the Performance of High-Tech Start-Ups
——Based Data on Listed Companies

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ABSTRACT

Based on the resource-based theory, this paper uses data from 162 high-tech start-ups listed on the Shenzhen Stock Exchange's SME Board and ChiNext Board to discuss the choice of R&D mode for high-tech start-ups and test the relationship between R&D model, technological innovation capability, and high-tech start-ups' performance empirically. The results show that participating in cooperative R&D is not conducive to the performance of high-tech start-ups when the variable of technological innovation capability is not introduced; The relationship between R&D mode and performance of high-tech start-ups are significantly regulated by technological innovation capability used as a contingency factor. That is, the participation of high-tech start-ups in cooperative R&D with high technological innovation capability has a negative impact on their performance growth; The participation of high-tech start-ups in cooperative R&D with low technological innovation capability has no significant impact on their performance growth.

Keywords: R&D mode, Technological innovation capability, Enterprise performance, High-tech start-ups.

1. INTRODUCTION

Reasonable selection of R&D mode is essential to reduce R&D costs and R&D risks, optimize resource allocation and improve innovation effects. It is an important factor to improve performance and survive in fierce competition for high-tech start-ups. But the impact mechanism of R&D mode on the performance of high-tech start-ups has not yet been clarified. More empirical research is needed to further explore the ways and conditions in which R&D models affect the performance of high-tech start-ups. Therefore, this paper investigates the R&D activities of high-tech start-ups, empirically tests the impact mechanism of R&D models on the performance of high-tech start-ups. Based on the contingency theory, the paper demonstrates the moderating effect of technological innovation capability on the relationship between R&D mode and performance of high-tech start-ups from the perspective of resources, expanding the perspective of new ventures' performance theory research and providing theoretical and practical guidance for the choice of R&D mode for high-tech start-ups.

2. HYPOTHESIS

Peteraf (1993) pointed out that resources are the decisive factor in the formation of performance differences between enterprises and constructed the resource-strategy-performance model. As part of the technology strategy, R&D mode is also a strategic resource of companies, affecting enterprise performance. This paper divides the R&D mode into independent R&D and cooperative R&D based on whether high-tech start-ups have participated in cooperative R&D. Scholars have formed two different views on the impact of participating in cooperative R&D on corporate performance. Most scholars' researches had proved that cooperative R&D is beneficial to improve corporate performance. Based on the resource-based theory, cooperative R&D can effectively make up for the lack of resources of enterprises and enhance innovation output. At the same time, cooperative R&D helps reduce the R&D costs and risks, shorten the R&D cycle, and improve R&D quality. Luo Ronggui et al. (2004)[1] believed that for the high-tech industry, cooperation between enterprises and enterprises can enhance their technological innovation capabilities. Pei Yunlong et al. (2011)[2]

held that cooperative R&D between enterprises and universities or scientific research institutions can significantly promote the performance of corporates. Huang Lu (2019)[3] pointed out that external R&D can significantly improve performance. Some scholars held that the correlation between cooperative R&D and enterprise performance is weak, even negative. Huang Xianfeng et al. (2014)[4] believed that cooperative R&D cannot have a significant positive impact on performance. Wang Baolin (2015)[5] found that the correlation between cooperative R&D and enterprise performance is weak and negative through research on innovative companies. This paper takes high-tech start-ups as the research object, having disadvantages in terms of external legitimacy and reputation. It is difficult to realize cooperative R&D. Also, it requires greater search costs and negotiation costs, facing coordination, management, and benefit distribution issues, which inhibit innovation efficiency. In cooperative R&D, companies do not have exclusive rights to R&D results, so they cannot obtain high returns through technical barriers. In addition, the uncertainty of cooperative R&D may threaten the survival of high-tech start-ups. Ma Zhiqiang et al. (2018)[6] found based on prospect theory that small and micro technology enterprises tend to independent R&D, holding that the increased benefits of cooperative R&D are low. Yu Qian (2018)[7] also pointed out that compared with cooperative R&D, independent R&D can play a long-term role in promoting innovation.

Technological innovation capability, the foundation of R&D, affects the implementation effect of R&D model and the output of R&D results, and then influences enterprise performance. Now the academic community has not yet formed a unified understanding of the concept of technological innovation capability. From the perspective of resources, this paper believes that the it is the ability to integrate internal and external resources to achieve technological breakthroughs. New ventures are small in scale and have disadvantages of insufficient resources and R&D experience, having to obtain resources from external organizations. High-tech start-ups with weak technological innovation capability are more likely to benefit from cooperative R&D. They can choose the right partner according to comparative advantage to make up for shortcomings in resource capacity. It is conducive to reduce R&D costs and risks and improve the efficiency of technological innovation. Also, it is beneficial to the realization of technological breakthrough innovation. At the same time, through cooperative innovation, it is helpful for high-tech start-ups to accelerate the commercialization of innovation results and reduce disadvantages caused by external constraints. When high-tech start-ups have high technological innovation capabilities, they can fully acquire the ownership of R&D results through independent R&D, form technical barriers, and gain

competitive advantages. Moreover, for high-tech start-ups with high technological innovation capabilities, the risk of technology leak in cooperative R&D is greater. Companies must strengthen the protection of core technologies and increase the cost of monitoring core technology spillovers.

In summary, this paper believes that the cost of high-tech start-ups participating in cooperative R&D is higher than the benefits and selects technological innovation capability as the moderating variable. Then the paper put forward the following hypothesis:

H1: High-tech start-ups participating in cooperative R&D are not conducive to their performance growth.

H2: Technological innovation capability has a moderating effect on the relationship between R&D mode and performance of high-tech start-ups.

H2a: The participation of high-tech start-ups with low technological innovation capabilities in cooperative R&D has a positive impact on performance growth.

H2b: The participation of high-tech start-ups with high technological innovation capabilities in cooperative R&D has a negative impact on performance growth.

3. RESEARCH DESIGN

3.1. Sample Selection

Lin Qiang (2003)[8] pointed out that due to the influence of industries, information resources, corporate strategy, etc., companies have different time in the early stage, ranging from 3 to 5 years for short periods and 8 to 12 years for long periods. There are differences in the timing of start-ups in different economic environments and industries. Since the research object of this paper is high-tech start-ups needing a lot of funds for innovation, and the capital market in China is not mature enough, high-tech start-ups need a long time to grow. Combining with the research results of previous start-ups, this article conducts research on high-tech start-ups that have been established within 8 years. At the same time, this paper selects SME board and ChiNext board listed companies as samples for empirical research. On the one hand, SME board and ChiNext board companies have short establishment time, small scale, high technology content, strong innovation ability, high R&D investment, strong profitability and high growth. Their characteristics are in line with the main characteristics of high-tech start-ups. On the other hand, listed companies operate independently in the market, with good asset integrity, sound systems, strict supervision and complete and effective information disclosure. 162 high-tech start-ups have been selected as the effective samples of this paper based on whether the key information of the company and the data of various performance indicators are complete. They are all listed

companies on the SME board and the ChiNext board established within 8 years.

3.2. Variable Measurement and Data Source

The R&D model is a dummy variable. This article sets this value to 0 for high-tech start-ups that do not participate in cooperative R&D and sets this value to 1 for high-tech start-ups participating in cooperative R&D. According to Chen Guanghua' research on cooperative R&D output, this paper determines whether high-tech start-ups have participated in cooperative R&D based on whether they have substantial technological cooperation projects or results with external organizations (such as technological and new product cooperation R&D, cooperative patent application, etc.) Data source is corporate prospectus.

Considering the integrity of listed company data, this article uses financial indicators to measure the performance of high-tech start-ups. Since the research object are high-tech start-ups, this paper draws on the research of Li Hao, Liu Hongchao to select the growth rate of total assets and the growth rate of owner's equity to examine their growth. Growth rate of total assets = growth of total assets for the current period / total assets at the beginning of the period, Growth rate of shareholders' equity = increase in retained earnings for the current period / initial shareholders' equity. Data source is the Cathay Pacific database.

Drawing lessons from Chen Yunwei (2007)[9]'s view that invention patents are an important criterion for measuring technological innovation capabilities, this article uses independent R&D invention patents to measure the technological innovation capability of enterprises. Data source is corporate prospectus.

For control variables, business age is measured from the date of establishment of the company to the date of listing. The size of the company is expressed by the total number of employees in the year of the initial public offering. The region is divided into East China, South China, Central China, North China and others. The performance of high-tech start-ups also depends on R&D intensity and the proportion of R&D personnel. R&D intensity is the average value of the ratio of the company's R&D investment to operating income in the past 3 years. The proportion of R&D personnel is expressed as the ratio of the number of R&D personnel to the total number of employees at the time of listing. Furthermore, according to the research conducted by He Weihong on the performance of high-tech companies on the GEM, this paper also uses the asset-liability ratio as a control variable to reflect the capital structure of the company. The above data come from company prospectus and the Cathay Pacific database.

4. HYPOTHESIS TEST

This paper uses SPSS to process and analyze the data. Table 1 shows the results of descriptive statistics and correlation analysis on all variables.

With reference to the data analysis method of Cao Qing et al. (2009)[10], this paper uses a grouping method to test the moderating variables and the relationship between the independent variable and the dependent variable in each group through hierarchical regression analysis.

First of all, without considering the moderating variable of technological innovation capability, this paper conducts a regression analysis of the R&D mode and other control variables on the performance of high-tech start-ups. The regression results pass the significance test. Hypothesis H1 is verified. There is a significant negative correlation between the R&D mode and the performance of high-tech start-ups. That is, the participation of high-tech start-ups in cooperative R&D has a negative impact on their performance. The results of regression analysis are shown in Table 2.

Secondly, technological innovation capability is investigated as a moderating variable between the R&D model and the performance of high-tech start-ups. Since technological innovation ability is a dummy variable, this article will group the samples according to the value of the adjustment variable, and test the significance of the difference between the two groups. The results are shown in Table 3.

Model A1 and Model A2 are hierarchical analysis models for high-tech start-ups with low technological innovation capabilities. Model B1 and Model B2 are hierarchical analysis models for high-tech start-ups with high technological innovation capabilities. Model A1 and Model B1 are basic models that only contain control variables. Model A2 and Model B2 add R&D mode based on Model A1 and Model B1.

The results of model A group show that the regression effect of the R&D mode and the performance of high-tech start-ups is not significant, that is, the participation of high-tech start-ups in cooperative R&D has no obvious effect on their performance. This result is inconsistent with the hypothesis H2a of this research. The results of model B group show that among high-tech start-ups with high technological innovation capabilities, the R&D mode and their performance are significantly negatively correlated, indicating that high-tech startups' participation in cooperative R&D has a negative effect on their performance. This result supports H2b.

This paper uses the growth rate of owner's equity as the dependent variable and performs regression analysis on the variables based on the same method. The results are shown in Table 4. The nature of the relationship

between the variables has not fundamentally changed, ensuring the robustness of the research model.

Table 1. Means, standard deviations and correlation coefficients of variables

Variable	Mean	Standard deviation	1	2	3	4	5	6	7	8	9
1. Business age	6.49	1.34	1								
2. Enterprise size	819	898	0.11	1							
3. R&D intensity	5.28	2.67	-0.01	-0.03	1						
4. District	1.69	1.12	-0.04	-0.04	0.21***	1					
5. Ratio of assets to liabilities	0.24	0.13	0.13	0.20**	-0.21**	0.01	1				
6. R&D personnel ratio	19.49	13.18	0.03	-0.16**	0.54***	0.23***	-0.11	1			
7. Technological innovation ability	0.52	0.50	0.01	-0.29**	0.20**	-0.01	-0.24**	0.07	1		
8. R&D mode	0.55	0.50	-0.00	0.00	0.08	0.05	0.06	-0.10	0.01	1	
9. Growth rate of total assets	0.70	0.38	-0.28***	-0.12	0.17**	0.05	-0.41***	0.01	0.09	-0.14*	1
10. Rate of increase in owners' equity	1.04	0.55	-0.27***	-0.05	0.01	-0.03	-0.43***	-0.10	0.04	-0.12	0.87***

N=162 *p<0.10,**p<0.05,***p<0.01

Table 2. Full sample regression analysis

	Growth rate of total assets		Rate of increase in owners' equity	
	Model A1	Model A2	Model B1	Model B2
Constant	1.30***	1.37***	2.13***	2.27***
Business age	-0.23***	-0.23***	-0.09***	-0.21***
District	0.04	0.05	0.00	0.00
Enterprise size	-0.04	-0.05	-0.04	0.01
R&D intensity	0.15*	0.18**	0.02	0.04
Ratio of assets to liabilities	-0.35***	-0.34***	-0.42***	-0.44***
R&D personnel ratio	0.12	-0.15*	-0.13	-0.17*
R&D mode		-0.19**		-0.12*
Technological innovation ability		-0.03		-0.14*
F value	7.96***	6.62***	8.61***	7.40***
R-Square	0.23	0.26	0.25	0.28
Adjusted R^2	0.20	0.22	0.22	0.24

N=162 *p<0.10,**p<0.05,***p<0.01

Table 3. Grouped regression analysis (total asset growth rate)

	Low technological innovation capability		High technological innovation capability	
	Model A1	Model A2	Model B1	Model B2
Constant	0.79***	0.80***	1.75***	1.81***
Business age	-0.04	-0.04	-0.34***	-0.32***
Enterprise size	-0.07	-0.08	-0.01	-0.03
R&D intensity	0.19	0.21	0.12	0.14
District	0.12	0.12	0.00	0.00
R&D personnel ratio	-0.02	-0.04	-0.21*	-0.23**
Ratio of assets to liabilities	-0.36***	-0.36**	-0.34***	-0.33***
R&D mode		0.04		-0.19**
F value	3.47***	3.0***	6.14***	6.11***
R-Square	0.23	0.23	0.32	0.36
Adjusted R^2	0.16	0.15	0.27	0.30

N=162 *p<0.10,**p<0.05,***p<0.01

Table 4. Grouped regression analysis (the growth rate of owner's equity)

	Low technological innovation capability		High technological innovation capability	
	Model A1	Model A2	Model B1	Model B2
Constant	1.56***	1.54***	2.63***	2.70***
Business age	-0.01	-0.01	-0.34***	0.33***
Enterprise size	-0.01	-0.01	0.04	-0.03
R&D intensity	-0.08	-0.09	0.05	0.07
District	0.09	0.09	-0.03	-0.03
R&D personnel ratio	-0.05	-0.04	-0.19*	-0.20*
Ratio of assets to liabilities	-0.46***	-0.46**	-0.43***	-1.21***
R&D mode		0.02		-0.17*
F value	3.12***	2.7***	7.80***	7.40***
R-Square	0.22	0.22	0.38	0.40
Adjusted R^2	0.15	0.14	0.33	0.35

N=162 *$p<0.10$,**$p<0.05$,***$p<0.01$

5. CONCLUSION

Based on the data of high-tech start-ups listed on the Shenzhen Stock Exchange's SME Board and ChiNext, this article empirically tests the impact of R&D models on the performance of high-tech start-ups and the moderating effect of technological innovation capabilities on the relationship between them. Based on the empirical research results, this paper mainly draws the following research conclusions and corresponding management recommendations.

Firstly, when the moderating variable of technological innovation capability is not introduced, the participation of high-tech start-ups in cooperative R&D has an inhibitory effect on performance growth. This conclusion is inconsistent with the conclusions of many related empirical studies. The main reason is that the characteristics of the research samples are different. In the past, relevant studies have focused on large-scale mature organizations, while the research samples in this article are high-tech start-ups. On the one hand, from the perspective of resource-based theory, compared with large-scale mature enterprises with abundant resources and rich management experience, the characteristics of "new creation disadvantages" of start-ups have an important impact on the smooth implementation of cooperative R&D. On the other hand, new ventures cannot effectively coordinate internal and external relations due to lack of management experience. There are also some problems in resource integration, resulting in a waste of limited resources, thus weakening the benefits of cooperative R&D for new ventures. In addition, high-tech start-ups face high transaction costs such as search costs, bargaining costs, decision-making costs, and supervision costs for cooperative R&D, and there are many unstable factors in cooperative R&D, which may bring more risks to enterprises having a negative impact on the performance improvement of high-tech start-ups. Therefore, although most national policies and theoretical studies believe that companies

should actively participate in cooperative R&D, in the management practice of high-tech start-ups, they should carefully examine their own resources and capabilities, and seek to match their own resources with capabilities, strategies, and environment. Do not blindly implement cooperative R&D strategies.

Secondly, when taking technological innovation capability as a contingency factor, the study found that the participation of high-tech start-ups with low technological innovation capabilities in cooperative R&D has no significant impact on their performance growth; the participation of high-tech start-ups with high technological innovation capabilities in cooperative R&D has a negative impact on their performance growth. The results show that technological innovation capability has a significant moderating effect on the relationship between R&D mode and performance of high-tech start-ups, that is, for high-tech start-ups, the choice of R&D mode is strongly dependent on specific contingency factors. With low technological innovation capabilities, the willingness of external organizations to cooperate with high-tech start-ups is weak, and high-tech start-ups are difficult to obtain cooperation opportunities. Even if they participate in cooperative R&D, they will be at a disadvantage in the relationship between the two parties. Therefore, it is difficult to obtain large benefits, so the participation of high-tech start-ups with low technological innovation capabilities in cooperative R&D cannot significantly improve their performance. High-tech start-ups with high technological innovation capabilities lack the urgent need for cooperative R&D, and the R&D goals of enterprises and scientific research institutions are different. The R&D entities lack enthusiasm in cooperation, which reduces the efficiency of technological innovation. At the same time, innovation entities are also faced with communication and collaboration issues in the process of cooperation, which is not conducive to the improvement of the performance of high-tech start-ups. In addition, for high-tech start-

ups with high technological innovation capabilities, the risk of technological leakage will increase in cooperative R&D. Enterprises need to strengthen the protection of core technologies to prevent core technologies from overflowing, thereby incurring additional monitoring costs.

So high-tech start-ups should combine their own technological innovation capabilities when choosing R&D models. High-tech start-ups with weak R&D foundation and low technological innovation capabilities need to select cooperative R&D partners purposefully and strategically, and conduct in-depth innovation cooperation. It also requires that they have certain communication skills, coordination and management capabilities, etc.. At the same time, it is necessary to train technological innovation talents, accelerate core technology research, actively improve its own technological innovation capabilities. At the same time, we must cultivate technical innovation talents, accelerate core technology research, actively improve our own technological innovation capabilities, ensure the smooth progress of research and development activities, improve research and development efficiency, and promote the growth of corporate performance. But High-tech start-ups with high technological innovation capabilities are not recommended to participate in cooperative R&D. Independent research and development may be more conducive to high-tech start-ups' exclusive R&D results, which is helpful to forming unique competitive advantages, promoting performance growth and further improvement of technological innovation capabilities . Consequently, realize the long-term development of the enterprise.

The shortcoming of this research is that only the total asset growth rate and the owner's equity growth rate are selected as the measurement indicators of the performance of high-tech start-ups to simplify the research. The performance evaluation may not be accurate enough. Meanwhile, due to the limitation of the sample size of enterprises and data acquisition, this paper does not distinguish the types of partners. Future research can further study the heterogeneity of partners, and investigate in depth the different effects of cooperative R&D with universities or scientific research institutions and cooperative R&D with enterprises on the performance of high-tech start-ups, hoping to have more and richer research conclusions.

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