How to encourage Social Capital to invest on Sea-related Science and Technology Enterprises?--An Empirical Analysis Based on fsQCA Portfolio Model of China

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Abstract. The innovation in marine science and technology is pivotal in driving the establishment of maritime power. Social capital involvement provides a crucial avenue for addressing financial challenges encountered by sea-related science and technology enterprises, marked by high investments, significant operational risks, and considerable return uncertainty. Leveraging Distributed Cognition Theory and Perceived Value Theory, this study constructs a theoretical framework to elucidate driving factors behind social capital investment in such enterprises. Subsequently, a fuzzy set qualitative comparative analysis model is employed to explore synergistic driving paths of diverse factors guiding social capital investment. Utilizing micro-survey data from Qingdao, a leading hub of marine science and technology in China, the analysis reveals that there are four equivalent synergistic paths motivating social capital investment. Private venture capital organizations predominantly lead the value-driven type, whereas government-guided type is primarily dominated by state-owned enterprises. These findings offer valuable insights for policymakers and technology entrepreneurs.

Keywords: social capital; sea-related science and technology enterprises; fsQCA; distributed cognition theory; perceived value theory

1 Introduction

As a significant maritime power globally, China's marine economy plays a crucial role in supporting the nation's maritime prowess. However, the lack of motivation for innovation in marine science and technology, coupled with limited finance support, has become increasingly apparent. The "Action Program on Increasing Support for Financing of Science and Technology Enterprises (2023)", issued by the State Council, highlights the challenges faced by technology enterprises, including weak profitability, high risk, and extended return period, resulting in challenging and costly financing.

Issues such as the maturity of sea-related property rights in confirmation and assessment, including sea-using right and offshore facilities, pose challenges. This immaturity contributes to the common problems faced by marine science and technology enterprises, such as a lack of collateral and difficulty in guaranteeing repayment. Moreover, the susceptibility of their productions and operations to marine disasters and extreme weather further complicates financing. Addressing these financing difficulties requires collaborative efforts from both

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governments and the market [1].

In 2022, the Ministry of Rural Agriculture issued the "Social Capital Investment in Agriculture and Rural Areas Guidelines" to strengthen the establishment of a diversified investment and financing mechanism involving social capital participation, government guidance, and credit support. This initiative aims to provide financial support for the growth of technology-based enterprises. However, due to the limited coverage of the policy, different risk preferences of capitalists in the marine sector. However, the limited coverage of the policy, diverse risk preferences among capitalists, and shortage of ideal projects have resulted in inefficient and sometimes false investment behaviors in this process[2][3][4][5]. Notable cases include Jiangsu Meike Solar Energy Science and Technology Co. Ltd. and Sichuan Huiyu Pharmaceutical Co (These companies convert their investments into debt relationships with fixed returns, but on surface, they are equity investments.). Therefore, establishing a diversified investment and financing mechanism with well-defined resource allocation programs and comprehensive supporting policies has become a vital proposition for promoting the high-quality development of China's marine economy.

2 Literature Review

The introduction of social capital investment can diversify the financing channels available to enterprises, alleviating the financing constraints and consequently fostering increased R&D investments, thereby enhancing their competitiveness[6]. Simultaneously, it serves to alleviate financial burdens on the government, promoting economic growth[7]. At present, the major methods guiding investment include government-direct funds, which primarily invest in areas with positive externalities and susceptible to market failure[8]. These funds exhibit characteristics such as being non-profit, providing indirect support, and operating with a market-oriented payment structure[2].

Public-Private Partnership (PPP) models, which concentrate on infrastructures[9], exhibit characteristics of substantial investment and extended operational periods[10]. Investment and loan linkage models, designed primarily for science and innovation-oriented enterprises[11], Represent another avenue for directing social capital. Examining the motivating factors for social capital investment, existing studies focus on policy supports[12][13] and social responsibility [14][15]. Additionally, these studies consider economic conditions, technological development, financial market dynamics, and the regional legalization[16][17][18], along with investment returns[19][20], among other factors.

Capital investment typically hinges on an optimistic market outlook and mature technology, placing substantial pressure on science and technology enterprises during the pre-development period[21][22]. Owing to the high risk, uncertain returns, and prolonged operating duration, the issue of financing difficulties becomes more pronounced for sea-related science and technology enterprises[23].

The literature offers theoretical support for this issue, however, certain challenges persist. Researchers have employed econometric models such as double-difference model[12], co-equation model[17], and regression analysis[18], all within the framework of the principal-agent perspective [20][24] and rational person assumptions. Nevertheless, these models may not accurately reflect real-world situations. Additionally, many studies focus on only 2-3

influencing factors[17][19][25], falling short of establishing a comprehensive and enduring mechanism that propels social capital toward investments in science and technology enterprises. Consequently, there exists a significant gap in the exploration of incentivizing social capital investment in sea-related science and technology enterprises.

Hence, this study formulates an analytical framework for social capital investment decision-making grounded in the Perceived Value Theory and Distributed Cognition Theory. By integrating micro-survey data from Qingdao, the study scrutinizes the multi-driver linkage effects influencing the investment behavior of capitalists within the sampled area. The objective is to offer a theoretical foundation for future research on incentivizing social capital to invest in sea-related science and technology enterprises. Furthermore, the study aims to furnish the government with a basis for formulating pertinent guiding policies in practice.

3 Theoretical Framework

Perceived Value Theory (PVT) contends that there exists a significant positive correlation between an individual's behavioral willingness and behavioral response and the magnitude of the perceived value[26]. Therefore, we categorized the advantages stemming from investments in sea-related science and technology enterprises into explicit and implicit benefits. Consequently, we incorporate PVT to explore the investing decision made by social entities. Explicit benefits encompass the average investment return, the cumulative count of Initial Public Offerings (IPO) , and the count of projects where capital is present. The listing of a sea-related technology company signifies significant benefits for investors. Simultaneously, the investment exit mechanism becomes operational when the invested enterprise faces risks, allowing the venture capital institution to realize capital appreciation or mitigate and minimize property losses through investment withdrawal[27]. Hidden gains primarily pertain to the signal effects of investing in sea-related science and technology enterprises. These effects may result in easier access to financing, tax reduction and exemption, as well as government subsidies[28].

The concentric circle model of Distributed Cognition Theory (DCT) posits that the cognitive activities of individuals are shaped through interactive game between individuals and the system environment[29]. The investment decision of social capital in sea-related science and technology enterprises represents a complex, dynamic process influenced by internal and external factors. This complexity can be elucidated by the varying degrees to which territorial power, Individual force, and cultural forces impact the cognitive level of participants, according to the principles of DCT[30]. Individual force refers to the characteristics of the investment institution, gauged by the number of experiences in investing in technology-based enterprises[31]. This metric indicates the investors' familiarity with the industry. Territorial power denotes the resource endowment of the region where the investment institution is located. It encompasses a variety of natural and social resources such as labor, capital, land, technology, and management. This factor signifies the constraints imposed by resource conditions in the local context and influence individual behavior directly[32]. In this study, it encompasses the resource endowment and policy dividends of sea-related science and technology enterprises, with a higher availability of financing linked to greater resources. Within the scope of territorial power resource endowment includes founder characteristics (education level and government work experience)[33], enterprise patents, and trademark rights. The founder's education level positively impacts technological innovation and venture capital accessibility for the

enterprise[34]. Government work experience indicates the founder's political affiliation, directly affecting the enterprise's value[35]. As this survey targets social capitalists, their attention to these endowments directly influences investment behavior. When capitalists prioritize the mentioned conditions, the enterprise's endowment significantly impacts investment behavior; otherwise, it does not. Thus, the importance attached to these indicators is measured by the degree of significance assigned by the social capital side. The policy dividends are measured by social capitalists' satisfaction with development level of sea-related science and technology enterprises, the local business environment, and the policy support received[36]. Investment institutions with a strong willingness to invest scrutinize the relevant policy system more critically, whereas those with a weaker indication do not prioritize policy improvements. Consequently, higher satisfaction levels are associated with less favorable investment behavior. Cultural strength encompasses the perspectives of investment organizations regarding policies and the environment, including their understanding of sea-related science and technology industry policies, assessment of industry prospects, and their sense of social responsibility. A deeper understanding of relevant policies positively influences the rationality of investments in the sea-related science and technology industry. Industry prospects significantly impact project investment value[37], with investors favoring industries demonstrating promising development prospects. Investors who choose to follow others in making the investment decisions suggest susceptibility to external public opinion, indicating low utilization of real information in decision-making. The phenomenon, known as the "surge phenomenon" and "herd effect", negatively impacts market stability and enterprise development[38]. The stronger the sense of social responsibility within investment institutions, the greater their willingness to invest.

Hence, this paper establishes a model for multi-factor driving of social capital investment in sea-related science and technology enterprise, assuming the profitability and risk aversion characteristics of social capital (Figure 1).

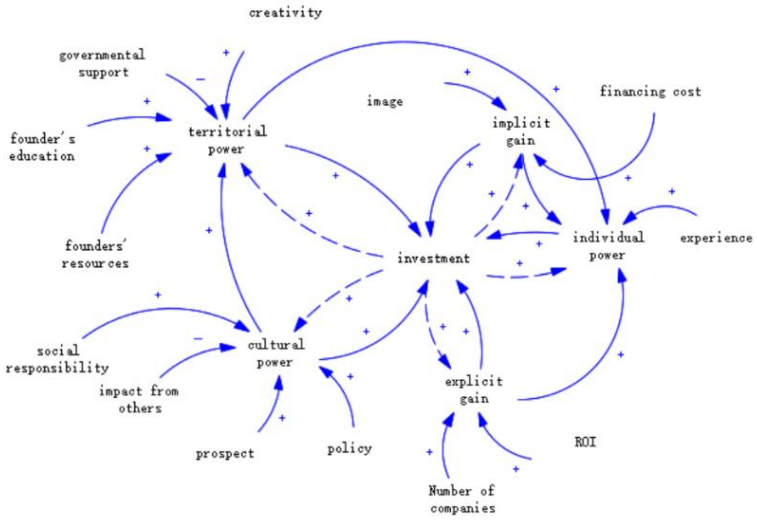

Figure 1. Framework of causality of multifactor linkages on social capital investment.

4 Methodology and Data Collection

4.1 Fuzzy set qualitative comparative analysis (fsQCA)

This paper employes the fuzzy set qualitative comparative analysis (fsQCA) method to identify the multiple driving factors influencing social capital investment in sea-related science and technology enterprises. Three reasons justify the selection of this method: firstly, traditional measurement methods are suitable for analyzing the "net effect" of a single factor but cannot unveil the complexity of multi-factor coupling, interaction, and combination configuration. The qualitative comparative analysis (QCA) method enables exploration of how the interdependence and linkage matching of causal conditions lead to changes in the interpreted results. It investigates the combination of antecedent conditions at multiple levels and possesses a unique advantage in elucidating the influencing mechanism of a specific phenomenon. This aligns with the research purpose of this study, which aims to explore the synergistic influence of multiple factors on the motivation of social capital investment in sea-related science and technology enterprises. Secondly, the QCA method can effectively overcome the limitations of unavailable data and small sample size. Thirdly, QCA comprises three main types: clear set qualitative comparative analysis (csQCA), multivalue qualitative comparative analysis (mvQCA) and fuzzy set qualitative comparative analysis (fsQCA). Compared to the first two analysis methods, fsQCA can study the degree to which antecedents affect the outcome[39].

The application of the fsQCA method undergoes the following three phases. First, the creation of a truth table occurs, with a number of rows that doubles the number of conditions, capturing all logical combinations. Second, given a certain minimum consistency level, the truth table reduces according to the minimum number of required cases to induce the emergence of the outcome. Third, the truth table transforms into combinations of the variables that produce the outcome.

4.2 Data collection

This study focuses on Qingdao, Shandong Province, as the research area. Qingdao has began to host the "Global Venture Capital Conference" since 2019, boasting one of the highest numbers of investment institutions in the country and creating an optimal environment for investment and financing. In 2021, Qingdao launched the "Sea Innovation Program" to foster the growth of sea-related science and technology enterprises. According to the "National Ocean Innovation Index Report 2022", Qingdao holds the top position among coastal cities in China regarding the innovation capacity of marine emerging industries. So the survey not only will have strong representativeness and comprehensiveness, but also have strong applicability and guidance for improving the investment of China's sea-related science and technology enterprises. We send anonymous questionnaires to venture capital (VC) institutions. In total, 24 questionnaires were ultimately collected, comprising 8 state-owned enterprises (SOEs), 3 private enterprises, 12 VC institutions, and 1 industrial and commercial capital entity. Following a thorough examination of the questionnaire content and completeness test, all questionnaires were valid.

4.3 Statistical analysis

Given the limited sample size of private enterprises and industrial and commercial capital, the analysis primarily focuses on SOEs and VC institutions (Figure 2).

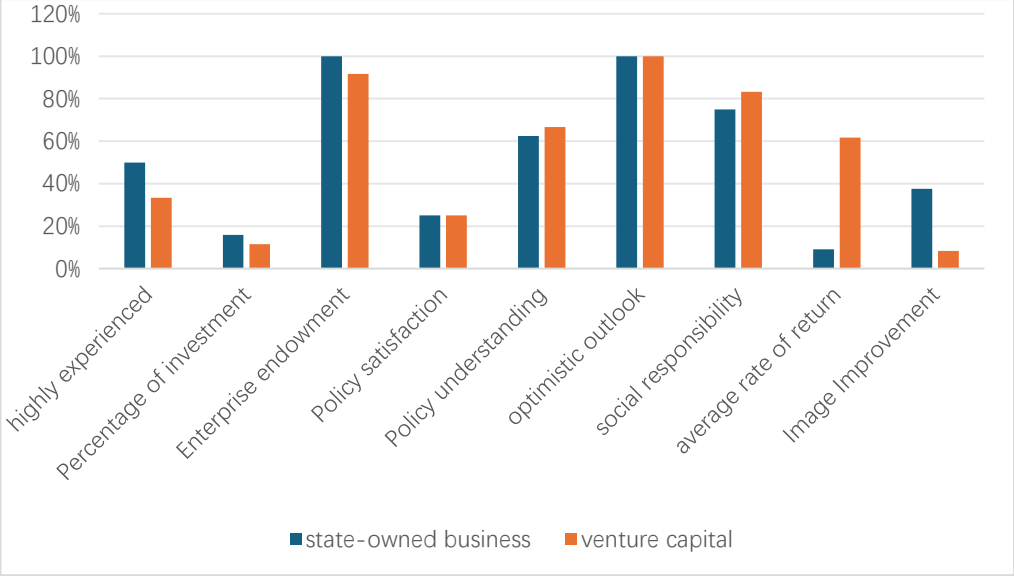

Figure 2. Sample characteristics and distribution

There exists a notable disparity in investment experience, average rate of return, and image enhancement between SOEs and VC organizations. Firstly, concerning investment experience, 50% of SOEs have "very much" and "much" experience in investing sea-related science and technology enterprises, compared to only 33.33% of VC organizations, indicating that SOEs constitute the primary investing force. Secondly, in terms of invest returns, the average rate of return of state-owned enterprises is only 9.14%, whereas for VC organizations, it stands at 66.67%. VC organizations tend to choose mature sea-related science and technology enterprises, while social responsibility has a more substantial impact on SOEs compared to VC institutions. Finally, 37.5% of SOEs believe that investing in sea-related technology enterprises can enhance their image, whereas only 8.33% of VCs agree.

4.4 Measurement of data

In this study, the support of social capital is reflected by the relative value, which is the ratio of the investment in sea-related science and technology enterprises to the total investment. All conditioning variables were obtained using a 5-point Likert scale, and the relevant variables and measurements are presented in Table 1.

Table 1. Variables and description.

Latent variable	Measurable variable	Measurement methods	Direction of influence
Individual force	Number of similar investment experiences	0~2 =1; 2~4 =2; 4~6 =3; 6~8= 4; >=8 =5	+
Territorial power	Satisfaction with the relevant policy system	Very satisfied=1; Satisfied=2; Neutral=3; Dissatisfied=4; Very dissatisfied=5	-

	Satisfaction with the industry's business environment system	Very satisfied=1; Ssatisfied=2; Neutral=3; Dissatisfied=4; Very dissatisfied=5	-
	Founder's education level	Very unimportant=1; unimportant=2; Neutral=3; Important=4; Very important=5	+
	Founder's government service experience	Very unimportant=1; Unimportant=2; Neutral=3; Important=4; Very important=5	+
	Importance of enterprise trademarks and patent rights	Very unimportant=1; Unimportant=2; Neutral=3; Important=4; Very important=5	+
Cultural power	Industry policy knowledge level	Completely no idea=1; No idea=2; Generally understand=3; Relatively familiar=4; know very well=5	+
	Assessment of the industry's prospects	Very negative=1; Negative=2; Neutral=3; Positive=4; Very positive=5	+
	Extent of influence by other investment institutions	Completely refer to=1; Strongly depend on=2; Partially depend on=3; Little influence=4; No influence=5	-
	Commitment to invest in sea-related science and technology enterprises	Strongly disagree=1; Disagree=2; Neutral=3; Agree=4; Strongly agree=5	+
Explicit gain	Average return on similar investments in 2020-2022	0~20%=1; 20%~40%=2; 40%~60%=3; 60%~80%=4; >=80%=5	+
	Total count of successful IPOs and exits in comparable investments	0~2 =1; 2~4=2; 4~6=3; 6~8=4; >=8=5	+
Implicit gain	Investing in the industry enhances the reputation.	Strongly disagree=1; Disagree=2; Neural=3; Agree=4; Strongly agree=5	+
	Investing in the industry facilitates easier financing.	Strongly disagree=1; Disagree=2; Neutral=3; Agree=4; Strongly agree=5	+

This study calculates the proportion of investment in marine technology enterprises to total investment over the past three years (2020-2022), using relative values to effectively avoid errors caused by different institutional sizes due to absolute values (investment in marine technology enterprises), and better represent the investment preferences of investment institutions. The direct calibration method[40] was employed to establish the anchor points for full affiliation, crossover, and full non-affiliation using the 0.95 quartile, 0.5 quartile, and 0.05 quartile of the sample descriptive statistics. Calibration details and descriptive statistics for each condition and outcome are presented in Table 2.

Table 2. Set, calibration, and descriptive statistics

Set		Calibration Information			Descriptive Statistics			
		Full non-membership	Crossover point	Full membership	Mean	Std. Dev.	Min	Max
Investment decision	Proportion	0.01	0.09	0.351	0.132	0.12	0	0.5
Risk perception	Individual power	1.01	2.99	3.99	3.042	1.042	1	5
	Territory power	2.36	3.16	3.64	3.063	0.42	2	3.67
	Cultural power	2.79	3.49	3.99	3.51	0.407	2.75	4.25
Perceived gain	Explicit gain	1.01	1.49	3.49	1.833	0.893	1	4
	Implicit gain	2.01	2.99	3.925	2.771	0.691	1.5	4

5 Empirical Results and Analysis

5.1 Single-factor necessity analysis

To determine the indispensability of a specific condition for the occurrence of the outcome, it is essential to examine whether an individual factor (including its non-set) serves a necessary condition to drive social capital investment in sea-related science and technology enterprises. As shown in Table 3, the consistency of each condition variable falls below the threshold of 0.9, indicating that none of them individually qualifies as a necessary condition for driving social capital investment. Subsequently, the collaborative impact of Individual force, territorial power, cultural power, explicit returns, and implicit returns on social capital investment in sea-related science and technology enterprises is analyzed.

Table 3. Necessary conditions for high/non-high social capital investment

Condition Variables		High investment		Non-high investment	
		Consistency	Coverage	Consistency	Coverage
Risk perception	Individual force	0.862	0.758	0.651	0.562
	~ individual force	0.502	0.594	0.720	0.837
	Territorial power	0.650	0.673	0.646	0.656
	~territorial power	0.668	0.658	0.678	0.655
	Cultural power	0.800	0.738	0.578	0.523
	~ cultural power	0.483	0.538	0.711	0.38
Perceived gain	Explicit gain	0.629	0.662	0.592	0.612
	~ explicit gain	0.631	0.612	0.673	0.641
	Implicit gain	0.600	0.721	0.521	0.615
	~ implicit gain	0.680	0.591	0.764	0.652

5.2 Multifactor sufficiency analysis

This study employs the fsQCA method to analyze the groupings of drivers that generate high and non-high social capital investments separately. As shown in Table 3, the consistency of the solutions exceeds 0.8, signifying that they can all be considered equivalent and sufficient conditions for factors to synergistically influence social capital investment. The coverage of the solutions is 0.625103 and 0.613961, respectively, indicating that the H1-H4 grouping pattern effectively explains 62.5% of cases in reality, and the NH1-NH2 grouping pattern effectively explains 69.7% of cases in reality.

Factor configurations of high investment. As shown in Table 4, the study identified 4 factor groupings (H1-H4) that resulted in the solution of high social capital investment. To facilitate a comparison between these groupings, the 4 groupings were consolidated into 2 broader categories: value-driven and government-guided.

Table 4. Factor configurations for high/non-high social capital investment

Condition Variables		High investment				Non-high investment	
		H1	H2	H3	H4	NH1	NH2
Risk perception	Individual power	●	●	●	⊗	⊗	
	Territory power	⊗	⊗	●	●		
	Cultural power	●		●	●	⊗	●
Perceived Gain	Explicit gain		●	⊗	⊗	⊗	●
	Implicit gain	●	●	⊗	●		⊗
Consistency		0.928	0.929	0.868	0.895	0.970	0.848
Raw consistency		0.396	0.365	0.347	0.219	0.495	0.411
Unique coverage		0.015	0.021	0.142	0.046	0.286	0.202
Solution consistency		0.859				0.902	
Solution coverage		0.625				0.697	

Notes: ● indicates the presence and ⊗ the absence of the core condition. ● indicates the presence and ⊗ the absence of the edge condition.

The value-driven path (comprising groups H1 and H2) centers around hidden earnings as the core driver, supplemented by Individual force factors, without the inclusion of territorial power. This suggests that when explicit income incentives are lacking, government guidance and support become crucial to solve the dilemma of social capital investment. Conversely, in the presence of sufficient explicit income, social capital will be invested in sea-related science and technology enterprises irrespective of the strength of government guidance and support.

Government-guided (comprising groups H3 and H4), emphasizes cultural power as the core

condition, supplemented by territorial power synergy, without explicit income factors. In scenarios with robust government policy guidance and support, coupled with high industry innovation and profitability, social capital investment is likely, especially when the investor possesses a strong sense of social responsibility, is familiar with the enterprises, and even if the current investment may yield a low profit level.

Factor configurations of non-high investment. As observed in Table 4, there are two similar factor grouping conditions. Grouping state NH1 indicates that in the absence of high Individual force, high cultural power, and high explicit returns, social capital will not invest science based small and micro enterprises. Grouping condition NH2 demonstrates that, even under policy support and explicit returns, social capital may choose not to invest due to the absence of implicit returns, which could entail significant financing costs.

In grouping H1-H2, there exists substitution relationship between explicit returns and cultural power. VC institutions constitute more than half of this grouping. These institutions possess ample investing experience but limited internal funds, and profit serves as their primary driving factor. Consequently, they will invest in sea-related science and technology enterprises when presented with substantial returns.

In grouping H3-H4, it is evident that cultural power is also a core factor driving social capital investment, with half of the samples representing SOEs. This is attributed to the stronger sense of social responsibility among SOEs[41]. Given their government support and ample funds, profit maximization is not their primary goal[42][43].

6 Conclusions and Policy Implications

Drawing on the Distributed Cognition Theory and the Theory of Planned Behavior, this paper establishes a factor-driven framework for social capital investing in sea-related science and technology enterprises, utilizing Qingdao as a case study. The fsQCA method is employed to explore diversified paths resulting from the synergistic influence of factors. The study reveals that individual force, territorial power, cultural power, explicit gain, and implicit gain factors are not necessary conditions for driving social capital investment. Group analysis demonstrates that the driving paths can be categorized into value-driven and government-guided, with implicit gain and cultural power emerging as the core factors driving social capital investment in sea-related science and technology enterprises in both paths respectively. SOEs, predominant in the government-driven path, primarily rely on cultural power as a driving factor. On the other hand, VC organizations, prevalent in the value-driven path, primarily aim at reducing financing costs and maximizing profit.

Based on the conclusions, this paper proposes specific policy recommendations. Governments can establish special funds to incentivize SOEs to invest in sea-related science and technology enterprises, particularly those with low short-term returns. To prevent misappropriation of funds, the government should collaborate with relevant risk assessment organizations to establish investment risk control. Leveraging its information advantages, the government should facilitate the creation of an information exchange platform between enterprises and VC institutions, thereby mitigating the risk of information asymmetry for the latter. Additionally, the establishment of financial products such as risk conversion funds can enhance the risk resilience of VC institutions.

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