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Research Article

The Impact of Innovation Investment Volatility on Technological Innovation of Enterprises in Different Life Cycles

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Empirical findings from the impact of innovation investment volatility on enterprise technological innovation are mixed. Based on the punctuated equilibrium theory, this study explores the impact of innovation investment volatility on enterprise technological innovation in different life cycles and whether innovation subsidy has expected effects on enterprises' technological innovation. By using the 205 Chinese listed enterprises in strategic emerging industries from 2010 to 2019 as the research sample, the results show that the innovation investment volatility has a positive impact on technological innovation of enterprise in the growing stage, while it has no significant effect on enterprise technological innovation in the mature and declining stages. In addition, the negative moderating effect of innovation subsidy on the relationship between innovation investment volatility and technological innovation is the most significant for enterprises in the growing stage, weakly significant for enterprises in the mature stage, and insignificant for enterprises in the declining stage.

1. Introduction

In recent years, in order to realize the optimization of economic structure and the transformation of growth momentum, the Chinese government has proposed to build an innovative country [1]. The construction of an innovative country requires the support of enterprise technological innovation [2]. Under such a background, China's enterprises have been very active in innovation activities. The innovation investment in China's enterprises is increasing every year (see Figure 1), and the total amount of innovation investment has consistently been the second-highest in the world. However, the continuous increase in innovation investment has not led to improvement in innovation level, and China's enterprises as a whole continue to show a relatively low level of innovation. The reality of the innovation paradox has made innovation investment questioned. Recent studies have pointed out that the volatility of enterprises' innovation investment is more likely to promote the level of innovation. First, the innovation investment volatility has an effect on resource allocation. It eases the resource constraints of dual innovation through time separation [3]. When the technological environment is relatively stable, enterprises focus innovation resources on product improvement and technology refinement, which is conducive to forming incremental innovation [4, 5]. When the technological environment is turbulent and profoundly changing, enterprises focus innovation resources on exploratory innovation into new knowledge areas, which is conducive to fostering disruptive innovation [6]. Second, the innovation investment volatility has the effect of signal transmission. The high level of innovation investment volatility indicates that the enterprise is conducting both exploratory and exploitative innovation activities at the same time [7]. The innovation signal indicates the enterprise's competitive market advantage, low default risk, and strong governance capabilities. Enterprises with higher levels of innovation investment volatility are more likely to be favored by investors, which can alleviate the financial constraints required for enterprise technological innovation.

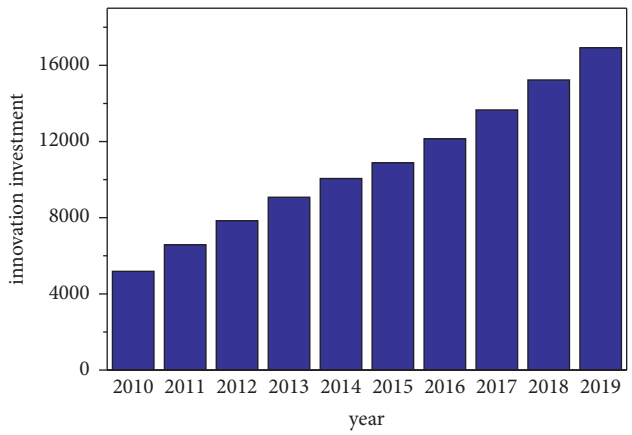

Figure 1: Innovation investment in China's enterprises (unit: 100 million yuan; source: Statistical Bulletin on China's Scientific and Technological Expenditure).

Therefore, they also tend to be more active in improving the level of innovation. However, whether China's enterprises are applicable to this mechanism needs to be further tested. Most of the existing literature regards enterprises as a homogeneous sample, ignoring the heterogeneity effect in different life cycle stages. Therefore, it is necessary to further explore the impact of innovation investment volatility on enterprise technological innovation in different life cycles.

Based on these insights, this study selects 205 Chinese listed enterprises in strategic emerging industries from 2010 to 2019 as a research sample to explore the impact of innovation investment volatility on technological innovation in different life cycles. Further, the public product nature of innovation activities often leads to market failure [8]. Innovation subsidy, as a significant means for the Chinese government to intervene in innovation activities, has an impact on innovation activities. Therefore, the study further introduces innovation subsidy policy as a moderating variable to test its influence on the relationship between innovation investment volatility and technological innovation of enterprises in different life cycles. Through the regression test of panel data, the research conclusions are as follows First, the innovation investment volatility has a positive impact on enterprise technological innovation in the growing stage, while it has an insignificant effect on enterprise technological innovation in the mature and declining stages. Second, the negative moderating effect of innovation subsidy on the relationship between innovation investment volatility and technological innovation of enterprises in the growing stage is the most significant, followed by the mature stage and the least in the declining stage. This study has several contributions. First, the study is conducive to deepening the theoretical study of innovation investment volatility and providing brand-new ideas for enterprise innovation investment activities by separately testing the impacts of innovation investment volatility on technological innovation of enterprises in different life cycles. Second, by distinguishing whether the innovation subsidy is effective in the life cycle stage of enterprises, the study provides a theoretical basis for formulating a more accurate innovation subsidy policy. It is also conducive to avoiding the waste of policy resources and creating a win-win situation between the government and enterprises. Finally, enterprises in strategic emerging industries of China are selected as the research sample. The impact of industry differences has been eliminated, which will provide reliable China microevidence for the research on innovation investment volatility.

The rest of the study is structured as follows. Section 2 reviews the previous research and analyzes the theoretical basis of the research. Section 3 explains the constructed research framework and hypotheses. Section 4 introduces the data and methodology. Section 5 contains the main results and robustness tests. In the last section, the study ends up with a discussion and conclusion.

2. Conceptual Framework

Depending on the different reasons for the volatility, innovation investment volatility includes three types: proactive innovation management, internal financing, and innovation manipulation. First, one of the reasons for the innovation investment volatility is proactive innovation management, which regards innovation investment volatility as a result of proactive management by managers [8]. The manager is not passively waiting for the results of innovation but allocates innovation resources in a timely manner based on the innovation stage and invests more resources into high-value innovation projects [8]. Therefore, it can lead to the volatility of innovation investment by the management of the innovation stage or resource allocation of innovation projects. Second, one of the reasons for the innovation investment volatility is internal financing, which regards the change of internal financing as the cause of innovation investment volatility [9]. Due to the high risk of innovation activities, the uncertainty of returns, and the asymmetry of information, there are constraints on external financing channels [9]. Internal financing channels have become the main source of innovation investment. When the amount of internal financing decreases, there will be a shortage of funds for the investment activities that have already been carried out. Enterprises tend to use tight internal funds to pay for investment activities with fast returns, low risk, and low uncertainty. Thus, when enterprises face financial problems, innovation investments of enterprises that rely on internal financing are characterized by volatility. Finally, one of the reasons for the innovation investment volatility is innovation manipulation, which regards innovation investment volatility as a result of innovation investment manipulation [8]. Managers may manipulate innovation expenditures to satisfy the expected returns or opportunistically manipulate innovation investment to obtain more government subsidies [10, 11]. Both performance catering and policy rent-seeking can lead to a sudden increase in innovation intensity, which will lead to a volatile character of innovation investment.

Enterprises in each life cycle stage have different financing constraints, innovation decisions, innovation capabilities, etc. Therefore, the causes for their innovation

investment volatility are also different in different life cycles. The innovation investment volatility in the growing stage is caused by proactive innovation management. First, enterprises in the growing stage face great pressure on innovation funds. They have internal and external financing constraints, resulting in limited innovation resources, which require managers to proactively identify the value of innovation projects and invest innovation resources in higher-value projects. The phenomenon of actively allocating innovation resources leads to innovation investment volatility. Second, enterprises in this stage have less internal financing. They still do not have the ability to make stable profits and lack sufficient internal funding to support innovation activities [12]. Therefore, the innovation investment volatility of enterprises in the growing stage is not caused by internal financing. Finally, innovation manipulation by enterprises in the growing stage may endanger their survival. In this stage, enterprises have not established a stable foothold and good reputation in the industry. Once they are found to have carried out innovation manipulation, it will bring negative consequences to the economy and reputation [13]. Therefore, the innovation investment volatility of enterprises in the growing stage is not caused by innovation manipulation.

Innovation investment volatility of enterprises in the mature stage is caused by internal financing. First, the internal financing of enterprises in this stage is sufficient. Enterprises with gradually mature production and operation model can obtain stable profits [14]. They have adequate internal financing. However, the cost of external financing tends to be higher compared to internal financing. Enterprises in the mature stage tend to use internal financing as the source of innovation investment. When internal financing is reduced, they naturally choose to prioritize internal funds to pay for investment activities with fast returns, low risk, and low uncertainty. Therefore, the innovation investment of enterprises in the mature stage presents the characteristics of volatility. Second, it is difficult for them to proactively manage innovation projects. Compared to enterprises in other stages, enterprises in the mature stage have a higher degree of diversity [7]. Manager's innovation decisions are mainly based on standardized experience rather than proactive management [15]. Therefore, the innovation investment volatility of enterprises in the mature stage is not caused by proactive innovation management. Finally, enterprises in the mature stage are less likely to engage in innovation manipulation. They have richer innovation experience and higher output levels. When allocating subsidy funds, government officials need to be under pressure to avoid waste. Enterprises with higher levels of innovation output are likely to be granted subsidies [16]. Therefore, they do not need to use innovation manipulation to obtain government subsidies. The innovation investment volatility in the mature stage is not caused by innovation manipulation.

The innovation investment volatility of enterprises in the declining stage is caused by innovation manipulation. First, the innovation manipulation motivation of enterprises in the declining stage is more likely to occur. In this stage, enterprises often face the risk of delisting or being merged. To prevent the continuous decline of stock prices, they may make an adverse selection. Innovation subsidy, as a low-cost source of funding for innovation activities, is naturally favored by enterprises in the declining stage. Therefore, to satisfy the criteria of innovation subsidy, enterprises may choose to increase innovation investment, which in turn leads to the volatility of innovation investment. Second, enterprises in the declining stage are less likely to undertake proactive management of innovation projects. They often suffer from institutional rigidity, section redundancy, and increased internal shifting of responsibilities [17]. Their judgment of innovation projects often follows the principle of path dependence rather than relying on proactive management. Therefore, the innovation investment volatility of enterprises in the declining stage is not caused by proactive innovation management. Finally, the sales of enterprises begin to decrease, and the market share shows a downward trend in the declining stage, resulting in limited internal financing. Therefore, the innovation investment volatility of enterprises in the declining stage is not caused by internal financing.

3. Hypotheses

3.1. The Different Impact of Innovation Investment Volatility. First, the innovation investment volatility caused by proactive innovation management can alleviate the limitations of innovation resources for enterprises in the growing stage, which can promote their technological innovation level. Although enterprises in the growing stage have an intense will for innovation, they have internal and external financing constraints due to the instability of profitability and information asymmetry, which restricts the development of innovation activities. However, the innovation investment volatility caused by proactive innovation management signals to outside investors that the enterprise is focusing on innovation. It conveys a low default risk and strong governance ability which is beneficial for the enterprise to access external financing. This enriches enterprise innovation funds. It can also alleviate the resource constraints of dual innovation through time compartmentalization and maximize the utilization of available resources [3]. Therefore, the volatility of innovation investment has a positive impact on the technological innovation of enterprises in the growing stage.

Second, the innovation investment volatility of enterprises in the mature stage is a result of the change in internal financing. The production and operation models of enterprises in the mature stage are becoming more mature and their profitability is strong. Internal financing channels are the main source of innovation investment for them. However, due to environmental uncertainties, policy uncertainties, and other factors, the internal financing of enterprises in the mature stage often exhibits volatility characteristics. When the amount of internal financing decreases, enterprises in the stage tend to prioritize internal funds to pay for investment activities with fast returns, low risk, and low uncertainty. The innovation investment becomes the main target of reduction. When the amount of

internal financing increases, enterprises in this stage tend to use internal funds to pay for innovation projects with long return cycles and large future returns. However, the increase or decrease of innovation investments is not an innovation decision based on changes in the market environment, but an adjustment behavior influenced by changes in internal financing. It may affect the normal innovation process of enterprises and may not improve the level of technological innovation. Therefore, the innovation investment volatility of enterprises in the mature stage has an insignificant incentive effect on technological innovation.

Finally, the innovation investment volatility caused by innovation manipulation is a strategic innovation behavior because enterprises in the declining stage lack new profit growth points or even face the threat of delisting [14]. To reach the criteria of government subsidy, enterprises in the stage often use accounting account adjustments to inflate innovation investment or purchase some advanced innovation equipment that is not put into actual operation [11]. The innovation manipulation does not substantially invest innovation funds into innovation activities. Therefore, the innovation investment volatility does not contribute to the level of technological innovation of enterprises in the declining stage but is merely a manifestation of policy rent-seeking. Based on the above analysis, the following hypotheses are proposed in this study.

H1: The volatility of innovation investment has a positive impact on enterprise technological innovation in the growing stage, while it has no significant effect on enterprise technological innovation in the mature and declining stages.

3.2. The Moderating Effect of Innovation Subsidy. The general impact of innovation investment volatility on technological innovation of enterprises in different life cycles is analyzed above. It has been found that the impact of innovation subsidy varies depending on the life cycle stage of the enterprise [18]. First, innovation subsidy weakens the effect of the innovation investment volatility by enterprises in the growing stage. The innovation investment volatility promotes the technological innovation level of enterprises in the growing stage by alleviating the limitations of their innovation resources. Although innovation subsidy directly complements the lack of innovation resources for enterprises in the growing stage and reduces their pressure to proactively manage innovation investments, it also transmits to outside investors that enterprises in the growing stage are too dependent on the government [19], weakening the signal that enterprises are innovation-oriented and hindering external financing channels. Thus, innovation subsidy weakens the positive impact of innovation investment volatility on enterprise technological innovation in the growing stage.

Second, innovation subsidy has led to changes in the reasons for innovation investment volatility of enterprises in the mature stage. When the amount of internal financing decreases, enterprises in the mature stage can also use innovation subsidies to support the research and development activities. In fact, the availability of innovation subsidies brings more media attention to enterprises. Managers are forced by media pressure to terminate little-value innovation projects in time. Therefore, the volatility of innovation investment in the mature stage becomes proactively managed. The innovation investment volatility caused by proactive innovation management invests innovation funds into more valuable projects through resource allocation, which promotes technological innovation of enterprises in the mature stage. However, while innovation subsidy brings media attention, it may also interfere with managers' judgments on the innovation stage [20]. Managers are more confident in devoting significant resources to exploratory innovation activities. Due to the originality and high risk of exploratory innovation, the exploratory innovation will consume a lot of resources and affect other innovation projects [21]. Thus, innovation subsidy has a negative effect on the relationship between the volatility of innovation investment and technological innovation of enterprises in the mature stage.

Finally, while innovation subsidy enhances the innovation investment volatility of enterprises in the declining stage, it does not substantially promote the level of technological innovation. In order to recover losses, enterprises in the declining stage often carry out innovation manipulation to acquire police resources. The acquisition of innovation subsidy, in turn, stimulates the motivation of innovation manipulation by enterprises in the declining stage and enhances the volatility of innovation investment. However, after receiving an innovation subsidy, enterprises in the stage often use it to recover losses or prevent stock price declines instead of using it for innovation activities. Thus, although innovation subsidy enhances the innovation investment volatility of enterprises in the declining stage, the level of technological innovation has not been substantially improved. Based on the above analysis, the following hypotheses are proposed in this study.

H2: The negative moderating effect of innovation subsidy on the relationship between innovation investment volatility and technological innovation is the most significant for enterprises in the growing stage, weakly significant for enterprises in the mature stage, and insignificant for enterprises in the declining stage.

4. Data and Methodology

4.1. Sample. Our data covers the listed enterprises of Chinese strategic emerging industries from 2010 to 2019. First, compared with other industries, listed enterprises in strategic emerging industries have the characteristics of active innovation investment activities, which creates realistic conditions for the observation of the volatility of innovation investment in this study. Second, data selection started in 2010. After the international financial crisis in 2008, the business activities and innovation investment activities of strategic emerging industries have gradually stabilized after two years of adjustment, which provides a realistic basis for our research. According to relevant studies, in the digital economy era, most enterprises, especially those in strategic emerging industries, can complete profound changes in two years [22]. Therefore, for the robustness of the study findings, only samples with innovation investment observations

for more than 3 consecutive years are retained in this study. Finally, data of doubtful reliability were excluded, including missing, incorrect, or unreasonable data, and enterprises' registration period of less than 2 years. The final sample of 205 enterprises was obtained, and the total number of observations was 1681. The patent data used in the study are drawn from the Chinese Research Data Services (CNRDS) database, while other data are drawn from the China stock market and accounting research (CSMAR) database.

At present, there is no consensus on the division of the enterprise life cycles. Compared with the traditional financial comprehensive index method and single variable method, the cash flow model method can reflect the characteristics of the operating conditions, profitability, and growth rate of enterprises in different life cycle stages, which has strong objectivity. Based on the above analysis, the study selects the cash flow model method to divide the enterprise life cycle into three stages: the growing, mature, and declining stages [14]. A total of 194 samples and 877 observations are finally obtained for enterprises in the growing stage, 176 samples and 543 observations for enterprises in the mature stage, and 123 samples and 261 observations for enterprises in the declining stage.

4.2. Measures

4.2.1. Dependent Variables. The number of patents is one of the most direct measures of enterprise technological innovation. The study adds 1 to the number of patents granted variable and then takes a natural logarithm to measure enterprise technological innovation (ETI) [8, 23]. In addition, in the robustness test section, the study adds 1 to the number of invention patents granted variable and then takes a natural logarithm to remeasure the enterprise technological innovation.

4.2.2. Independent Variables. In order to eliminate the effect of price, based on the algorithm of Mudambi and Swift [7] and Patel et al. [24], the actual innovation investment is used to measure the variable of innovation investment volatility (IIV), as shown in Table 1. The actual innovation investment is equal to the nominal research and development expenditure divided by the enterprise research and development expenditure price index (with 2010 as the base period). Among them, the enterprise research and development expenditure price index is obtained by the weighted summation of the consumer price index and fixed asset investment price index of the base period in 2010 [25].

4.2.3. Moderating Variables. Learning from the research of Chen et al. [26], the method of text analysis is used to search for the keywords of the innovation subsidy details. This is coded as 1 if the enterprise was supported by the innovation subsidy policy in the current year and 0 otherwise (IS). In addition, the number of the innovation subsidy plus 1 in the natural logarithm scale is used to measure the robustness test section.

4.2.4. Control Variables. Enlightened by the extant researches, the study also takes these variables as crucial control variables: enterprise growth, enterprise age, enterprise innovation effort, enterprise profitability level (pro), debt assets ratio, enterprise size, and enterprise human capital. The definitions of all the control variables are shown in Table 1.

5. Results

5.1. Main Results. Table 2 presents the means, standard deviations, minimum and maximum values, and correlations for the variables of the full sample and each life cycles samples. As can be seen from the results, the observations in the growing and mature stages account for 84.5% of the total sample, indicating that the vast majority of listed enterprises in Chinese strategic emerging industries are in the growing or mature stages. There is a large difference between the maximum and minimum values of the number of patent grants and innovation investment volatility, which indicates that the degree of innovation investment volatility and innovation capability of each enterprise differs greatly. From the perspective of different life cycle stages, the average value of the number of patents granted is the largest in the mature stage of the enterprise, followed by the growing stage, and the least in the declining stage. In addition, the size of the enterprise will gradually decrease with the evolution of the life cycle. From the results of the correlation coefficient test between variables, there is a correlation between the number of patent grants and the volatility of innovation investment in different life cycle stages. In addition, the variance inflation factor (VIF) is used to test multicollinearity. VIF values are all less than 1.5, indicating that there is no serious multicollinearity problem among the variables.

After using the Hausman test, the two-way random-effects model was finally chosen in this study. The estimation results are shown in Table 3.

Model 1 shows that the coefficient of IIV is significantly positive with ETI in Chinese strategic emerging industries because innovation investment volatility can alleviate the internal and external financing constraints of strategic emerging industry enterprises through time division and signal transmission and then promote their technological innovation. In model 2, the study included the moderator variables finding that IS has a significant negative moderating effect on the relationship between IIV and ETI (see Figure 2). Because the innovation resources are supplemented, the pressure for enterprises to take advantage of innovation investment volatility is reduced. Innovation subsidy intervenes in the allocation of internal resources, which is not conducive to promoting the level of technological innovation.

Models 3, 5, and 7, respectively, examine the impact of innovation investment volatility on the technological innovation of enterprises in different life cycles. In model 3, the regression results show that the coefficient of IIV is significantly positive with ETI. In the growing stage, the innovation investment volatility of enterprises is caused by proactive innovation management. That is conducive to

Table 1: Variable description and definition.

Dependent variables	Definition
ETI	The number of patents granted plus 1 in the natural logarithm scale
Independent variables	
IIV	Based on the regression of time trends in innovation investment, innovation investment volatility is equal to the standard residual term of the time trend regression divided by the mean value of innovation investment of the enterprise
Moderating variables	
IS	This is coded as 1 if the enterprise was supported by the innovation subsidy policy in the current year and 0 otherwise
Control variables	
Grow	(Operating income of the current year - operating income of the previous year)/Operating income of the previous year
Age	Total number of years between business registration year and research year
Effort	Natural logarithm of innovation expenditure costs
Pro	Earnings per share
Size	Natural logarithm of total corporate assets
Debt	Total liabilities/total assets
Human	Natural logarithm of the number of employees in the enterprise

Table 2: Sample distribution and statistics.

	Variables	Mean	SD	Min	Max	1	2	3	4	5
Full sample ($N = 1681$)	1.ETI	0.800	1.347	0	6.466	1				
	2. IIV	−0.445	0.992	−14.076	0.195	0.163***	1			
	3. grow	0.241	1.459	−0.790	55.759	−0.031	0.011	1		
	4. size	22.545	1.317	18.793	27.468	0.285***	0.180***	0.029	1	
	5.effort	−3.256	1.174	−14.539	6.783	0.046*	0.221***	−0.062**	−0.224***	1
The growing stage ($N = 877$)	1.ETI	0.796	1.393	0	6.466	1				
	2. IIV	−0.446	1.179	−14.076	0.146	0.145***	1			
	3. grow	0.321	1.992	−0.680	55.759	−0.037	0.014	1		
	4. size	22.664	1.236	19.270	26.651	0.294***	0.098***	0.041	1	
	5.effort	−3.323	1.263	−14.539	6.783	0.046	0.261***	−0.063*	−0.181***	1
The mature stage ($N = 543$)	1.ETI	0.863	1.359	0	6.120	1				
	2. IIV	−0.412	0.714	−6.00	0.195	0.212***	1			
	3. grow	0.154	0.292	−0.489	2.894	−0.030	0.054	1		
	4. size	22.429	1.420	18.893	27.468	0.306***	0.300***	−0.033	1	
	5.effort	−3.194	1.021	−12.303	0.063	0.013	0.163***	−0.058	−0.260***	1
The declining stage ($N = 261$)	1.ETI	0.678	1.150	0	5.209	1				
	2. IIV	−0.511	0.779	−5.368	0.172	0.181***	1			
	3. grow	0.154	0.402	−0.790	3.596	−0.064	−0.104*	1		
	4. size	22.388	1.327	18.793	27.386	0.215***	0.396***	−0.044	1	
	5.effort	−3.171	1.161	−11.848	−0.847	0.122**	0.122**	−0.161***	−0.285***	1

*, **, and ***represent 10%, 5%, and 1% significance levels, respectively.

promoting the level of technological innovation because it can alleviate the internal and external financing constraints of enterprises through time separation and signal transmission. Therefore, innovation investment volatility is conducive to promoting the level of technological innovation. Model 5 shows that the coefficient of IIV is positive but insignificant. The result suggests that the incentive effect of innovation investment volatility on technological innovation of enterprises in the mature stage is insignificant. A tentative explanation for this finding is that the innovation investment volatility of enterprises in the mature stage is caused by internal financing. In this stage, innovation investment volatility is an adjustment behavior affected by the change of internal financing, rather than an innovation decision made according to the change of market environment. This may affect the normal innovation process of enterprises in the mature stage. Thus, innovation investment volatility is not conducive to improving their technological innovation level. Model 7 indicates that the coefficient of IIV is positive but insignificant. The result suggests that the innovation investment volatility has no significant incentive effect on enterprise technological innovation in the declining stage because the innovation investment volatility of enterprises in the declining stage caused by innovation manipulation has not actually invested innovation funds in innovation activities. Therefore, their technological innovation level has not been substantially improved. In conclusion, H1 is supported.

Table 3: Regression results.

	Full sample		The growing stage		The mature stage		The declining stage	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IIV	0.094** (0.045)	0.159*** (0.058)	0.108** (0.052)	0.187*** (0.069)	0.071 (0.091)	0.229** (0.116)	0.132 (0.090)	0.041 (0.112)
IIV × IS		−0.068** (0.030)		−0.078** (0.035)		−0.026* (0.143)		0.122 (0.100)
IS	−0.048 (0.059)	−0.085 (0.068)	−0.082 (0.084)	−0.132 (0.097)	−0.126 (0.101)	−0.217* (0.122)	0.117 (0.116)	0.189 (0.140)
Human	0.107* (0.058)	0.104* (0.058)	0.107 (0.071)	0.101 (0.071)	0.180* (0.097)	0.176* (0.096)	0.016 (0.070)	0.020 (0.070)
Grow	−0.013** (0.005)	−0.013** (0.005)	−0.018*** (0.006)	−0.017*** (0.006)	−0.053 (0.221)	−0.064 (0.224)	−0.017 (0.112)	−0.019 (0.070)
Age	−0.007 (0.017)	−0.007 (0.017)	−0.005 (0.018)	−0.005 (0.018)	−0.017 (0.019)	−0.016 (0.019)	−0.015 (0.018)	−0.019 (0.111)
Effort	0.034 (0.025)	0.030 (0.025)	0.017 (0.029)	0.009 (0.030)	0.058 (0.044)	0.059 (0.044)	0.120** (0.048)	0.124*** (0.047)
Pro	0.024 (0.055)	0.022 (0.055)	0.057 (0.071)	0.055 (0.071)	−0.008 (0.116)	−0.005 (0.117)	0.021 (0.068)	0.021 (0.068)
Debt	0.038 (0.038)	0.035 (0.037)	0.039 (0.200)	0.020 (0.202)	0.002 (0.033)	0.006 (0.033)	0.127* (0.075)	0.130* (0.075)
Size	0.104* (0.057)	0.103* (0.057)	0.155* (0.079)	0.154* (0.079)	0.118* (0.066)	0.132** (0.066)	0.234** (0.115)	0.237** (0.116)
Constant	−2.352** (1.119)	−2.290** (1.113)	−3.587** (1.497)	−3.499** (1.493)	−2.736** (1.287)	−2.948** (1.293)	−4.241** (2.108)	−4.397** (2.118)
Enterprise	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1681	1681	877	877	543	543	261	261
R^2	0.113	0.115	0.123	0.124	0.136	0.142	0.098	0.100

Note that standard errors are in parentheses. *, **, and ***represent 10%, 5%, and 1% significance levels, respectively.

Subsequently, this study adds the interaction of the innovation investment volatility with innovation subsidy to test the regulatory effect of innovation subsidy in different life cycles. As shown in model 4, the coefficient of IIV×IS is negative and significant, indicating that innovation subsidy has a significant negative effect on the relationship between innovation investment volatility and technological innovation of enterprises in the growing stage (see Figure 3). Perhaps, it can be explained that innovation subsidy transmits to external investors that enterprises in the growing stage rely too much on the government [24], which will hinder external financing channels and is not conducive to their technological innovation. In model 6, the coefficient of innovation IIV × IS is negative and significant, which means that innovation subsidy has a significantly weak negative regulatory effect on the relationship between innovation investment volatility and technological innovation of enterprises in the mature stage (see Figure 4). Because innovation subsidy may interfere with managers' judgment on the innovation stage, managers are more confident to use a large number of resources for exploratory innovation activities. Exploratory activities are innovative and high risk, which will consume a lot of resources of the enterprise. The development of other innovation projects may be affected [21]. In model 8, the coefficient of IIV×IS is positive but insignificant, which means that innovation subsidy has an insignificant effect on the relationship between innovation investment volatility and enterprise technological innovation in the declining stage because enterprises in the declining stage often use innovation subsidies to recover losses or prevent the decline of stock prices instead of actually using them in innovation activities. In conclusion, H2 is supported.

5.2. Robustness Checks

5.2.1. Substitution of Dependent Variables. To verify whether the model constructed is influenced by the choice of variables, the study adds 1 to the number of invention patents granted and then takes a natural logarithm as the substitute variable for the number of granted patents [23]. Table 4 shows that the results have not changed greatly.

5.2.2. Substitution of Moderating Variables. The number of the innovation subsidy plus 1 in the natural logarithm scale is used as the substitute variable [26]. Table 5 shows that the results are consistent with the findings of the above study.

5.2.3. Delete Sensitive Years. Considering the impact of the 2012 National Strategic Emerging Industry Development Plan on innovation investment volatility of the sample enterprises, the 2012 sample is removed and reregressed [27]. Table 6 shows that the results are consistent with the findings of the above study.

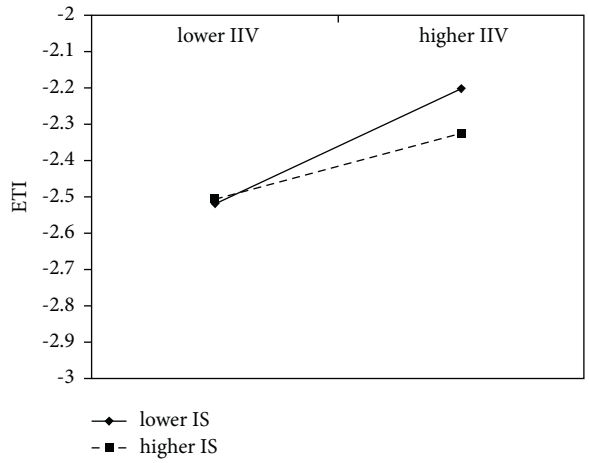

Figure 2: The relationship between IIV and ETI—moderated by IS.

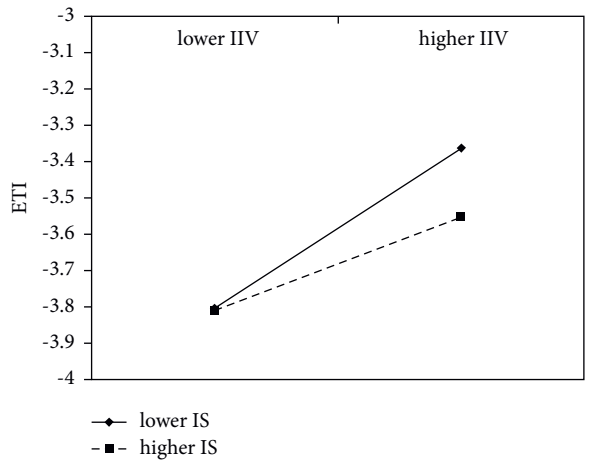

Figure 3: The relationship between IIV and ETI in the growing stage—moderated by IS.

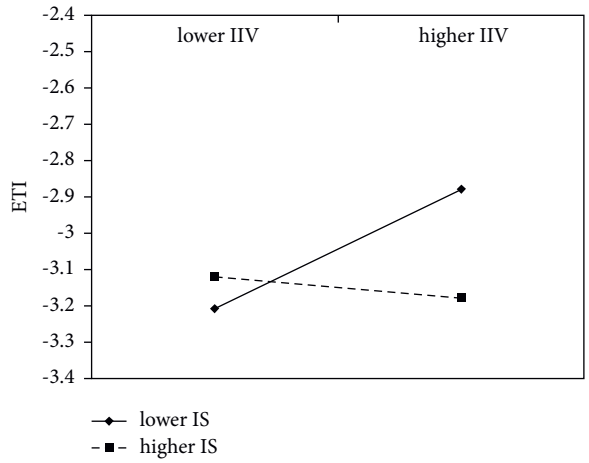

Figure 4: The relationship between IIV and ETI in the mature stage—moderated by IS.

Table 4: Substitution of dependent variables.

	Full sample		The growing stage		The mature stage		The declining stage	
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
IIV	0.099** (0.040)	0.155*** (0.05)	0.099** (0.043)	0.167*** (0.057)	0.097 (0.069)	0.230** (0.104)	0.110 (0.067)	0.029 (0.097)
IIV × IS		−0.059** (0.026)		−0.069** (0.030)		−0.230* (0.121)		0.109 (0.110)
IS	−0.044 (0.052)	−0.075 (0.061)	−0.082 (0.077)	−0.125 (0.090)	−0.080 (0.089)	−0.159 (0.108)	0.034 (0.095)	0.099 (0.106)
Human	0.076 (0.049)	0.073 (0.049)	0.075 (0.063)	0.070 (0.063)	0.123 (0.075)	0.119 (0.074)	−0.007 (0.049)	−0.003 (0.050)
Grow	−0.012** (0.005)	−0.012** (0.005)	−0.017*** (0.006)	−0.016*** (0.006)	−0.026 (0.205)	−0.035 (0.208)	−0.033 (0.111)	−0.035 (0.111)
Age	−0.002 (0.012)	−0.0015 (0.012)	0.001 (0.013)	0.001 (0.013)	−0.005 (0.014)	−0.0037 (0.014)	−0.0165 (0.014)	−0.016 (0.014)
Effort	0.023 (0.022)	0.019 (0.022)	0.010 (0.026)	0.003 (0.027)	0.046 (0.035)	0.0469 (0.036)	0.082** (0.040)	0.086** (0.040)
Pro	0.022 (0.049)	0.020 (0.049)	0.051 (0.061)	0.049 (0.061)	−0.003 (0.088)	−0.002 (0.089)	0.046 (0.062)	0.046 (0.062)
Debt	0.041 (0.033)	0.038 (0.032)	−0.015 (0.178)	−0.032 (0.180)	0.0084 (0.026)	0.012 (0.026)	0.091 (0.067)	0.094 (0.067)
Size	0.105** (0.050)	0.105** (0.050)	0.145** (0.070)	0.144** (0.070)	0.109** (0.056)	0.121** (0.056)	0.201** (0.086)	0.204** (0.087)
Constant	−2.403** (0.955)	−2.352** (0.948)	−3.326*** (1.291)	−3.253** (1.288)	−2.476** (1.058)	−2.671** (1.072)	−3.556** (1.599)	−3.695** (1.599)
Enterprise	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1681	1681	877	877	543	543	261	261
R^2	0.118	0.120	0.129	0.130	0.135	0.139	0.112	0.114

Note that standard errors are in parentheses. *, **, and ***represent 10%, 5%, and 1% significance levels, respectively.

Table 5: Substitution of moderating variables.

	Full sample		The growing stage		The mature stage		The declining stage	
	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
IIV	0.094** (0.045)	0.148*** (0.057)	0.109** (0.052)	0.168** (0.068)	0.071 (0.091)	0.218* (0.113)	0.132 (0.090)	0.059 (0.113)
IIV × IS		−0.005* (0.003)		−0.005* (0.003)		−0.019* (0.011)		0.0068 (0.007)
IS	−0.004 (0.004)	−0.007 (0.005)	−0.009 (0.006)	−0.012* (0.007)	−0.008 (0.007)	−0.014 (0.009)	0.034 (0.095)	0.012 (0.010)
Human	0.107* (0.058)	0.105* (0.058)	0.075 (0.063)	0.105 (0.071)	0.182* (0.096)	0.182* (0.095)	0.014 (0.069)	0.017 (0.070)
Grow	−0.013** (0.005)	−0.013** (0.005)	0.107 (0.071)	−0.017*** (0.006)	−0.055 (0.221)	−0.064 (0.224)	−0.016 (0.112)	−0.018 (0.111)
Age	−0.007 (0.017)	−0.007 (0.017)	−0.018*** (0.006)	−0.005 (0.018)	−0.017 (0.019)	−0.016 (0.019)	−0.015 (0.018)	−0.014 (0.018)
Effort	0.034 (0.025)	0.031 (0.025)	−0.005 (0.018)	0.011 (0.030)	0.059 (0.044)	0.061 (0.044)	0.120** (0.048)	0.123*** (0.047)
Pro	0.024 (0.055)	0.022 (0.055)	0.015 (0.030)	0.058 (0.070)	−0.006 (0.116)	−0.006 (0.117)	0.020 (0.070)	0.020 (0.070)
Debt	0.038 (0.038)	0.037 (0.037)	0.058 (0.070)	0.026 (0.201)	0.002 (0.033)	0.007 (0.033)	0.127* (0.075)	0.126* (0.076)
Size	0.105* (0.057)	0.105* (0.057)	0.041 (0.200)	0.156** (0.079)	0.121* (0.066)	0.135** (0.066)	0.232** (0.115)	0.235** (0.116)
Constant	−2.368** (1.116)	−2.354** (1.113)	−3.582** (1.487)	−3.557** (1.487)	−2.806** (1.288)	−3.083** (1.304)	−4.194** (2.098)	−4.314** (2.106)
Enterprise	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1681	1681	877	877	543	543	261	261
R^2	0.114	0.115	0.125	0.126	0.137	0.143	0.099	0.102

Note that standard errors are in parentheses. *, **, and ***represent 10%, 5%, and 1% significance levels, respectively.

Table 6: Delete the 2012 sample.

	Full sample		The growing stage		The mature stage		The declining stage	
	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
IIV	0.098** (0.045)	0.174*** (0.057)	0.107** (0.051)	0.202*** (0.068)	0.113 (0.088)	0.257** (0.126)	0.115 (0.097)	0.007 (0.135)
IIV × IS		−0.075** (0.0293)		−0.089*** (0.034)		−0.246 (0.150)		0.137 (0.114)
IS	−0.070 (0.060)	−0.112 (0.070)	−0.110 (0.082)	−0.168* (0.095)	−0.155 (0.109)	−0.240* (0.134)	0.133 (0.127)	0.217 (0.159)
Human	0.106* (0.058)	0.101* (0.058)	0.093 (0.074)	0.086 (0.074)	0.168* (0.097)	0.165* (0.096)	0.028 (0.072)	0.030 (0.073)
Grow	−0.013** (0.005)	−0.012** (0.005)	−0.018*** (0.006)	−0.017*** (0.006)	−0.065 (0.238)	−0.071 (0.240)	−0.010 (0.117)	−0.011 (0.116)
Age	−0.007 (0.017)	−0.007 (0.017)	−0.001 (0.018)	−0.001 (0.018)	−0.021 (0.019)	−0.020 (0.020)	−0.014 (0.019)	−0.012 (0.019)
Effort	0.029 (0.025)	0.024 (0.025)	0.017 (0.029)	0.006 (0.030)	0.051 (0.040)	0.052 (0.041)	0.130** (0.053)	0.136*** (0.052)
Pro	0.019 (0.058)	0.017 (0.058)	0.071 (0.075)	0.071 (0.075)	0.027 (0.119)	0.028 (0.120)	0.019 (0.070)	0.018 (0.069)
Debt	0.047 (0.035)	0.044 (0.034)	0.038 (0.190)	0.018 (0.192)	−0.001 (0.033)	0.004 (0.033)	0.129* (0.078)	0.135* (0.078)
Size	0.102* (0.057)	0.101* (0.057)	0.166** (0.081)	0.164** (0.081)	0.105 (0.066)	0.118* (0.066)	0.241** (0.122)	0.251** (0.123)
Constant	−2.313** (1.119)	−2.231** (1.111)	−3.729** (1.509)	−3.613** (1.503)	−2.327* (1.254)	−2.541** (1.264)	−4.449** (2.265)	−4.740** (2.295)
Enterprise	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1503	1503	794	794	471	471	238	238
R^2	0.111	0.112	0.124	0.125	0.136	0.137	0.100	0.101

Note that standard errors are in parentheses. *, **, and ***represent 10%, 5%, and 1% significance levels, respectively.

6. Discussion and Conclusion

6.1. Theoretical Contributions. This study provides several theoretical contributions to the research of firm innovation investment. First, the study proposes that the reasons for enterprises' innovation investment volatility in different life cycle stages are different and their impact on technological innovation is also different. Most prior studies have discussed the effect of innovation investment volatility in a homogeneous sample of enterprises. The differences in the effect of innovation investment volatility for enterprises in different life cycle stages may be ignored. The study finds that the innovation investment volatility of enterprises in the growing stage is caused by proactive innovation management and it has a positive impact on technological innovation. In contrast, innovation investment volatility of enterprises in the mature and declining stages, respectively, is caused by internal financing and innovation manipulation, which has no significant effect on technological innovation.

Second, our framework provides a heterogeneous perspective extending the research related to the volatility of innovation investment by treating innovation subsidy as a shock to the enterprise's external environment. Most existing studies emphasized the impact of internal enterprise factors such as resource redundancy and technological capability on the volatility of innovation investment [9, 28]. Few studies have considered the impact of the enterprise's external environment. This study finds that innovation subsidy does not have the desired effect, which is consistent with the research of Zhou et al. [23]. They found that, with the development of market mechanisms, the government's role in promoting enterprise technological innovation will decline.

Finally, this study adopts the data of Chinese strategic emerging industry enterprises as a sample to further explore, enriching the relevant research on the innovation investment volatility. Most previous studies focusing on the volatility of innovation investment mostly used samples from enterprises in developed countries such as the United States and South Korea [9, 28]. However, the technology path constraint and the nonsustainability of innovation investment fees are more prominent in developing countries. Meanwhile, most innovation investment in developed countries exhibits countercyclical characteristics, while innovation investment in developing countries tends to show procyclical characteristics [29]. Therefore, it remains to be tested whether the relevant studies on the volatility of innovation investment in developed countries are applicable to China, an emerging economy.

6.2. Implications for Managers and Policy Makers. Based on the perspective of punctuated equilibrium and life cycle theory, we examine the impact of innovation investment volatility on enterprise technological innovation and the moderating role of innovation subsidy in a sample of listed enterprises in China's strategic emerging industries from 2010 to 2019. The study finds that the volatility of innovation investment eases the financing constraints of enterprises,

which is conducive to improving the level of technological innovation of enterprises in the growing stage. However, the innovation investment volatility of enterprises in the mature stage is caused by internal financing, which may affect the normal process of innovation activities. It is difficult to improve the level of enterprise technological innovation. The innovation investment of enterprises in the declining stage is caused by using innovation manipulation to obtain government subsidies, and it is also difficult to improve the level of enterprise technological innovation. This study further finds that innovation subsidy cannot interfere with the relationship between the volatility of innovation investment and the technological innovation of enterprises in the declining stage. The innovation subsidy policy has counterproductive effects on the volatility of innovation investment and technological innovation in the growing and mature stage. For enterprises in the growing stage, innovation subsidy not only reduces the pressure on innovation investment but also weakens the enterprises' signal of reinnovation, which is not conducive to improving the level of technological innovation. For enterprises in the mature stage, the acquisition of innovation subsidy makes the managers more confident to use their main resources for exploratory innovation activities, which consumes a lot of resources and affects the development of other innovative projects.

The research conclusions provide several practical insights for business managers and the government. First, enterprise technological innovation is affected not only by the absolute amount of innovation investment but also by the volatility of innovation investment. However, not all types of innovation investment volatility can promote enterprise technological innovation level. The study finds that the innovation investment volatility caused by proactive management is conducive to improving the level of enterprise technological innovation. Therefore, managers should implement proactive management of innovation projects. When new opportunities appear in the external environment, managers should increase innovation investment in time. They should also promptly terminate investment in projects that do not have prospects rather than increase or decrease investment in the process of innovation.

Second, the life cycle stage of enterprises should be fully taken into consideration when the manager formulates the innovation strategy. For enterprises in the growing stage, the innovation investment volatility is conducive to improving the level of enterprises' technology innovation. However, for enterprises in the mature or declining stage, innovation investment volatility is not conducive to promoting technological innovation levels. Therefore, managers of enterprises in the growing stage should take advantage of organizational flexibility to adjust the focus and direction of innovation projects in a timely manner. Managers of enterprises in the mature stage should ensure adequate internal financing and avoid innovation investment volatility. For enterprises in the declining stage, managers should devote resources to imitative innovation activities and avoid the waste of limited resources caused by strategic innovation.

Finally, although the Chinese government has been committed to helping enterprises promote their technological innovation, with the development of market mechanisms, the role of innovation subsidy in promoting technological innovation of enterprises is declining. In some cases, innovation subsidies can even have counterproductive effects. For example, enterprises in the growing stage that receive innovation subsidies may weaken their pressure to proactively manage innovation resources and reduce the effect of innovation investment volatility. The acquisition of innovation subsidy by enterprises in the mature stage may increase the confidence of managers in exploratory innovation activities, which makes the enterprise at a high level of risk in the long term. Therefore, the life cycle stage of the enterprise should be considered when the government formulates an innovation subsidy policy.

6.3. Limitations and Future Research. First, the study only involves a specific industry (strategic emerging industry) in a specific emerging economy (China). Although China is the largest emerging economy, it may be different from other economies in terms of institutions, culture, etc. Compared with other industries, innovation investment in strategic emerging industries is more active in China. Therefore, the choice of other economies or industries may affect the results of the research. The research objects can be reselected for testing in future studies. Second, the study only considers the effects of different life cycle stage characteristics of enterprises. In future research, we can further examine the influence of other internal factors of the enterprise, such as the nature of enterprise ownership and the degree of enterprise financialization to supplement related research. Finally, regarding the impact of the external environment of the enterprise, our analysis only considers the institutional environment of innovation subsidy. Further research is needed to examine the impact of other policies (such as talent subsidy, high-tech enterprise qualification recognition, etc.) or other external environments (such as the market environment).

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this study.

Authors' Contributions

Miaomiao Li and Zhaoxing Hao explored the whole research ideas and wrote the paper. Zhaoxing Hao and Meng Luan carried out the empirical analysis. Miaomiao Li and Haibo Li provided guidance for the research process and supervised the entire project. Meng Luan and Guikun Cao revised the manuscript. All the authors participated in this research project.

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