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Financial Constraints and R&D Investment: The Moderating Role of CEO Characteristics

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Received: 3 July 2019; Accepted: 30 July 2019; Published: 1 August 2019

Abstract: How CEOs with different characteristics act differently on R&D investment under the condition of financial constraints is an important but understudied question towards firms' sustainable innovation. Employing the dataset from China-Enterprise Survey 2012 of the World Bank, this study tests the impact of financial constraints on firms' R&D investment and the moderating role of CEO characteristics. Empirical results show that: (1) firm's financial constraints have a significant restricting effect on their R&D investment; (2) internal financial constraints have no significant restricting effect on R&D investment for firms with female CEOs in comparison with firms with male CEOs, while the external financial constraints have a significant restricting effect on R&D investment for both groups. (3) CEO experience has a non-linear moderating effect on the relationship between financial constraints and a firm's R&D investment. When the accumulated experience is overloaded, the positive moderating effect of CEO experience begins to decline and even become negative. Robustness tests further confirm these empirical findings. This study directly contributes to the literature of financing innovation and top management team's impact on firms' sustainable innovation, and generates insights on firms' R&D management under the condition of financial constraints.

Keywords: sustainable innovation; financial constraints; R&D investment; moderating effect; CEO characteristics

1. Introduction

Research and Development (R&D) investment through which knowledge is produced is the key to sustainable innovation and firm performance [1–5]. Firms' investment decisions not only depend on the cost-benefit analysis of the investment projects, but is also constrained by the access of capital [6–8]. R&D activities usually require a large amount of long-term capital investment, and there is often significant information asymmetry between the demander and the supplier of R&D capital [9,10]. Fazzari et al. [11] put forward the concept of financing constraints in their pioneering study, that is, some firms do not have sufficient access to external capital markets because of imperfections in markets for equity and debt. Firms are often confronted with financing constraints at different degrees, which restrict their innovation activities, leading to the failure of innovation projects and therefore restrain the firms' innovation behavior [12,13].

In recent years, innovation scholars began to analyze and study financing issues related to innovation, especially the impact of financing constraints on firms' innovation activities [6,12,14] However, on one hand, these studies have not obtained consistent conclusions yet. On the other hand, they were generally carried out according to institutional environment and firm characteristics. However, the effect of top management team, especially the characteristics of chief executive officer(CEO), on firms' innovation activities under the condition of financial constraints remains to be further explored [10] (see Coles et al. [15] as a review). The upper echelon theory [15,16] advocates

that a top management team (TMT) makes highly personalized interpretations and choices on the organizational situations, and their behaviors are the reflection of their personal characteristics such as cognition, values and experience. The top management team determines the formation of organizational strategy. Scholarly work, for example Coles et al. [10], have examined the managerial attributes and associated incentives for firm policy, risk and performance, finding that manager—especially CEO—characteristics are highly associated with firm risk preference, R&D behavior and performance. In turn, scholars also find that sustainability and social responsibility may influence managers' risk-taking behaviors and strategic decisions [4,17]. However, how CEOs with different characteristics act differently on R&D investment under the condition of financial constraints is an important but understudied question towards sustainable innovation.

In this paper, drawing from the perspectives of financing innovation [7,9,11] and upper echelon theory [15,16,18], we ask: What are the differences in R&D investment decisions of CEOs with different characteristics when facing financing constraints? We employed the dataset from China-Enterprise Survey 2012 of the World Bank to test the impact of financial constraints on firms' R&D investment, as well as the moderating role of CEO characteristics. Empirical results show that a firm's financial constraints have a significant restricting effect on their R&D investment. Internal financial constraints have no significant restricting effect on R&D investment for firms with female CEOs in comparison with firms with male CEOs, while the external financial constraints have a significant restricting effect on R&D investment for both groups. Furthermore, CEO experience has a non-linear moderating effect on the relationship between financial constraints and a firm's R&D investment. When the accumulated experience is overloaded, the positive moderating effect of CEO experience begins to decline and even becomes negative. Robustness tests further confirm these empirical findings.

This study contributes to the literature of innovation management and sustainable innovation in three aspects. First, the underlining assumptions behind the current research on financial constraints and its impact on firms R&D behavior is that a firm's behaviors are shaped by external factors and the firm itself usually just passively undertakes financial constraints. However, these studies usually ignore the fact that a firm is not a mechanical existence but an organic unit composed of people [16,18], and have not yet looked into the micro-level reasons to explain why firms adjust their R&D behavior under the condition of financial constraints. Drawing from the upper echelon theory [15,16], this study introduces CEO gender and experience to examine how financing constraints affect firms' R&D behavior. By empirically testing the joint effect of financial constraints and CEO characteristics on R&D investment, this study pushes forward current research on innovation management, and provides a multidisciplinary approach for scholars to further inquiry into the linkages between top managers, organizational risky behaviors and their competitive environments.

Second, it is becoming more common that women take the position of firms' top management. The studies in the western context show that a female top manager has the characteristic of risk aversion, and female top management participation tend to reduce firms' risky behavior [19,20]. The CEO is the core of a firm's top management team [18]. When confronted with financing constraints, do female CEOs and male CEOs make different decisions on R&D investment? This study documents that internal financial constraints have no significant restricting effect on R&D investment for firms with female CEOs in comparison with firms with male CEOs, while external financial constraints have a significant restricting effect on R&D investment for both groups. This finding enriches the literature on the female top manager and gender differences by providing a context-based empirical case. In this way, this study opens new possibilities for scholars to develop a better understanding of the boundary conditions of scholarly theories [21]. Finally, this study reveals the moderating mechanism of CEO experience on the relationship between financing constraints and firms' R&D investment. We discuss recent literature on managerial attributes [10], adding a more comprehensive understanding of the attributes and values of management experience, thus providing firms with both theoretical and practical insights for sustainable innovation management.

2. Literature Review and Hypothesis

2.1. Financial Constraints and Firm R&D Investment

Innovation has a substantial long-term impact on both firm competitive advantage and sustainable industry growth [1,4,5]. Since innovation usually requires more time and continuous investment than other generally organizational activities, the availability of R&D capital is a key factor that affects R&D investment of firms [6,9]. R&D activities of firms often require strong financing ability of firms to ensure a large amount of continuous resource input, especially capital input, to prevent the interruption of innovation caused by insufficient capital [8,12]. External financing is critical for reducing and alleviating the risk of R&D investment. The management team is assumed to know more about the firm's value and risk than their potential investors [10]. The relative confidentiality of firms' innovation activities leads to information asymmetry between firms and external investors, which increases the external financing cost of firms' innovation activities [10,22,23]. Due to the uncertainty of investment returns, adverse selection and moral hazard, it is difficult for firms to obtain effective financial support from external financing channels [9]. External financing has a more obvious positive impact on R&D activities of small and medium-sized firms, private firms and high-tech firms, these firms face more severe financing constraints in their innovation activities [22,24]. For instance, Guariglia and Liu [25] examined to what extent financing constraints affect innovation activities, and found that Chinese firms' innovation activities are constrained by the availability of internal finance. They found that private firms suffer the most, followed by foreign firms, while state-owned and collective enterprises are the least constrained. In a long R&D cycle, even firms with strong competence may suffer from capital shortage due to the turbulent market environment. Given the limited internal capital, only external financing can ensure the continuous development of innovation activities [11,12]. For example, Acharya and Xu [14] used U.S. firms' data to examine the relationship between financial dependence and firms' innovation, finding that public firms in external finance dependent industries spend more on R&D and generate a better patent portfolio than private firms. Canepa and Stoneman [26] found that financing constraints have a significant negative impact on firms' R&D and innovation activities, which is more obvious in high-tech firms and small firms.

As one of the typical examples of emerging economies, current market environment and financial environment in China is underdeveloped [27–29]. Due to imperfect financial market and social credit mechanism, low resource allocation efficiency and even resource misallocation in the financial industry, firms are faced with financing constraints of different degrees in the innovation process [27,29]. The more serious the financing constraint is, the higher the financing cost of firms' innovation activities and more restrained the R&D investment of firms will be. Based on this, we propose the following hypothesis:

Hypothesis 1. *Financing constraints have a significant negative impact on firms' R&D investment.*

The existing literature has accumulated plenty of knowledge of financing constraints and characterized financing constraints as internal financing constraints and external financing constraints, where internal financing constraints refer to the availability of internal finance and external financing constraints refer to the limit of access to external finance [30,31]. Different financing constraints may have different impacts on firms R&D investment [14,29]. In order to further specify the restricting effect of financing constraints on firms' R&D investment, this study proposes the following two sub-hypotheses:

Hypothesis 1a. *Internal financing constraints have a significant negative impact on firms' R&D investment.*

Hypothesis 1b. *External financing constraints have a significant negative impact on firms' investment.*

2.2. Moderating Effect of CEO Characteristics

2.2.1. Moderating Effect of CEO Gender

R&D investment is characterized by long-term investment with high risk. The R&D attitude and risk tendency of a firm's CEO may significantly influence on R&D investment [18,32]. Although research conclusions in existing literature all show that there are significant differences in risk perception, risk preference and risk-taking among top management of different genders, the difference in sense of competition between male and female is affected by social environment and can be adjusted through policy intervention [33–35]. The differences in gender characteristics may vary under different contexts, and female characteristics are becoming more neutral from a holistic perspective [36,37]. For example, some studies found that female executives place wider bounds on earnings estimates and are more likely to exercise stock options early [19].

Due to gender discrimination and prejudice, many female top managers have to imitate their male counterparts to gain respect and recognition from their subordinates [38,39]. Especially in some male-dominated industries, there is little difference between male and female top management' leadership styles and decision-making preferences. Under the influence of Chinese traditional culture, combined with the natural cruelty in the workplace, female managers must make more efforts than male to become CEOs. Any female promoted to top management has generally done so by reducing the gender factor. Furthermore, they possibly have the ability to bear risk the same or even better than a male CEO [20]. For example, a study conducted by U.S. think tank New York Centre for Work-Life Policy shows that the Chinese female is the most ambitious female in the world, with 76% of women in China aspiring to hold top positions, compared with 52% in the U.S. [40]. The CEO is the core of any firm's top management team. When faced with financing constraints, female CEOs may become more aggressive in R&D investment, thus easing the restricting effect of financing constraints on firms' R&D investment. Therefore, this study proposes the following hypothesis:

Hypothesis 2. *CEO gender has a moderating effect on the relationship between financing constraints and firms' R&D investment. That is, when the CEO is female, the financing constraints faced by firms have a weaker restricting effect on R&D investment than when the CEO is male.*

More specifically, we have:

Hypothesis 2a. *CEO gender has a moderating effect on the relationship between internal financing constraints and firms' R&D investment.*

Hypothesis 2b. *CEO gender has a moderating effect on the relationship between external financing constraints and firms' R&D investment.*

2.2.2. Moderating Effect of CEO Experience

Work experience refers to a kind of internalized tacit knowledge and skills accumulated based on work experience [40,41]. Work experience of top management is an important factor influencing their decision-making behavior [41]. Experienced managers are better at dealing with the uncertainty and ambiguity in management, are easier able to obtain information and resources for effectively implementing firms' strategies, and can better understand how to coordinate task-oriented and relationship-oriented leadership behaviors, so as to achieve better performance. The more experienced the CEO is, the more accurate and correct judgments about investment projects the CEO will make. In R&D investment decisions known for high returns and high risks, the experience value of management personnel is more likely to be reflected, and rich experience helps reducing decision-making errors.

For management personnel, however, an appropriate reserve of experience is an asset, and excessive accumulation of experience can be a burden. Experience is a double-edged sword, which is an invaluable treasure when it plays a positive role and an invisible "poison" when it plays a negative role [42] In the process of continuous accumulation of experience of management personnel, the rigidity of their cognitive pattern keeps rising and it is difficult for them to accept new things and new ideas, which may cause the firms to miss opportunities. As the research conducted by Luo et al. [42] shows, CEOs serving for a long term may be skilled in handling employee relations, but not good at coping with the market. These leaders may be great motivators, but weak strategists. The accumulation of management experience is conducive to improving the quality of management decision and risk management ability. However, when management personnel experience is "overloaded", they will gradually lack the consciousness of innovation and change, and their cognitive rigidity will even strengthen the restricting effect of financing constraints on R&D investment. Therefore, this study proposes the following hypothesis:

Hypothesis 3. *CEO experience has a non-linear moderating effect on the relationship between financing constraints and firms' R&D investment. Specifically, in the early stage of the tenure, the accumulation of CEO experience helps alleviate the restricting effect of financing constraints on firms' R&D investment. However, with the accumulation of experience and even when the accumulated experience is overloaded, the positive moderating effect of CEO experience begins to decline and even become negative.*

More specifically, we have:

Hypothesis 3a. *CEO experience has a non-linear moderating effect on the relationship between internal financing constraints and firms' R&D investment.*

Hypothesis 3b. *CEO experience has a non-linear moderating effect on the relationship between external financing constraints and firms' R&D investment.*

3. Research Methods

3.1. Data

This paper selects the dataset from China-Enterprise Survey 2012 of the World Bank to empirically test the theoretical hypothesis. The original sample questionnaire involves 2848 firms in 25 cities, covering sales, finance, competition, financing and other aspects. As a scientific sampling method is strictly followed, the estimation error of the data is small and the accuracy is high. In sample selection, this paper follows the following principle: (1) This study classifies the industries of firms based on questionnaire A4b issue. Due to the lack of data of 148 state-owned firms, sample data of state-owned firms were not selected in the study. (2) Samples of non-manufacturing firms were deleted according to questionnaire A4 issue. (3) Samples of subsidiaries were deleted according to questionnaire A7 issue. Finally, 1487 firms were selected, covering 18 industries including food manufacturing, textile manufacturing and clothing manufacturing. What the difference between this study and previous studies based on data of listed firms is that there are 711 firms with sole proprietorship among the samples of this study, accounting for 47.81% of total samples. Therefore, it can better reflect the actual composition of industrial firms in China. There are only 59 state-owned joint-stock firms, accounting for only 3.97% of the total sample. Therefore, the research objects of this paper are mostly small and medium-sized private firms. Based on relevant literature, main variables in this paper are defined as follows. (1) R&D investment: firms' R&D investment behavior, and two indicators are used to measure R&D investment. If there is internal R&D investment or external cooperative R&D investment, it is defined as 1; otherwise, it is defined as 0. (2) Internal financing constraints: internal financing constraints are financing constraints caused by the availability of internal capital of firms. If a firm has

sufficient internal capital for innovation, it is defined as 0; otherwise, it is defined as 1. (3) External financing constraints: external financing constraints are financing constraints caused by the access to external finance of firms. If a firm has an overdraft facility (K7) or has obtained bank loans or bank credit (K8), this index takes 0; otherwise, it takes 1. (4) CEO gender: if CEO gender is female, the value is 1; otherwise, the value is 0; (5) CEO experience: the work experience of CEO, it is measured by the tenure of CEO.

Based on relevant literature, main control variables in this paper are defined as follows. (1) Size of firm: the size of a firm, measured by the number of people in employment/1000; (2) Industry competition degree: the competition degree of the industry of the firm, measured according to the negative impact of industry competition on the firm; (3) Capacity: current capacity of a firm, it is measured according to the capacity utilization rate of the firm; (4) Performance level: three-year average sales growth rate. Main variables of this study are defined as shown in Table 1.

Table 1. Main Variables and Definitions.

Variable Name	Variable Explanation	Questionnaire No.	Variable Type	Variable Value
RDINV	R&D investment	CNo3, CNo5	Classified variable	If CNo3 or CNo5 is 1, the value is 1, otherwise the value is 0
INFC	Internal financing restraints	K17	Classified variable	If k17 is 1, it is defined as 0, otherwise it is defined as 1
EXFC	External financing restraints	K7, k8	Classified variable	If k7 or k8 is 1, the value is 0, otherwise the value is 1
GEND	CEO gender	b7a	Classified variable	If the CEO gender is female, the value is 1, otherwise the value is 0
EXPE	CEO experience	b7	Continuous variable	b7
SIZE	Size of firm	l1	Continuous variable	l1/1000
AGE	Age of firm	b6b	Continuous variable	2012 − b6b + 1
MAIN	Proportion of main products	d1a3	Continuous variable	d1a3
COMP	Competition degree	e30	Rank variable	e30
CAPA	Capacity	f1	Continuous variable	f1
AREA	Area	a3a	Classified variable	The value is selected according to the province and city of a3a
INDUS	Industry	a4a	Classified variable	a4a
GROW	Performance level	d2, n3	Continuous variable	2 (d2 − n3)/3(d2 + n3)

Table 2 shows descriptive statistics. The average value of the R&D investment variable *RDINV* is 0.40, indicating that 40% of the 1487 manufacturing firms have invested in R&D activities. The mean value of CEO gender variable GEND is 0.0815, which means that 8.15% of firms' CEOs are female, which is higher than the proportion of female CEOs in fortune global 500 companies in magazine *Fortune* 2017 (6%) [43], indicating that the data structure conforms to the objective reality.

Before the analysis of the relationships among variables, the relationship between every two variables is tested in this paper. Pearson's correlation coefficient of the main variables is shown in Table 3. The correlation coefficient between explanatory variables and control variables is lower than 0.6. The correlation coefficients between financing constraints variable *INFC* and *EXFC* and the R&D investment *RDINV* are respectively −0.10 and −0.34, which are both negative, indicating that variables are in a negative correlation. However, the correlation coefficient only reflects the degree of correlation between variables, rather than the causal relationship between variables. Therefore, regression analysis of explanatory variables should be carried out when controlling other factors, so as to obtain the accurate direction, influence degree and significance level of the relationship between dependent variables and explanatory variables.

Table 2. Descriptive Statistics of Main Variables.

Variable	Observations	Means	St. Dev.	Minimum	Maximum
RDINV	1487	0.40	0.49	0	1
INFC	1487	0.39	0.49	0	1
EXFC	1487	0.55	0.50	0	1
SIZE	1487	0.21	0.88	0.01	16
EXPE	1466	16.76	7.42	1	47
GEND	1484	0.08	0.27	0	1
GROW	1487	0.09	0.16	−0.49	0.67
AGE	1447	13.80	7.41	1	126
COMP	1464	0.84	0.86	0	4
CAPA	1459	86.76	10.59	7	100
MAIN	1482	95.37	8.11	10	100

Table 3. Correlation Coefficients of Main Variables.

	RDINV	INFC	EXFC	SIZE	EXPE	GEND	GROW	AGE	COMP	CAPA	MAIN
RDINV	1										
INFC	−0.10	1									
EXFC	−0.34	0.24	1								
SIZE	0.06	0.03	−0.05	1							
EXPE	0.14	−0.06	−0.14	0.09	1						
GEND	0.02	0.02	−0.05	−0.03	−0.057	1					
GROW	0.05	0.03	−0.02	0.04	0.00	0.07	1				
AGE	0.01	0.06	−0.05	0.13	0.35	−0.02	0.00	1			
COMP	0.07	−0.18	0.01	−0.05	0.06	0.06	0.01	−0.02	1		
CAPA	0.03	−0.03	0.00	0.01	0.04	−0.08	−0.01	0.05	−0.06	1	
MAIN	−0.06	0.03	0.06	−0.04	−0.06	−0.05	−0.06	0.01	0.00	0.04	1

3.2. Model Specification

In statistics, the Probit regression model (Probit model) is a type of regression where the dependent variable can take only two values [44]. As the functional form of Probit model guarantees that the marginal effect of each independent variable on Pr(Y) is conditional on the value of every independent variable in the model, Probit model is widely used in quantitative research [45]. One of the most common applications is to estimate the effect of a particular variable of interest on a binary outcome when potentially confounding variables are controlled [46]. The decision to invest or not in a R&D project is a binary response to the financial constraint. Therefore, in this paper, we firstly use Probit model to test the main impact of financing constraints on R&D investment:

$$Pr\{Y_{ija} = 1 \mid X_{ija}\} = \beta_0 + \beta_1 GEND_{ija} + \beta_2 EXPE_{ija} + \beta_3 INFC_{ija} + \gamma Ctrl_{ija} + \delta_j + \eta_a + \varepsilon_{ija} \quad (1)$$

$$Pr\{Y_{ija} = 1 \mid X_{ija}\} = \alpha_0 + \alpha_1 GEND_{ija} + \alpha_2 EXPE_{ija} + \alpha_3 EXFC_{ija} + \phi Ctrl_{ija} + \delta_j + \eta_a + \varepsilon_{ija} \quad (2)$$

where Y_{ija} indicates whether the firm i conducts R&D investment activities, subscripts i, j and a represent firms, industries and provinces respectively; *GEND* represents CEO gender, *EXPE* represents CEO experience, *INFC* represents internal financing constraint, *EXFC* represents external financing constraint, *Ctrl* represents control variable, and δ_j and η_a represent industry effect and province effect respectively. In Model (1) and Model (2), the coefficients focused in this paper are β_3 and α_3. According to the theoretical hypotheses proposed above, it is predicted that financing constraints have a negative impact on firms' R&D investment, so it is expected the coefficients β_3 and α_3 are both smaller than 0.

In order to test the moderating effect of CEO gender on the relationship between financing constraints and R&D investment, this study then divided the sample into two sub-sample and tested Model (2) through grouped regression [47], Model (3) and Model (4) shows the results. Among them, Model (3) is the male CEO group and Model (4) is the female CEO group. Among the two models, the coefficients focused in this paper are β_2 and α_2. According to the theoretical hypotheses proposed in the theoretical section, it is predicted that financing constraints have a weaker restricting effect on R&D investment for firms with female CEO, thus it is expected the coefficients β_3 and α_3 are both smaller than 0. Then we use seemingly unrelated regression (SUR) test to verify whether β_3 is significantly smaller than α_3.

$$Pr\{Y_{ija} = 1 \mid X_{ija}\} = \beta_0 + \beta_1 EXPE_{ija} + \beta_2 INFC_{ija} + \gamma Ctrl_{ija} + \delta_j + \eta_a + \varepsilon_{ija} \quad (3)$$

$$Pr\{Y_{ija} = 1 \mid X_{ija}\} = \alpha_0 + \alpha_1 EXPE_{ija} + \alpha_2 EXFC_{ija} + \phi Ctrl_{ija} + \delta_j + \eta_a + \varepsilon_{ija} \quad (4)$$

In order to test the non-linear moderating effect of CEO experience on the relationship between financing constraints and R&D investment, this study employs the hierarchical regression [44] to test Models (5) and (6). Wherein, $EXPE \times INFC$ is the first-order interaction term of CEO experience $EXPE$ and internal financing constraint $INFC$; $EXPE \times EXFC$ is the first-order interaction term of CEO experience $EXPE$ and external financing constraint $EXFC$; and $EXPE^2 \times$ INFC and $EXPE^2 \times EXFC$ are the corresponding second-order interaction terms. The coefficients focused in this paper are β_6 and α_6. According to the theoretical model proposed above, we believe that CEO experience has non-linear effects on the relationship between financing constraints and firms' R&D investment, so it is expected the coefficients β_6 and α_6 are both smaller than 0 and are very significant.

$$\begin{aligned} Pr\{Y_{ija} = 1 \mid X_{ija}\} &= \beta_0 + \beta_1 GEND_{ija} + \beta_2 EXPE_{ija} + \beta_3 EXPE^2 + \beta_4 INFC_{ija} \\ &+ +\beta_5 EXPE \times INFC + \beta_6 EXPE^2 \times INFC + \gamma Ctrl_{ija} + \delta_j + \eta_a + \varepsilon_{ija} \end{aligned} \quad (5)$$

$$\begin{aligned} Pr\{Y_{ija} = 1 \mid X_{ija}\} &= \alpha_0 + \alpha_1 GEND_{ija} + \alpha_2 EXPE_{ija} + \alpha_3 EXPE^2 + \alpha_4 EXFC_{ija} \\ &+ +\alpha_5 EXPE \times EXFC + \alpha_6 EXPE^2 \times EXFC + \gamma Ctrl_{ija} + \delta_j + \eta_a \\ &+ \varepsilon_{ija} \end{aligned} \quad (6)$$

4. Results

4.1. Regression Results of the Full Sample

In this paper, regression analysis is carried out through the following steps. Step 1: Probit model is used for regression of control variables; Step 2: internal financing constraint variable *INFC* is added to the model; Step 3: external financing constraint variable *EXFC* is added to the model. The regression results are shown in Table 4. The results of Model 1.2 show that the regression coefficient of internal financing constraint variable *INFC* on firms' R&D investment is −0.3200 (t = −3.99) and it is very significant, indicating that internal financing constraints have a significant negative impact on firms' R&D investment. Therefore, Hypothesis 1a is supported. The results of Model 1.3 show that the regression coefficient of external financing constraint variable *EXFC* on firms' R&D investment is −0.8431 ($p < 0.01$), indicating that external financing constraints have a significant negative impact on firms' R&D investment. This is in line with the Hypothesis 1b. Taken together, the regression results above show that both internal and external financing constraints have a significant negative impact on firms' R&D investment, thus Hypothesis 1 is supported.

Table 4. Results of Basic Regression Analysis.

Model	Model 1.1	Model 1.2	Model 1.3
	RDINV	RDINV	RDINV
GEND	0.0742 (0.55)	0.0989 (0.73)	0.0213 (0.15)
EXPE	0.0318 *** (5.76)	0.0304 *** (5.51)	0.0254 *** (4.50)
INFC		−0.3200 *** (−3.99)	
EXFC			−0.8431 *** (−10.05)
N	1377	1377	1377
chi2	217.246	232.911	320.614
r2_p	0.1159	0.1243	0.1711

Notes: *, ** and *** represent significance levels of 10%, 5% and 1% respectively; T value is shown in brackets in the table; Due to space limitation, regression results of control variables and constant terms are omitted from the table, and similarly below.

4.2. Moderating Effect of CEO Gender and Experience

4.2.1. Moderating Effect of CEO Gender

In order to empirically test the moderating effect of CEO gender, based on the full sample Model 2.1, this study divides the full sample into two groups according to the CEO gender and conducted regression analysis respectively. The test results of grouped regression are shown in Table 5.

Table 5. Results of Overall Regression and Grouped Regression Based on CEO Gender.

Model	Model 2.1 (Full Samples)	Model 2.2 (Male)	Model 2.3 (Female)	Model 2.4 (Full Samples)	Model 2.5 (Male)	Model 2.6 (Female)
	RDINV	RDINV	RDINV	RDINV	RDINV	RDINV
INFC	−0.3158 *** (−3.94)	−0.3093 *** (−3.67)	−0.2554 (−0.80)			
EXFC				−0.8428 *** (−10.05)	−0.8537 *** (−9.74)	−0.8091 ** (−2.13)
N	1378	1261	108	1378	1261	108
chi2	231.448	197.927	30.042	319.634	259.453	36.971
r2_p	0.1234	0.1338	0.1932	0.1705	0.1819	0.2184

Notes: *, ** and *** represent significance levels of 10%, 5% and 1% respectively; T value is shown in brackets in the table.

As shown in Table 5, when the CEO is male (Model 2.2), the regression coefficient of internal financing constraint *INFC* is −0.3093 (t = −3.90) and it is very significant, indicating that when the CEO is male, internal financing constraints have a significant restricting effect on firms' R&D investment. What should be noted is that when the CEO is female (Model 2.3), the regression coefficient of internal financing constraint variable *INFC* is −0.2554 (t = −0.80) and it fails to pass the significance test, indicating that when the CEO is female, internal financing constraints have no significant restricting effect on firms' R&D investment. Therefore, Hypothesis 2a of this study is supported.

Models 2.4–2.6 show that when the CEO is male (Model 2.4), the regression coefficient of external financing constraint variable *EXFC* is −0.8537 (t = −9.74) and it is very significant, indicating that when the CEO is male, external financing constraints have a significant restricting effect on firms' R&D investment. When the CEO is female (Model 2.3), the regression coefficient of external financing

constraint *EXFC* is −0.8091 (t = −2.13). Since the model specification of the two sample groups is the same, the coefficients between the two groups can be directly compared. Although the regression coefficient of female CEO group is higher than that of male CEO group, the conclusion that the regression coefficient of female CEO group is significantly higher than that of male CEO group cannot be directly drawn from the statistical significance. To keep consistent with existing studies, this study used a seemingly unrelated model (SUR) to test the inter-group coefficient differences. Test results show that the Chi2 value of the inter-group regression coefficient differences of external financing constraint variable *EXFC* is 0.75 and the corresponding *p*-value is 0.386, indicating that variable *EXFC* has no significant difference in the regression coefficient of the two groups. Therefore, Hypothesis 2b in this study is not supported.

Based on the results above, it can be found that compared with firms with male CEO, the internal financing constraints of firms with female CEO have no significant restricting effect on firms' R&D investment, but there is no statistically significant difference in the restricting effect of external financing constraints. Therefore, Hypothesis 2 of this study is partially supported.

4.2.2. Moderating Effect of CEO Experience

This study uses the hierarchical regression method to test the moderating effect of CEO experience, and the regression results are shown in Table 6. On the basis of Model 3.1, the interaction term *INFC* × *EXPE* of internal financing constraint variable *INFC* and CEO experience variable is firstly added for regression analysis (Model 3.2). Results of Model 3.2 show that the regression coefficient of the interaction term *INFC* × *EXPE* is 0.0163 (t = 1.57), but it fails to pass the significance test at the 10% level. Besides considering the first-order interaction effect, higher-order interaction effect can also be considered to analyze the non-linear moderating effect of moderating variables. Therefore, on the basis of Model 3.2, this study adds the quadratic term $EXPE^2$ of CEO experience variable *EXPE* and the higher-order interaction term $INFC \times EXPE^2$ of internal financing constraint variable *INFC* to the model (Model 3.3). The regression analysis results of Model 3.3 show that the coefficient of the first-order interaction term *EXPE* × *INFC* is 0.0288 (t = 2.44), the coefficient of the second-order interaction term $EXPE^2 \times INFC$ is −0.0022 (t = −2.13), indicating that the moderating effect curve has open side down, the turning point is within the first quadrant, and CEO experience has non-linear moderating effects on the relationship between internal financing constraints and firms' R&D investment, providing support for our Hypothesis 3a.

The regression results of Models 3.4–3.6 in Table 6 also show that after the quadratic term $EXPE^2$ of CEO experience variable *EXPE* and the higher-order interaction term $INFC \times EXPE^2$ of external financing constraint variable *EXFC* are added to the model, the coefficient of the first-order interaction term *EXPE* × *EXFC* is 0.0209 (t = 1.72), the coefficient of the second-order interaction term $EXPE^2 \times INFC$ is −0.0027 (t = −2.56), indicating that the moderating effect curve has open side down, the turning point is within the first quadrant, and CEO experience has non-linear moderating effects on the relationship between external financing constraints and firms' R&D investment. This is in line with our Hypothesis 3b.

Based on the results above, it can be found that CEO experience has a second-order non-linear moderating effect on the relationship between financing constraints and R&D investment, rather than a simple linear moderating effect. The results of empirical study show that the moderating effect curves of CEO experience on internal and external financing constraints both have open side down and the turning point is within the first quadrant. Therefore, Hypothesis 3 is supported.

Table 6. Results of Hierarchical Regression Based on CEO Experience.

Model	Model 3.1	Model 3.2	Model 3.3	Model 3.4	Model 3.5	Model 3.6
EXPE	RDINV 0.0304 *** (5.51)	RDINV 0.0236 *** (3.42)	RDINV 0.0159 ** (1.96)	RDINV 0.0254 *** (4.50)	RDINV 0.0225 *** (2.90)	RDINV 0.0139 (1.51)
INFC	−0.3200 *** (−3.99)	−0.3230 *** (−4.01)	−0.2042 ** (−2.09)			
EXPE × INFC		0.0163 (1.57)	0.0288 ** (2.33)			
$EXPE^2$ × INFC			−0.0022 ** (−2.05)			
$EXPE^2$			0.0013 ** (2.00)			0.0015 ** (1.97)
EXFC				−0.8431 *** (−10.05)	−0.8456 *** (−10.05)	−0.7036 *** (−7.05)
EXPE × EXFC					0.0055 (0.53)	0.0209 * (1.67)
$EXPE^2$ × EXFC						−0.0027 ** (−2.50)
N chi2 r2_p	1377 204.445 0.1243	1377 205.115 0.1256	1377 206.976 0.1284	1377 271.082 0.1711	1377 270.707 0.1712	1377 269.617 0.1749

Notes: *, ** and *** represent significance levels of 10%, 5% and 1% respectively; T value is shown in brackets in the table.

5. Robustness Test

In order to verify the robustness of the research findings above, this paper retested them from the aspects of instrumental variables and model specification.

Firstly, researches using survey data rarely mention the endogenous nature of firms' financing constraints, which may be a common problem of such survey data. As China has a financial system dominated by relational financing, small and medium-sized firms need a lot of collateral in the financing process. To keep consistent with existing studies, this paper selects the logarithm of firms' machinery and equipment and real estate value as instrumental variables of internal financing constraints and external financing constraints respectively (questionnaire No.: n7a, n7b) [28] and retests the basic Models 1.2–1.3. The regression results are shown in Table 7. It can be seen that both internal and external financing constraints have a significant negative impact on firms' R&D investment and Hypothesis 1 of this study is supported again. It can be seen that after the introduction of instrumental variables, the negative impact of financing constraints on firms' R&D investment is still robust. Therefore, the results of this paper are not affected by the endogeneity problem of financing constraints.

Table 7. Regression Results of Instrumental Variables of Financing Constraints.

Model	Model 6.1	Model 6.2
INFC	RDINV −2.2364 *** (−38.64)	RDINV
EXFC		−2.3596 *** (−28.08)
N	1152	1152
chi2	1745.47	1122.10

Notes: *, ** and *** represent significance levels of 10%, 5% and 1% respectively; T value is shown in brackets in the table.

The Probit model has been used in this study to test the hypothesis of this study. For comparison, the Logit regression model (Logit model) was used in this paper to have regression again of Models 1.2, 1.3, 3.3 and 3.6 respectively. The regression results are shown in Table 8. It can be found that the regression results of all models are consistent with the research hypothesis of this paper, that is, internal financing constraints and external financing constraints have a significant negative impact on firms' R&D investment and CEO experience has a non-linear moderating effect on the relationship between internal and external financing constraints and firms' R&D investment.

Table 8. Robustness Test of Moderating Effect of CEO Experience Based on Logit Regression.

Model	Model 4.1	Model 4.2	Model 4.3	Model 4.4
	RDINV	RDINV	RDINV	RDINV
EXPE	0.0508 *** (5.55)	0.0267 ** (2.02)	0.0428 *** (4.51)	0.0236 (1.55)
$EXPE^2$		0.0021 * (1.89)		0.0025 * (1.88)
INFC	−0.5259 *** (−3.90)	−0.3269 ** (−1.99)		
EXPE × INFC		0.0517 ** (2.56)		
$EXPE^2$ × INFC		−0.0039 ** (−2.27)		
EXFC			−1.3957 *** (−9.92)	−1.1559 *** (−6.89)
EXPE × EXFC				0.0385 * (1.86)
$EXPE^2$ × EXFC				−0.0048 *** (−2.62)
N	1377	1377	1377	1377
chi2	233.035	241.330	321.329	328.948
r2_p	0.1244	0.1288	0.1715	0.1755

Notes: *, ** and *** represent significance levels of 10%, 5% and 1% respectively; T value is shown in brackets in the table.

This study used the Logit model to retest Models 2.2–2.3 and 2.5–2.6. The regression results are shown in Table 9. It can be found by observing Models 5.1–5.2 that when the CEO is male, the regression coefficient of internal financing constraints *INFC* on firms' R&D investment is −0.5107 (t = −3.62), and when the CEO is female, the regression coefficient of financing constraints *INFC* is −0.3998 (t = −0.71), but it fails to pass the significance test. Therefore, Hypothesis 2 of this study was proved again. It can be found by observing Models 5.3–5.4 that when the CEO is male, the regression coefficient of *EXFC* is −1.4120 (t = −9.59), and when the CEO is female, the regression coefficient of financing constraint variable *EXFC* on firms' R&D investment is −1.3363 (t = −2.04). However, the conclusion that the regression coefficient of the female CEO group is significantly higher than that of the male CEO group cannot be directly drawn from the statistical significance. We use seemingly unrelated model (SUR) to test the inter-group coefficient differences. Test results show that the Chi2 value of regression coefficient differences of external financing constraint variable *EXFC* is 0.65 and the corresponding *p*-value is 0.419, indicating that variable *EXFC* has no significant difference in the regression coefficient of the two groups.

Table 9. Robustness Test of Moderating Effect of CEO Gender Based on Logit Regression.

Model	Model 5.1 (Male)	Model 5.2 (Female)	Model 5.3 (Male)	Model 5.4 (Female)
	RDINV	RDINV	RDINV	RDINV
INFC	−0.5107 *** (−3.62)	−0.3998 (−0.71)		
EXFC			−1.4120 *** (−9.59)	−1.3363 ** (−2.04)
N	1261	108	1261	108
chi2	179.847	24.630	234.153	30.701
r2_p	0.1340	0.1930	0.1822	0.2183

Notes: *, ** and *** represent significance levels of 10%, 5% and 1% respectively; T value is shown in brackets in the table.

6. Discussion

6.1. Contrubutions

Empirical findings from this study push forward the literature on influencing factors of firms' R&D investment and sustainable innovation from at least three aspects. First, this study examines the impact of firms' financing constraints on their R&D investment from the perspective of CEO characteristics, and tests the moderating effect of CEO characteristics on the relationship between firms' financing constraints and their R&D investment and makes up the deficiency of existing literature. Based on the existing study on female top management, this study, drawing from upper echelons theory, tests the moderating effect of CEO gender on the relationship between firms' financing constraints and R&D investment. As Hambrick and Mason [15] pointing out in their pioneering study, an organization is a reflection of its top managers, thus organizational outcomes both strategies and effectiveness could be predicted by managerial background characteristics. Inquiry to the upper echelon perspective may offer substantially greater power to predict organizational outcomes than current theories afford. Therefore, based on the upper echelon theory [15,16], this study introduces CEO gender and experience to analyze the mechanism of the impact of financing constraints on firms' R&D investment, which is an important supplement to existing study on the factors affecting R&D investment. By empirically testing the joint effect of financial constraints and CEO characteristics on R&D investment, this study pushes forward current study on innovation management, and provides a multidisciplinary approach for scholars to further inquiry the linkages between top managers, organizational risky behaviors and their competitive environments.

Second, a conclusion forming a contrast with the conclusion in the existing literature on female top management [20], is that the empirical study results show that risk-tolerance ability of female CEOs may not be lower than male CEOs but may even stronger than male CEOs in the Chinese context. Considering that most of the samples of this study are private small- and medium-sized firms, females must make more efforts than males to become CEOs and the risk aversion characteristic may be greatly adjusted due to competitive work environmental and cultural factors. This study is an important supplement to the existing study on female top management and sheds light on the management practice. Specifically, this finding generates critical insights on gender differences by providing a context-based empirical case. Scott and Einar [15], in their newly published research in 2019, examine cultural tightness (including the attitude to gender equality) and its impact on innovation and happiness using data and experiments from China; they found that provinces with tighter cultures have lower rates of substantive/radical innovations yet higher rates of incremental innovations. Their results confirm the significant cultural and context effect on people's decision behavior and risk preference [48]. In line with the context-based theory development trend, our study shows that the stereotype of gender effect may be different under different cultural and social

embeddedness [15,39,49], this opens new possibilities for scholars to develop a better understanding of the boundary conditions of scholarly theories [21,49].

Finally, the further tests on CEO experience in our study show that CEO experience has a non-linear moderating effect on the relationship between financing constraints and R&D investment. The continuously accumulated experiences are helpful for management personnel to make wiser and more clear value judgments, to make better deals with all the uncertainty and ambiguity of business operations, and to make proper judgments on R&D investment projects. The value of management personnel's experience is obvious, which is in line with current knowledge of manager experience [40,41]. However, when the accumulated experience is overloaded, the excessive reserve of experience would solidify the thinking mode and working style of management personnel, they would rely too much on paths, and they would prefer to stick to their main business and familiar fields rather than take big risks. In this sense, overly experienced CEOs are likely to make more conservative R&D investment decisions, which might finally hurt firm performance [42]. This study offers important theoretical enlightenment for a comprehensive and objective understanding of the R&D investment behaviors of firms' top management team [32,42], especially CEOs with different characteristics when they are faced with financing constraints [19], and also provides important policy basis for further optimizing financial policies and stimulating firms' sustainable innovation.

In summary, the findings from this study trigger theoretical conversations among at least three streams of literature, including innovation, corporate finance and corporate governance. Traditional research tends to focus on a specific discipline, while innovation is a complex, dynamic and risky process that requires multi-level factors involvement. These connotations of innovation call for a holistic and multidisciplinary approach to understanding its antecedents, process and impact [2,4]. Current scholarly work already addresses the important role of corporate finance on innovation, especially the capital structure [8,10,22] and financial constraints [12,26,29]. Scholars have also accumulated abundant knowledge of corporate governance and its impact on firm R&D behaviors and sustainability [10,48], especially the impact of incentive and characteristics of top management team [10,15,18]. However, our study shows that corporate finance and corporate governance could interactively influence firm-level R&D behavior. Therefore this study pushes the conversions from two streams of literature towards three or even more streams, such as gender studies [19,37].

6.2. Limitations and Suggestions for Future Research

However, since this study only focuses on the impact of financial constraints on firm R&D investment and the moderating effect of CEO gender and CEO experience, there are three main limitations that should to be addressed by future research so as to develop a comprehensive and holistic view that bridges innovation management, corporate finance and corporate governance.

First, firms that want to conduct R&D projects to maintain sustainable competitiveness not only face the problem of inside capital shortage [8] and external financial constraints, but also need to proactively deal with institutional factors, such as maturity of financial institutions [22,50], public policy related to tax [24,51] and industry/market tournaments [10,32]. In this study, we have controlled the firm size and competition level of the industry to deal with alternative explanation issues, but have not tested their impact directly. Future research could address this gap from two aspects. On the one hand, institutional factors, such as tax policy and changes in the financial system, should be taken into consideration. On the other hand, supply chain, intensity of competition, business cycles, market/industry structure and turbulence [10,52–54] should also be considered as these will significantly affect firm strategies and resource allocations between short-term and long-term R&D projects.

Second, financial constraints and CEO characteristics will not only affect firm R&D behaviors but also firm innovation performance [3,13] as well as overall business performance [27,52]. As the ultimate purpose of R&D investment is to produce innovation output and obtain business value, future research needs to employ a multi-level dataset and empirically examine the joint effect of financial constraints and managerial attributes on firm innovation performance and business performance. Only in this

way can we develop a comprehensive understanding of the "black box" between R&D investment to final profiting from innovation, and the multiple level factors that promote or hinder the complex and dynamic process [2].

Furthermore, due to the limitations of data availability and scope of research, it is a great pity that we could not empirically address more on the potential channels that could explain the moderating effect of CEO characteristics on the relationship between financial constraints and firm R&D investment. For example, the potential endogeneity issue of the moderating effect could be driven by the unobservable CEO characteristics, such as CEO overconfidence [19,55], and manager heterogeneity [10]. Additionally, corporate governance factors, such as monitoring system [50], and corporate finance factors, such as capital structure [56] might also work as important channels and drivers for the managerial response to financial constraints and strategic decisions on firm R&D activities. Different measures of firm size may also lead to dynamics of the results [57]. Therefore, future research should address these possible channels and alternative explanations by employing a multidisciplinary perspective, and empirically examine how corporate governance interact with corporate finance as a way to jointly affect firm innovation behaviors and performance.

6.3. Practical Implications

This study provides several practical implications for innovation management towards the firm's competitive advantage and sustainable growth.

The first practical implication concerns the public policy arrangement towards a sustainable growth-oriented financial system that encourages firm innovation. Innovation has been widely accepted as a key driving force for both firm sustainable competitive advantage and national long-term growth. However, there can be no innovation-driven development without continuous investment in research and development. The main results from this study show that both internal and external financial constraints are the key issues that hinder the firm's motivation and capability to invest in innovation. This denotes that public policy and institutional innovation on financial system is very important to mitigate firms' financial constraints. Especially for emerging economies, such as China, India, East Europe, Brazil and South Africa, improving the efficiency and transparency of a financial market is one of the key issues to release firms' financial constraints, which can further trigger entrepreneurship and long-term innovation investment [21,24,26,28]. The government can use the policy tools, such as tax deduction for R&D investment, innovation grants, and lower loan barriers for small and medium enterprises (SMEs), cultivate venture capital industry, to provide institutional support for the firm to acquire enough financial capital to do research and development.

The second practical implication concerns the corporate governance towards a long-term innovation-driven strategic decision mindset and process. As is shown in this study, top managers, particular CEOs, play an important role for a firm to make strategic R&D decisions under the conditions of financial constraints. Shareholders of public firms need to embrace a long-term mindset when considering the corporate governance structure. In this way, they can give more freedom and incentives for the top management team to invest risky R&D projects which is key to the firm's radical innovation and competitive advantage [10,56]. Managers and funders of startups and SMEs should also make the best of the debt market, equity market and venture capital market to deal with financial constraints [23,28]. Managers should also build high quality R&D investment portfolios of short-term and long-term R&D projects to balance incremental innovation and disruptive innovation. When recruiting top managers, a firm needs to take care of managerial attributes. Instead of being trapped by the gender stereotype or halo of CEO experience [42,49], firms in different social context and development stages should consider diversified strategies of corporate governance. Only in this way can a firm improve the quality of corporate governance to deal with corporate finance challenges and maintain sustainable R&D streams.

7. Conclusions

Employing the dataset from China-Enterprise Survey 2012 of the World Bank, this paper studies the impact of financial constraints on firms' R&D investment and analyzes the moderating effect of CEO characteristics on the relationship between them. The study shows that both internal and external financial constraints faced by firms have a significant negative effect on their R&D investment. Further study results show that when the CEO is female, the internal financing constraints have weaker restricting effects on firms' R&D investment and there is no significant difference in the restricting effect of external financing constraints on firms' R&D investment. Considering characteristics such as high investment and high risk of R&D investment, the results show that risk-tolerance ability of female CEOs may not be lower than male CEOs and that female CEOs may even have stronger risk-tolerance ability than male CEOs. In addition, CEO experience shows a non-linear moderating effect. In the early stage of CEO tenure, the accumulation of CEO experience is helpful for alleviating the restricting effect of financing constraints on firms' R&D investment. However, when the accumulated experience is overloaded, the positive moderating effect of CEO experience begins to decline and even become negative. After conducting the robustness test such as instrumental variables, the conclusions above are still valid. The contributions, limitations, suggestions for future research, and practical implications are discussed.

Author Contributions: Conceptualization, X.Y.; Data curation, B.-l.H.; Formal analysis, B.-l.H.; Funding acquisition, J.C.; Methodology, B.-l.H.; Project administration, J.C.; Supervision, J.C.; Writing—original draft, X.Y. and B.-l.H.; Writing—review & editing, X.Y. and B.-l.H.

Funding: This research was funded by the Major Program of National Fund of Philosophy and Social Science of China (Grant Number:17ZDA082) and the National Natural Science Foundation of China (Grant Number: 71941026).

Conflicts of Interest: The authors declare no conflict of interest.

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