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CFO age and R&D investment of gem-listed companies: The moderating role of female executives

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Abstract: This study focuses on examining the non-linear association between CFO age and enterprise R&D investment while also investigating the moderating role of female executives in effecting such a link between the two in order to promote enterprises' R&D investment and increase female executives' participation in corporate. Taking Chinese GEM-listed companies over 2009-2021 consisting of 5891 firm-year observations as the samples, conduct the empirical analysis. The findings indicate that a significant inverted U-shaped relationship exists between CFO age and R&D intensity. Specifically, the curve relationship initially exhibits a positive effect of CFO age on R&D intensity before the age of 44, and after that, it turns out to be negative. Moreover, and quite critically, female executives have a significant negative moderating effect on the inverted U-shaped relationship mentioned above. The findings were confirmed by rich robustness and endogeneity tests. Additionally, further exploration of the relationship between CEO tenure and R&D intensity reveals a similar inverted U-shaped curve but does not find any moderating effect of female executives. Based on these results, the study provides Chinese GEM-listed enterprises with rich theoretical guidance and practical implications to optimize the allocation and motivation of executive talents, the career planning of CFOs, and the decision-making patterns of female executives.

Keywords: *CFO age, China, Female executives, GEM-listed companies, R&D investment.*

1. Introduction

Technology innovation plays a key role as the source and driving force for the sustainable growth of enterprises in any specific country or region. China, which is in a transitional period, takes it one step further by viewing technological innovation as the strategic support for building a modern economic system. As the leading force in China's national scientific and technological innovation, according to the statistical results of the "China Science and Technology Statistical Yearbook 2020," Chinese enterprises' total Research and Development(R&D) investment reached approximately 1692.2 billion yuan in 2019, accounting for 76.42% of the total R&D investment in China and far exceeding any other entities in technology innovation activities. Hence, how to promote R&D investment by enterprises has become a key issue in achieving China's sustainable development and improving national competitiveness in the long term. And this topic has also attracted rich attention from a large number of scholars, achieving fruitful results. Based on the resource-based view, organizational characteristics, including firm size, R&D experience, and management capability, etc., have been proven to determine the enterprises' ability to invest in R&D activities [1]. Based on New Institutional Economics and Social Capital Theory, environmental characteristics, including governmental policy support, the readiness of the supply chain, industrial maturity, regional innovation atmosphere, etc., have been confirmed to determine the effectiveness of enterprise R&D activities [2, 3]. Based on principal-agent theory, management power theory, and upper echelon theory, it has been found that corporate

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governance characteristics such as equity structure, board structure, debt structure, executive team features, and CEO profiles may determine a company's R&D investment tendency [4, 5]. Scholars treat corporate governance characteristics as the most concerned and dynamic of the three groups of factors determining R&D activities, giving them the heaviest attention. Especially, the research on the impact of executive team structure and CEO profiles on enterprise R&D investment has made great progress, shedding light on the determining mechanisms of enterprise R&D decisions to a good degree [4, 6]. However, though the Chief Financial Officers (CFOs) are playing an increasingly greater strategic role in top executive teams, existing research on how CFOs affect corporate R&D investment has just emerged.

The CFO is considered to have the most important role in a company's top management team, apart from the CEO. Existing literature suggests that CFOs bear a dual fiduciary responsibility in the operation of enterprises. On the one hand, they play the role of gatekeepers of the quality of financial accounting information in companies [7] by supervising the entire process of financial reporting and overseeing the implementation of internal controls [8]; On the other hand, they hold the financial information and cash resources of a company, exerting the most direct impact on financial strategic decisions such as investment and financing [9]. The Upper Echelons Theory suggests that the executive team's background characteristics, such as psychological cognition, emotion, and social identity, are key factors that determine the strategic orientation and decision-making behavior of enterprises [10]. Drawing on the Upper Echelons Theory, scholars have begun to empirically investigate the different impacts of CFO background characteristics on the effectiveness of corporate governance, concluding that CFO background characteristics would exert substantial impacts on amounts of critical organizational variables, such as the level of accounting conservatism [11], the quality of internal controls [12], the quality of financial information disclosure [13], etc. A few scholars have proposed that we should address the crucial role of CFOs in guiding the CEO and the boards of director in making corporate investment decisions, particularly in technology innovation [14]. In response to this viewpoint, studies have begun to investigate how CFOs' profiles, including CFOs' accounting certificates [15], CFOs' gender, CFOs' educational degrees [14], and whether they are the founders of a company [16], affect their R&D investment preferences. And these studies have confirmed that the above-mentioned characteristics of CFOs have a significant impact on R&D investment.

However, a small number of studies have explored and confirmed the impact of CFO age on firm risk-taking [17], cost management systems [18], financial information disclosure [19], and the adoption of ERP systems [20]. There is still a lack of specialized and in-depth research on the impact of CFO age on corporate R&D investment, especially in China. Age is one of the most natural physiological characteristics of an individual, but there is relatively little formal research on it in the Chinese academic community in the management and economics fields. Many existing studies in China only treat CFO age as a control variable and subjectively believe that the age effect is simply linear, that is, the older the CFO, the more conservative the CFO is. In fact, the age of CFOs is closely related to their psychological capital, cognitive abilities, career considerations, signaling mechanisms, and social capital. At different age stages, CFOs have distinctive decision-making motivations and risk preferences [21], which would exert a complex and changeful impact on corporate R&D investment decisions. Therefore, this article takes CFO age as a focal factor of specialized concern and attempts to systematically reveal how CFOs' innovation preferences related to age characteristics affect corporate R&D investment, both theoretically and empirically.

As the era progresses, women are accelerating their integration into the workplace and upper decision-making levels. Research has demonstrated significant differences between male and female executives in corporate decision-making behavior, arguing that women exhibit strong heterogeneity in psychological cognition, personality, behavior, roles, and other aspects compared to males. The most consensus conclusion is that female executives are more ethical [22] and risk-averse [23] in decision-

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making, which also leads to the various strategies and investment decisions of enterprises being affected to varying degrees by the two characteristics of female executives. Correspondingly, many studies have explored the impact of female executives on innovation investment decisions from the perspective of their direct or moderating effects. In terms of the direct effects, there are contradictory empirical findings. For example, He and Jiang [24] found that when there are more than two female representatives in the upper echelons, they will play a weak positive role in enhancing green innovation, while Xie and Hou [25] found that the representation of female executives has a weak restraining effect on the R&D innovation level of enterprises.

In comparison, the moderating perspective has attracted more scholars' attention and made more consensus findings. For example, Yin, et al. [26] found that the presence of female CEOs can effectively alleviate the negative impact of internal financial constraints on R&D investment; Liu, et al. [27] pointed out that there is a significant "U-shaped" relationship between the proportion of female executives and corporate governance efficiency, and that when the proportion of female executives is higher than 27.7%, female executives would produce a significant positive promoting effect on corporate governance efficiency and thus an optimizing effect on R&D investment. In summary, there is considerable disagreement regarding the direct role of female executives in affecting R&D investment, while scholars have reached a basic consensus on the view that female executives can leverage their heterogeneous human capital to indirectly determine corporate R&D investment by changing the other (male) decision-makers' attitudes towards innovation activities. This study argues that the overall participation of female executives is still relatively low in China, and compared to male executives, who occupy the dominant roles, female executives usually take more affiliated or collaborative positions. Therefore, the probability of female executives having a significant and direct influence on strategic decision-making is relatively low, and they primarily exert their indirect influence by influencing the decision-making preferences of male executives. Accordingly, this paper attempts to examine the moderating effect of female executives on the link between CFO age and R&D investment.

Based on the above discussion, in order to fully examine the relationship among CFO age, female executives, and R&D investment, the paper selects Chinese GEM-listed companies from 2009 to 2021, which are of high-tech characteristics and consistent with the trend of sustainable social development, as the research samples to address two main questions: (1) Do CFOs at different age stages exhibit distinct innovation preferences that ultimately influence the enterprises' R&D investment decision-making outcomes? (2) Can female executives change the CFO's innovation preferences and further indirectly affect R&D investment intensity? There are three possible theoretical contributions shown as follows: Firstly, this study aims to identify and verify for the first time the non-linear relationship between CFO age and R&D investment, given the critical roles CFOs play in corporate financial decision-making. By doing so, this research not only expands the research boundary of executive background characteristics' effects on R&D activities but also improves companies' understanding of factors related to R&D investment in practice; Second, pioneering efforts would be made to incorporate female executives, CFO profiles, and R&D investment into a unified research framework, revealing for the first time the contingent nature of the link between CFO age and R&D investment decisions from the perspective of female executives' moderating effect, showing the unique value of female executives' human capital in the development of Growth Enterprises Market(GEM) listed companies. To be specific, the paper views female executives as being firm-serving and risk-averse, and focuses on capturing the moderating mechanism of female executives in determining corporate R&D intensity indirectly by optimizing CFOs' R&D innovation preferences during their interactions with CFOs; Third, a thorough examination of the influence mechanism of CFO tenure on R&D investment is expected to provide new empirical evidence for the research on "tenure-related theories."

The rest of this study is organized as follows: Section 2 reviews related literature and proposes research hypotheses, while Part 3 discusses data and research design. Section 4 presents the results,

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while the remainder of 5 provides an extended exploration of CFO tenure. And finally, Section 6 concludes this study.

2. Literature Review and Hypotheses

2.1. CFO Age and R&D Investment

This study believes that CFOs in different age stages adjust the level of R&D investment based on their preferences; specifically, there should be an inverted U-shaped nonlinear relationship between CFO age and R&D investment. From the perspective of the Life Cycle Theory, there are systematic differences in the psychological and behavioral characteristics of individuals at their different stages.

At different age stages, managers face different constraints and embrace diverse decision-making goals. Hence, the age effect on R&D investment should not be linear and unchangeable. For instance, previous literature has shown that CEO age has a significant inverted U-shaped impact on firm risk-taking [28], and there is an inverted U-shaped relationship between career concern and investment horizon [29]. It can be known that the decision-making motives of top executives vary at different age stages, indicating that the relationship between CFO age and R&D investment may not be a simple linear one, but rather a more complex nonlinear linkage. According to the relevant literature, there are four primary psychological mechanisms by which CFO age affects R&D investment decisions:

Career concerns are the primary psychological mechanism. Due to career concerns, younger CFOs who have not yet established a reliable reputation in the professional manager market would value the success rate of investment decisions more, to avoid the punishment of failure due to bearing higher investment risks [30]. The excessive pursuit of success in investment decisions can distort CFOs' behavior, encouraging younger CFOs to naturally avoid high-risk investment decisions and make more conservative investment decisions. Furthermore, when excessive risk-taking results in business failure, CFOs may confront the possibility of job loss or forced resignation, prompting them to adopt a more prudent and conservative approach to decision-making [28]. Therefore, due to the uncertain gains of R&D investment, younger CFOs are likely to exhibit a more conservative preference when it comes to R&D investment in order to safeguard their future career development.

The overconfidence theory, which links the second psychological mechanism, suggests that managerial overconfidence tends to rise with age. Older CFOs, having occupied critical positions for an extended period, possess extensive work experience and exposure. This factor allows them to easily garner the respect and support of their subordinates [31]. Simultaneously, their accumulated experience can also contribute to an enhanced sense of overconfidence, leading to an increased willingness to take risks [32]. As R&D activities are typically associated with both substantial benefits and high risks, older CFOs, who are driven by their overconfidence in corporate decision-making, are more inclined to amplify the R&D investment to obtain sustainable business returns.

The third psychological mechanism is related to signal theory. Drawing on the principal-agent theory, there is information asymmetry between shareholders and CFOs, that is, shareholders are unable to obtain sufficient information about the CFOs' management capabilities and levels of effort. In this case, younger CFOs would choose high-risk investment projects as a positive signal to express their personal abilities and convey to shareholders that they have strong management abilities. At the same time, younger CFOs are more susceptible to the implicit incentives from shareholders' evaluations of their management abilities and thus tend to bear more risks [33]. However, for middle-aged or even much older CFOs, years of work experience have helped them earn a well-established reputation, and releasing positive signals of their capabilities and efforts to shareholders is no longer their primary concern [28]. As a result, younger CFOs are more inclined to perceive R&D investment as an opportunity to showcase their abilities, thus increasing the likelihood of R&D investment.

The fourth psychological mechanism is associated with the resource dependence theory. External resources and information play a crucial role in shaping CFOs' confidence in R&D investments. As CFOs age, their social network expands, and they gain access to a broader range of social resources.

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This enables them to develop a robust network for sharing risks and obtaining valuable innovation advice and external resources for shareholders [6]. In this case, as CFOs accumulate more resources, their ability to mitigate risks strengthens, leading to an increased tolerance for risk and confidence in R&D investments. Therefore, the resources available to older CFOs contribute to fostering a more positive attitude towards risk-taking, stimulating creativity, and supporting innovation. This, in turn, makes it more feasible for companies to promote R&D investments as a means of ensuring their long-term sustainability.

In reality, the age stages of CFOs closely influence which of the four psychological mechanisms is more dominant [14]. In particular, career concerns and signal theory would play a dominant role in the young and middle-aged stages of CFOs. The younger the CFOs, the greater the benefits that the professional manager market's evaluation of their abilities brings. In this case, the career concerns of younger CFOs are stronger. Simultaneously, younger CFOs have a longer expected working horizon, and they can enjoy a more sustainable high salary. Therefore, out of career concerns, younger CFOs tend to prioritize the success rate of their investment projects and refuse decision-making behaviors that may lead to failure with a higher possibility, such as high-risk R&D activities. As the reputation of CFOs gradually establishes, the career concern effect gets weakened, and the signal theory gradually gains the upper hand. CFOs' risk preferences would change, and their age may exert a positive impact on corporate R&D investments.

In middle age, the professional manager market equilibrium will identify the true talent of CFOs, and the information asymmetry related to the talent of CFOs will almost disappear. Moreover, the advantages of the social network and resources accumulated and learned through years of work would lead middle-aged CFOs to have a more positive attitude toward risk-taking and R&D activities. In the meantime, middle-aged CFOs have established deep roots in their industry over many years, gaining reliable advantages that enhance the scientific nature of their investment decisions. Hence, they can improve the investment efficiency of their companies and are more likely to make the best financial decisions [34]. Furthermore, their rich social resources enable them to run high-risk investment projects, resulting in high firm-level R&D investment intensity.

However, when CFOs approach retirement age (probably after the age of 55), their cognitive abilities decline significantly. Compared to younger CFOs preference for a "busy life" of younger CFOs, elderly CFOs tend to achieve a "peaceful life" by inhibiting corporate innovation and avoiding complex and risky decisions [14]. For example, Zhang, et al. [35] found that the probability of financial restatement in companies with elderly CFOs is lower than that in companies with younger CFOs. Moreover, elderly CFOs with richer experience and knowledge can better exert pressure on the board of directors to make lower-risk decisions. Hence, elderly CFOs' decision-making behavior tends to be more conservative with a high degree of risk aversion, and their ability to affect the board of directors is stronger. That is, it is expected that elderly CFOs will decrease enterprise R&D investment.

Based on the above analysis, this paper proposes the following hypothesis:

H1: There is an inverted U-shaped relationship between CFO age and enterprise R&D investment.

2.2 The moderating role of female executives

According to the core viewpoint of Upper Echelon Theory, executives' behavior is a comprehensive reflection of their psychological cognition and values, and logically, executives' values can determine corporate strategic decisions to a large degree. Since there are systematic differences in psychological cognition and values of female and male executives in many aspects, the two groups may exhibit vastly different decision-making styles that are ultimately reflected in the strategic decision-making mechanisms of the enterprises. According to Song, et al. [36] in the process of formulating and implementing corporate strategies, the preferences of key decision-makers are influenced by other members of the top executive team. As one of the key decision-makers in the company's R&D investment, CFOs are inevitably influenced by female executives' cognitive patterns and value

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orientations in their interactions with female executives, and the psychological preferences of female executives would be ultimately reflected in the decision-making mechanism of enterprise R&D investment. Therefore, it is of significance for this study to explore the moderating effect of female executives on the relationship between CFO age and R&D investment from the perspective of gender differences in decision-making. The relevant literature on female executives and gender diversity illustrates the potential psychological pathways associated with gender differences in decision-making processes.

Firstly, the literature in the fields of psychology, physiology, and sociology confirms that females generally exhibit higher risk-aversion traits compared to men, which is attributed to varying levels of monoamine oxidase and societal expectations on gender roles [23]. As a result, women tend to approach multiple decision-making situations with greater caution and stability than men. Especially when making significant decisions, women are usually less overconfident than men [37]. Females' executives' lower overconfidence and greater risk aversion provide them with a seemingly conservative attitude when making strategic and financial decisions, as observed. Amounts of studies in the field of corporate governance have also reported empirical evidence that female executives attach importance to risk avoidance in financial decision-making [38] and a few studies have even treated hiring female executives as an effective measure to reduce enterprise risk, including the operational risk , the financial risk, and even the stock price collapse risk [39]. However, in recent years, with the gradual rise of theoretical research on female executives' characteristics and consequences, a few studies have found that although female executives have the trait of risk aversion, they are not necessarily conservative and rigid, blindly showing a tendency to avoid risks. Instead, it has been proven that they are more willing to adhere to the behavioral principles of prudence and strict risk control even in favorable decision-making situations, adhering to a steady and prudent decision-making style, rather than an over-conservative one [40]. Moreover, the high-risk control ability closely related to the risk aversion of female executives can also promote higher innovation output in enterprises and further transform innovation output into innovation performance [41].

Secondly, most studies on business ethics believe that women hold stronger moral standards or ethical baselines than men. Female executives have a more responsible work attitude and ethical standards, as well as stronger firm serving motivations compared to male executives. They can take care of the interests of a wider range of stakeholders since, in addition to a higher ethical baseline, they are able to engage in wiser and more comprehensive discussions in decision-making processes due to their better communication skills. Moreover, there query spirit makes them better at differentiated and independent thinking. Such attributes of female executives help to better supervise other male executives and further enhance the company's reputation and image. For example, according to Hu and Yang [42] companies with a higher proportion of female executives show a more positive performance in corporate environmental investment, which would significantly improve their social responsibility performance and thus their reputation.

This paper argues that female executives negatively moderate the inverted U-shaped relationship between CFO age and enterprise R&D investment. Specifically, on the one hand, in order to prove their abilities to shareholders and the other members of top executive teams, younger CFOs are more willing to make risky decisions with the accumulation of their work experience, risk control ability, and social capital, thereby continuously increasing the intensity of R&D investment. On the other hand, when age grows gradually at the first stage, compared to elderly CFOs in the next stage, younger CFOS are more willing to adopt innovative approaches and demonstrate their outstanding abilities by bearing greater risks, e.g., adopting more aggressive R&D investment decisions. According to this logic, with the continuous accumulation of the younger CFOs' experience and capabilities due to their age growth, they would make bolder and more risky decisions [43, 44] thus producing higher R&D intensity. As important members of the top executive teams, female executives exhibit decision-making preferences that are completely different from those of male executives. Facing the ever-increasing growth of R&D

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investment with the age growth of younger CFOs, female executives, who hold a firm-serving motivation and relatively prudent decision-making style, will consider the two following aspects: On the one hand, female executives would worry that excessive R&D investment may lead to a "catastrophic disaster" for the company due to uncontrollable innovation risks, harming the interests of stakeholders; On the other hand, it can also raise doubts among shareholders about whether female executives have fulfilled their due responsibilities in the company, which precisely hits the very traits of female executives in valuing fiduciary responsibilities and ethical bottom lines. The considerations of the two aspects would encourage female executives to map their concerns into the decision function of younger CFOs in their interactions, thereby slowing the pace of younger CFOs in excessively increasing R&D investment intensity.

By contrast, for elderly CFOs in the decline stage of the inverse U-shaped curve, it is another story. Because their cognitive abilities and energy levels decrease as they age, they are unwilling to break conventions, relying more on historical experience and following industry standards to make decisions. Hence, their decision-making behavior becomes more conservative; On the other hand, compared to younger CFOs, elderly CFOs enjoy much higher power, which makes them exert greater pressure on the board of directors to make lower-risk decisions reflecting elderly CFOs' preferences. This logic suggests that as they age, the motivation of elderly CFOs to invest in R&D activities diminishes. It has been argued that female executives will actively promote strategic changes in the company, when excessive conservatism in strategic decisions exists or the possibility of continual weak growth appears [45]. Hence, facing the dilemma of elderly CFOs' continuous reduction in R&D investment, female executives, considering that insufficient R&D innovation hinders the long-term development of enterprises, would play an effective supervisory role. To be specific, female executives would attempt to boost elderly CFOs' positive attitudes towards R&D investment, and simultaneously weaken elderly CFOs' intention of reducing R&D investment. In this case, female executives still play a negative moderating role in affecting the relationship between CFO age and R&D investment in the decline stage of the inverse U-shaped curve.

Based on the above analysis, this paper proposes the following hypothesis:

H_2: Female executives negatively moderate the inverted U-shaped relationship between CFO age and R&D investment.

3. Methodology

3.1. Sample and Data

The majority of companies listed on the GEM in China are involved in high-tech businesses that have the potential for sustainable growth. Considering that their innovation motivation and willingness are much stronger than those of other types of enterprises, the characteristics of Chinese non-financial GEM-listed companies are more in line with the research topic of this paper. To ensure the completeness and validity of the data, the paper selects the data of non-financial Chinese GEM-listed companies from 2009 to 2021 as the initial sample frame, and excludes the following samples:

(1) The samples of companies marked with ST or PT in each given sampling year; (2) The samples of companies that experience significant strategic reorganization or asset restructuring in each given sampling year; (3) The samples of companies with extreme or unexplainable fluctuations in business operations in each given sampling year (e.g., companies with a ROA less than -100%, and companies with an asset-liability ratio higher than 99%); (4) The samples of companies with missing or unreachable research data in each given sampling year; (5) The samples of companies with CFO change in each given sampling year. Ultimately, we obtained a total of 5891 valid observations from 732 sample companies.

We executed the tail reduction processing of 1% and 99% quantiles at both ends of all continuous variables, using the Winsorize rule, to reduce the impact of outlier data on the research findings during the data processing phase. The data on female executives' characteristics was manually collected from

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the annual reports published by the GEM-listed companies, and all the other data required for the study were sourced from the CSMAR (China Stock Market and Accounting Research) database. The statistical analysis software is STATA16.0.

3.2. Models and Variables

Considering the specialized relationships among variables in this study, it is necessary to verify that "CFO age exerts an inverted U-shaped effect on R&D intensity, and female executives exhibit a negative moderating effect on such a curve relationship." Referring to the moderating regression analysis method proposed by Aiken, et al. [46] three OLS regression models would be executed to test the hypotheses, respectively: the linear effect model designed as Model (1), the nonlinear effect model designed as Model (2), and the moderating effect model designed as Model (3). We would use the adjusted R2 to assess the models' effectiveness and significance.

We build Model (1) to investigate the existence of a direct linear effect of CEO age on R&D investment. Under the precondition of Model (1) successfully fitting the sample data, if β1 is statistically significant, the direct linear effect does exist. Otherwise, a curve relationship between the two would fit the sample data better.

$$RD_{i,t}(RD1/RD2/RD3) = \beta_0 + \beta_1 CFO\_Age_{i,t} + \sum Control_{i,t} + \sum Industry + \sum Year + \varepsilon_{i,t} \quad (1)$$

To test H1, Model (2) is constructed to examine the impact of CFO age on corporate R&D investment. Under the precondition of Model (2) successfully fitting the sample data, if β1 is statistically significant and positive, and simultaneously β2 is statistically significant and negative, H1 holds.

$$RD_{i,t}(RD1/RD2/RD3) = \beta_0 + \beta_1 CFO\_Age_{i,t} + \beta_2 CFO\_Age_{i,t}^2 + \sum Control_{i,t} + \sum Industry + \sum Year + \varepsilon_{i,t} \quad (2)$$

To test H2, Model (3) is constructed to examine the moderating effect of female executives on the curve relationship between CFO age and corporate R&D investment. Under the precondition of Model (3) successfully fitting the sample data, if β4 is statistically significant and negative, and simultaneously β5 is statistically significant and positive, H2 holds.

$$\begin{aligned} RD_{i,t}(RD1/RD2/RD3) = {} & \beta_0 + \beta_1 CFO\_Age + \beta_2 CFO\_Age_{i,t}^2 + \beta_3 PF_{it} \\ & + \beta_4 CFO\_Age \times PF_{i,t} + \beta_5 CFO\_Age^2 \times PF_{i,t} \\ & + \sum \text{Control}_{i,t} + \sum \text{Industry} + \sum Year + \varepsilon_{i,t} \end{aligned} \quad (3)$$

In Model (1), Model (2) and Model (3), the specific variables are defined as follows:

First, the explained variable is R&D intensity (RD1/RD2). Referring to the methods of existing literature on enterprise innovation [47, 48] the ratio of R&D expenses to total assets (RD1), and the ratio of R&D expenses to total sales (RD2) and the natural logarithm of R&D expenditures (RD3) are all used to measure R&D intensity. RD1 is used as the main measurement methods for empirical analysis, while RD2 and RD3 are used as the alternative measurement method for robustness tests.

Second, the explanatory variable: CFO age (CFO_Age). Referring to the practices widely used in existing literature [17, 20] the physiological age of CFOs (CFO_Age) is adopted as the measure of CFO age, and the natural logarithm of CFO_Age (LNCFO_Age) is used as an alternative measure for further robustness tests. Considering the fact that the titles of CFOs vary among Chinese companies, based on the actual disclosure status of listed companies, the definition of CFOs follows Jiang's approach [49].

Third, the moderating variable: the participation degree of female executives (PF). Three ways are adopted to measure female. (1) PF is the proportion of female executives in the top leadership team [50]; (2) NF is the number of female executives; (3) BLAU is calculated according to the formula expressed as "1-PF2- (1-PF2)" by referring to the commonly used approach in existing literature [51].

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We use PF for empirical analysis as the primary measurement method, while we adopt the latter two for conducting robustness tests as alternative methods. In this paper, female executives are defined in a broader sense by including all female top leaders in a company, including female CEOs and presidents, female supervisors, female directors, female board secretaries, and female top managers.

Finally, referring to existing research [52, 53] the following eight variables have been selected as control variables: CFO directorship, CEO duality, firm size, return on assets, leverage ratio, the ratio of independent directors, equity concentration and executive compensation level. The design of control variables is detailed in Table 1. Furthermore, this study considers the virtual variables of industry and year as control variables to regulate the impact of industry-specific factors and temporal variations on R&D investment.

Table 1.
Variables definitions and measures.

Variables categories	Variables names	Variables codes	Variables definitions
Explained variable	R&D intensity	RD1	R&D expenses/Total assets
		RD2	R&D expenses/Total sales
		RD3	Ln(R&D expenses)
Explanatory variable	CFO age	CFO_age	CFO chronological age
		LNCFO_age	Ln(CFO_age)
Moderating variable	Participation degree of female executives	PF	The proportion of female executives in the top leadership team
		NF	The number of female executives in the top leadership team
		BLAU	$1-PF^2-(1-PF)^2$
Control variables	Firm size	Size	The natural logarithm of total assets at the end of a given sample year
	CEO duality	Dual	If the chairman also serves as the ceo, dual is taken as 1; otherwise, dual is taken as 0.
	CFO directorship	CFO_direct	If the CFO also serves as a director, CFO_direct is coded as 1; Otherwise, CFO_direct is coded as 0.
	Return on assets	Roa	Net profit/Total assets
	Leverage ratio	Lev	Total liabilities/Total assets
	The ratio of independent directors	Ind_ratio	The number of independent directors/Board size
	Equity concentration	Top_share	The number of shares held by the largest shareholder/Total share capital
	Executive compensation level	Salary	The natural logarithm of total cash compensation of top three executives
	Capital intensity	Cap_intensity	The ratio of total assets to sales

3.3. Descriptive Statistics and Correlation Analysis

Table 2 displays the descriptive statistics and correlation analysis of the research variables. Regarding the descriptive statistics, the average R&D intensity of Chinese GEM-listed companies is

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about 3.1%, the average age of the CFOs in Chinese GEM-listed companies is 44.6 years old, and the average proportion of female executives of Chinese GEM-listed companies is 21.7%. Moreover, the descriptive statistical results of other variables are within a reasonable range, preliminarily indicating the reliability of the sample data.

The correlation results show that RD1 has varying but significant correlations with most control variables, and most correlations are basically consistent with the expectations of existing literature focusing on R&D investment, indicating the rationality of the control variables' selection in this paper. The correlations between the independent variable (CFO_Age) and the control variables are all less than 0.5, suggesting the potential multicollinearity problem is acceptable. Regarding the relationship between RD1 and CFO_Age, the Pearson correlation coefficient shows that there is no significant linear relationship, suggesting that there may indeed be a curvilinear relationship between the two.

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Table 2.
Research variables' descriptive statistics and Pearson correlation coefficients.

Variables	Mean	Std.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1. RD1	3.085	2.291	1											
2. CFO_age	44.620	6.464	-0.002	1										
3. PF	0.217	0.118	0.024*	-0.042***	1									
4. CFO_direct	0.320	0.468	-0.016	0.073***	-0.015	1								
5. Cap_intensity	2.586	1.306	-0.245***	-0.019	0.009	-0.025*	1							
6. Dual	0.310	0.464	-0.023*	-0.065***	0.011	0.088***	0.031**	1						
7. Size	21.323	0.874	-0.124***	0.052***	0.015	-0.058***	0.080***	-0.211***	1					
8. Roa	0.054	0.106	0.089***	-0.026**	-.043***	.086***	-0.227***	0.110***	-0.109***	1				
9. Lev	0.315	0.179	-0.099***	0.040***	0.027**	-0.039***	-0.168***	-0.135***	0.433***	-0.258***	1			
10. Top_share	29.877	12.501	-0.100***	-0.058***	0.011	0.024*	-0.071***	0.183***	-0.202***	0.200***	-0.094***	1		
11. Ind_ratio	0.382	0.054	.063***	-0.007	0.107***	-0.118***	0.029**	0.032**	-0.027**	-0.043***	0.024*	0.052***	1	
12. Salary	14.300	0.630	0.210***	0.048***	0.070***	-0.026**	-0.122***	-0.174***	0.483***	0.004	0.176***	-0.198***	0.004	1

Note: *, ** and *** represent the significance level of 10%, 5%, and 1%, respectively; N=5891.

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4. Empirical Results

4.1. Benchmark Regression

Table 3 showcases the benchmark regression findings.In column I, the regression coefficient of CFO_age is -0.002, which is insignificant. In column II, the regression coefficient of CFO_age is 0.145, which is significantly positive at the 1% level, and the regression coefficient of CFO_age^2 is -0.002, which is significantly positive at the 1% level,indicating that the inverted U-shaped curve relationship between CFO age and R&D investment is valid. We can conclude an inverted U-shaped relationship between CFO age and R&D investment by combining the results of Column I and II of Table 3. Therefore, H1 is validated.

In column III,CFO age and the ratio of female executives (PF × CFO_Age) are significantly negative (β =-0.889, $p<0.05$), while the regression coefficient of the interaction item of CFO age's square term and the ratio of female executives (PF × CFO_Age^2) is significantly positive (β = 0.011, $p<0.01$). Hence, the empirical regression results support H2.This suggests that female executives have a moderating effect on the curve relationship between CFO age and R&D investment.

Table 3.
Benchmark regression results.

Variables		RD1		
		Column I	Column II	Column III
		Model(1)	Model(2)	Model(3)
Linear effect	CFO_age	-0.002 (-0.630)	0.145*** (3.459)	0.326*** (3.638)
	PF	-0.199 (-0.907)	-0.177 (-0.808)	18.124** (2.198)
Curve effect	CFO_age^2		-0.002*** (-3.534)	-0.004*** (-3.842)
Moderating effect	CFO_age×PF			-0.889** (-2.416)
	CFO_age^2×PF			0.011*** (2.595)
	CFO_direct	-0.117** (-2.134)	-0.112** (-2.052)	-0.119** (-2.174)
	Cap_intensity	-0.377*** (-17.315)	-0.378*** (-17.410)	-0.377*** (-17.352)
	Dual	0.161*** (2.569)	0.152** (2.434)	0.150** (2.400)
Control variables	Size	-0.532*** (-13.896)	-0.532*** (-13.897)	-0.535*** (-13.987)
	Roa	0.748*** (2.767)	0.715*** (2.648)	0.732*** (2.713)
	Lev	-1.164*** (-6.698)	-1.195*** (-6.872)	-1.186*** (-6.823)
	Top_share	-0.013*** (-6.104)	-0.013*** (-5.807)	-0.012*** (-5.744)
	Ind_ratio	1.426*** (2.985)	1.466*** (3.073)	1.495*** (3.135)

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Variables		RD1		
		Column I	Column II	Column III
		Model(1)	Model(2)	Model(3)
	Salary	0.872*** (17.267)	0.870*** (17.259)	0.874*** (17.342)
Year/Industry		Yes	Yes	Yes
Constants		3.081*** (3.174)	-0.249 (-.184)	-3.997* (-1.773)
N		5891	5891	5891
F		73.408***	71.856***	68.436***
Adj- R^2		0.301	0.302	0.304

Note: *, * *, and * * * represent the significance levels of 10%, 5%, and 1%, respectively; The Robust-corrected value of t is shown in parentheses.

4.2. Robustness Test

(1) The robustness test confirms the existence of the inverted U-shaped

First, to determine the existence of an inverted U-shaped relationship, this paper would use the three-step approach proposed by Haans, et al. [54]: ①The regression coefficient of CFO_Age2 is significantly negative; ②The values of the slope at both ends within the range of CFO_age are respectively positive and negative (CFO_AgeLow = 31; CFO_AgeHigh = 63); ③The CFO age corresponding to the extremum value (i.e., at the turning point) of the inverted U-shaped curve is about 44.3 years old, which is between the maximum value (63 years old) and the minimum value (31 years old) of CFO age. The above three steps all meet the empirical analysis requirements of the standard inverted U-shaped relationship. Table 4 displays the results. Figure 1 illustrates a figure of inverted U-shaped curve, allowing for a visual observation of its shape and extremum. Both the results in Table 4 and Figure 1 show that the inverted U-shaped curve relationship between CFO age and R&D investment does exist with robustness.

Table 4.
The robustness test results of the inverted U-shaped curve relationship between CFO age and R&D investment.

Test steps and contents			RD1		
			Main effect	High PF	Low PF
①Step one	CFO_age		0.145***	0.001	0.167***
	CFO_age^2		-0.002***	-0.001	-0.002***
②Step two	Slope at CFO_age_{Low}		0.045	----	0.055
	Slope at CFO_age_{High}		-0.043	----	-0.068
③Step three	Extremum value		45.250	----	43.947
	Fieller test (95% confidence interval)	Low	37.501	----	34.988
		High	47.787	----	45.870

Note: * * * represent the significance levels of 10%, respectively; The Robust-corrected value of t is shown in parentheses.

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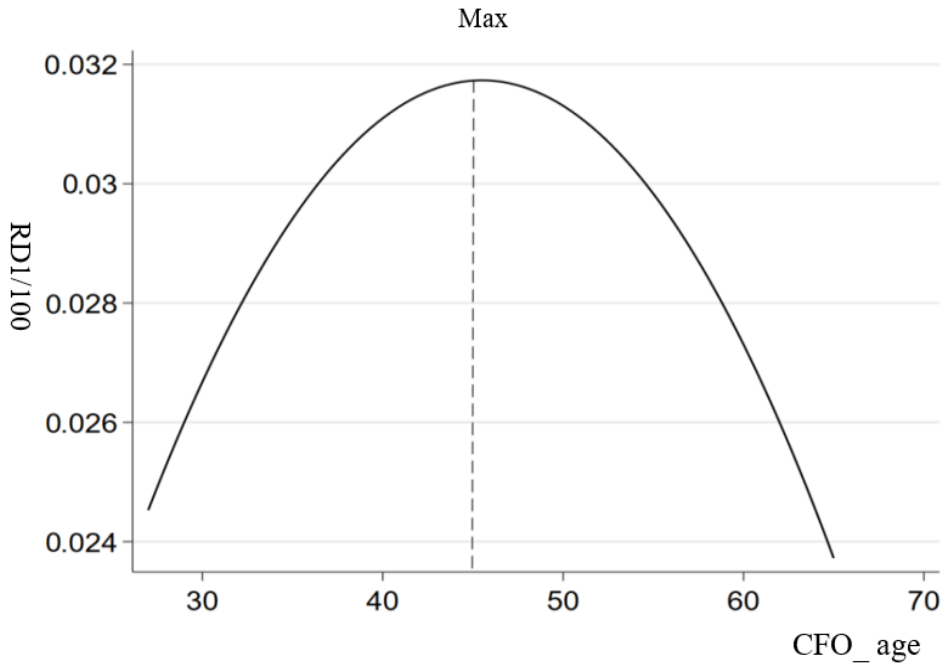

Figure 1.
The inverted U-shaped curve relationship between CFO age and R&D investment.

Second, to change the measure of R&D intensity by replacing RD1 in Model (1)-(3) with RD2. Column I of Table 5 reports the robustness regression results, which show the whole sample adopting RD2. The regression coefficient of CFO_age is significantly positive (β= 0.380, p<0.01), and the regression coefficient of the square term of CFO_age is significantly negative (β= -0.004, p<0.01), suggesting H1 cannot be rejected. Hence, the empirical results would not change due to the measure choice of R&D intensity.

Third, considering the possibility of the existence of higher-order power function curves, this study adopts the suggestion of Haans, et al. [54] and attempts to exclude the possibility of a S-shaped curve by adding a cubic term. The regression coefficient of CFO age's cubic term and R&D intensity is statistically insignificant (β=-0.000, p>0.1), suggesting that H1 cannot be rejected. The robustness test results are consistent with the benchmark regression.

Fourth, the whole sample has been split into the sub-sample with higher CFO age (S_Sample_HAge) and sub-sample with lower CFO age (S_Sample_LAge) at the extremum point of the curve between CFO age and R&D intensity (i.e., 44 years old). Columns V and VI of Table 5 respectively display the regression results of Model (1) with the two sum-samples. In the sub-sample with higher CFO age, the impact of CFO age on R&D investment is significantly negative (β=-0.063, p<0.01); while in the sample with lower CFO age, the impact of CFO age on R&D intensity is insignificantly positive (β=0.047, p>0.1). Therefore, we have once again confirmed the robustness of the benchmark regression.

In addition, the following robustness tests have been conducted: (1) to use the natural logarithm of CFO age (LNCFO_Age) as the alternative measure of CFO_Age for regression analysis; (2) to replace RD1 in Model(1)-(3) with the natural logarithm of R&D expenditures (RD3) for regression analysis. The above robustness tests all support H1. Due to length limitations, the detailed results are available on request.

(2) Robustness test of female executives' moderating effect

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First, for nonlinear models, it is not reliable to simply judge the changes in the inverted U-shaped curve based on the significance of the interaction item's coefficient. Instead, the graph shows how the inverted U-shaped relationship between CFO age and R&D investment changes when there are different percentages of female executives. More specifically, it shows whether the ratio of female executives does, in fact, weaken the inverted U-shaped relationship between CFO age and R&D investment. Hence, further analysis displayed in the form of graphical expression is needed.

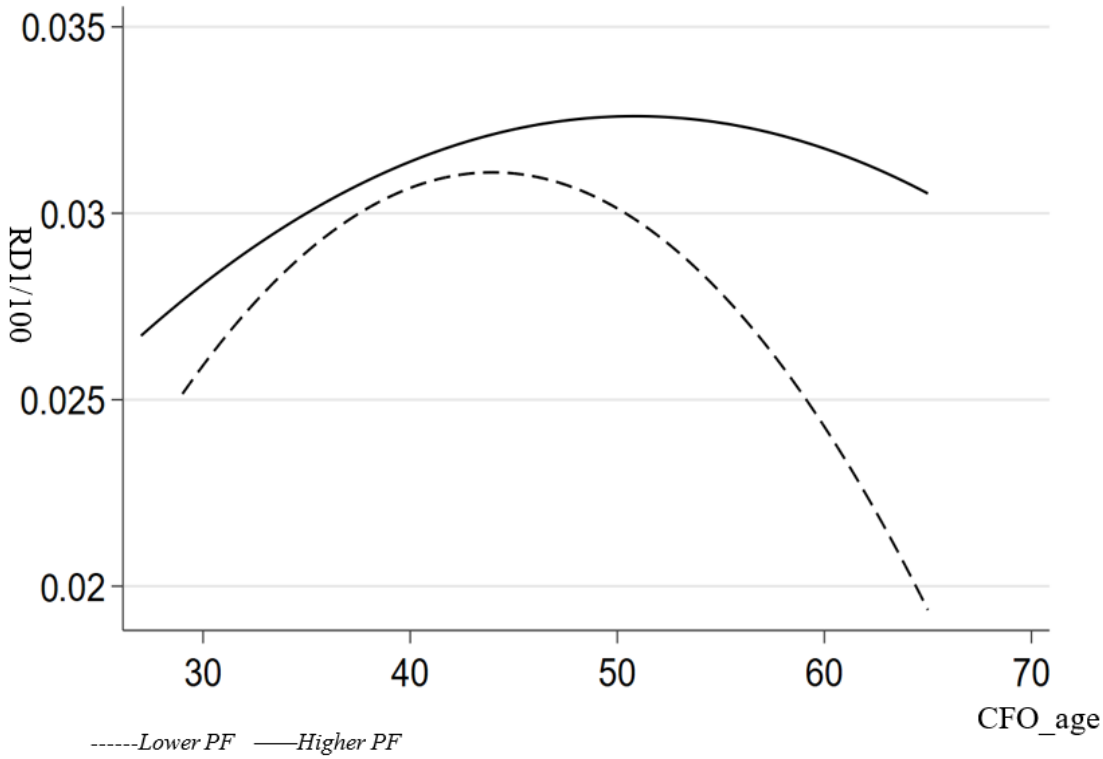

Figure 2.
The impact of the interaction between CFO age and female executive ratio on R&D investment.

Referring to the literature involving the moderating effect on an inverted U-shaped curve, to better demonstrate the moderating effect of female executives, this paper defines the sub-sample with higher FD female and the sub-sample with lower PF based on whether each given sample firm's PF is higher than the industry average level of PF. Next, we plot the relationship between CFO age and R&D investment, respectively, with the data from the two sub-samples (see Figure 2). According to Figure 2, it can be known that no matter the condition of lower or higher ratio of female executives, the relationship between CFO age and R&D investment still maintains an inverted U-shaped curve. Moreover, female executives' participation does weaken the impact of CFO age on R&D investment in each single stage. H2 still holds.

We aim to assess the resilience of the empirical findings concerning the R&D intensity measurement techniques. After replacing RD1 in Model (2) with the ratio of R&D expenditure to total sales (RD2), the new regression analysis has been executed, and the results are reported in Column II of Table 5. According to Column II, the regression coefficients for PF*CFO_Age and PF*CFO_Age2 are both significant. Specifically, the coefficient of PF*CFO_Age is negative (β=-1.624, $p<0.05$), and the coefficient of PF*CFO_Age2 is positive (β= 0.018, $p<0.05$), supporting H2. In addition, after replacing RD1 in Model (2) with the logarithm of R&D expenditures (RD3), the new regression

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analysis has been executed, and the results are shown in Column III of Table 5. According to Column III, H2 still holds. Hence, the benchmark regression results of H2 are robust to the change in R&D intensity's measures.

Third, we aim to modify the method of measuring the female executive participation degree by incorporating the BLAU index as an alternative measure of PF in Model (2). The new regression results are shown in Column IV of Table 5. In the light of Column IV, the coefficient of the interaction term between CFO age and BLAU index (BLAU*CFO_Age) is significantly negative (β=-1.788, $p<0.05$), and the coefficient of BLAU*CFO_Age2 is significantly positive (β= 0.020, $p<0.05$), suggesting H2 remains unchanged. Hence, the empirical results are robust to the measurement methods and design of female executive participation degree.

Fourth, the paper constructs two sub-samples, respectively, the sub-sample with lower NF and the one with higher NF, according to the industry mean value of NF. The regression results of the two sub-samples with Model (1) are shown in Columns VII and VIII of Table 5. For the sub-sample with higher NF, the inverse U-shaped relationship between CFO age and R&D intensity is no longer significant (β1= 0.261， $p>0.1$； β2=- 0.003, $p>0.1$), while for the sample with low NF, the inverse U-shaped relationship between the two is significant (β1= 0.470, $p<0.01$; β2=-0.005, $p<0.01$). When the two sub-samples are constructed according to the industry mean value of PF, H2 remains valid. Therefore, the sub-group regression methods results confirm that female executives negatively moderate the inverted U-shaped relationship between CFO age and R&D investment.

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Table 5.
Robustness test results.

Variables	*RD2*		RD3	BLAU/RD2	RD1			
	Column I	Column II	Column III	Column IV	Column V	Column VI	Column VII	Column VIII
	W_ sample	W_ sample	W_ sample	W_ sample	S_sample_HAge	S_sample_LAge	S_sample_HNF	S_sample_LNF
CFO_age	0.380***	0.724***	0.096***	0.928***	-0.063***	0.047*	0.261	0.470***
	(4.651)	(4.146)	(3.680)	(3.131)	(-2.976)	(1.825)	(1.511)	(3.578)
CFO_age^2	-0.004***	-0.008***	-0.001***	-0.010***			-0.003	-0.005***
	(-4.798)	(-4.249)	(-3.875)	(-3.212)			(-1.489)	(-3.725)
PF		34.830**	5.262**					
		(2.164)	(2.188)					
PF×CFO_age		-1.624**	-0.252**					
		(-2.261)	(-2.351)					
$PF\times CFO\_age^2$		0.018**	0.003**					
		(2.292)	(2.476)					
BLAU				38.001*				
				(1.898)				
BLAU×CFO_age				-1.788**				
				(-2.013)				
$BLAU\times CFO\_age^2$				0.020**				
				(2.060)				
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year/Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-10.012***	-17.651***	-5.970***	-24.953***	-10.263***	-1.954	-7.301	-15.698***
	(-3.796)	(-4.013)	(-9.082)	(-3.489)	(-2.830)	(-.559)	(-1.343)	(-3.651)
N	5891	5891	5891	5891	2829	3062	2680	3211
F	95.179***	90.361***	376.821***	81.706***	43.149***	48.725***	36.241***	55.002***
Adj- R^2	0.366	0.367	0.709	0.343	0.343	0.355	0.315	0.372

Note: *, * *, and * * * represent the significance levels of 10%, 5%, and 1%, respectively; The Robust-corrected value of t is shown in parentheses.

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4.3. Endogeneity Test

Endogeneity is an important issue in this study that affects the reliability of the research conclusions. Therefore, the study adopts the following three methods to deal with endogeneity:

To deal with the potential endogeneity of reverse causality, this study, drawing on the approach of Serfling [55] takes the Consumer Price Index (CPI) of the CFO's birth year as the instrumental variable of CFO age, and adopts the Two Stage Least Squares Method (2SLS) for endogenous treatment. For Model (1) and Model (2), the first-stage regression results based on 2SLS show that the adjusted partial R square of the model is greater than 0.1, and the minimum eigenvalue statistics of CPI are both much greater than 10, indicating that CPI is not a weak instrumental variable. Columns I and II of Table 6 report the regression results of Model (1) and Model (2) in the second stage, respectively. Among them, Column I indicates that the regression coefficient of CFO_Age is significantly positive (β=0.266, p<0.01), and the regression coefficient of the square of CFO_Age is significantly negative (β=-0.003, p<0.01), supporting existing conclusions on H1; Column II indicates that the regression coefficient of PF×CFO_Age is significantly negative (β=-0.058,p<0.05), and the regression coefficient of PF×CFO_Age2 is significantly positive (β=0.002, p<0.05), indicating that female executives' negative moderating effect on the inversed U-shaped curve relationship between CFO age and R&D intensity still holds. Hence, even considering the issue of reverse causality, the benchmark regression results still hold.

Second, the Propensity Score Matching Method (PSM) is used to alleviate endogeneity problems caused by self-selection bias. Since the companies with high levels of risk-taking may intend to hire younger CFOs, who are more inclined to implement high-risk strategic decisions such as R&D investment, the endogeneity issues caused by self-selection bias would appear. In order to alleviate the self-selection-related endogeneity problems, this study adopts the method of Yu, et al. [43] by dividing the whole sample into the sub-sample with higher CFO age (S_Sample_HCFO_Age) and the sub-sample with lower CFO age (S_Sample_LCFO_Age) according to the industry average CFO age. Furthermore, the study selects eight firm characteristics variables that determine the level of enterprise risk taking, including firm size, ROA, and leverage ratio, etc., as the matching rules. A Logit Model, i.e., Model (4), has been used to calculate the probability of each company selecting CFOs of different ages, and One-to-one Nearest Neighbor Matching has been performed. In Model (4), W_ Capital is the working capital ratio, Cash is the cash flow ratio, and other variables are consistent with the design in Section3.2. Columns III and IV of Table 6 display the specific endogeneity test results based on PSM.

$$Logit(CFO\_Age)_{i,t} = \alpha_0 + \alpha_1 Size_{i,t} + \alpha_2 Roa_{i,t} + \alpha_3 Lev_{i,t} + \alpha_4 Top\_Share_{i,t} + \alpha_5 Ind\_Ratio_{i,t} + \alpha_6 \text{W\_Capital}_{i,t} + \alpha_7 \text{Cap}_{i,t} + \alpha_8 \text{Cash}_{i,t} + \sum Industry + \sum Year + \varepsilon_{i,t} \quad (4)$$

According to Column III (β1=0.237,P<0.01; β2=-0.003, P<0.01) and Column IV (β4=-1.134, P<0.05; β5=0.014, P<0.05), the PSM regression results are consistent with the previous benchmark regression results.

Referring to existing literature, more control variables have been considered when estimating the Multiple Linear Models to address the endogeneity issues caused by omitted variables. Specifically, based on the existing control variables in Model (1) and Model(2), external environmental factors have been introduced as control variables, including whether the company is registered in the Yangtze River Delta region (Yangtze_RD), whether the company is registered in the Northeast Three Provinces (Northeast_TP), whether the company is registered in an autonomous region (Ethnic_AR), and whether the company is registered in a municipality directly under the Central Government (Municipality_DUCG). In addition, more company characteristics are added as control variables, namely CEO age (CEO_Age), working capital ratio (W_Capital), cash flow ratio (Cash), being state-owned enterprises (State) or not, and firm age (Firm_age). The new regression results after adding more control variables are respectively reported in Columns V (β1=0.137,P<0.01;β2=-0.002, p<0.01)

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and Column VI (β4=-0.733,P<0.05;β5=0.009, P<0.05) of Table 6. The results show that even considering the omitting variables, H1 and H2 still hold.

Table 6.
Endogeneity test results.

Variables	2SLS		PSM		Omitting variables	
	Column I	Column II	Column III	Column IV	Column V	Column VI
CFO_age	0.266*** (3.446)	0.243*** (3.100)	0.237*** (4.095)	0.456*** (3.759)	0.137*** (3.301)	0.284*** (3.188)
CFO_age²	-0.003*** (-3.257)	-0.003*** (-3.125)	-0.003*** (-4.087)	-0.005*** (-3.964)	-0.002*** (-3.362)	-0.003*** (-3.380)
PF		-2.716 (-1.221)		22.305** (1.971)		14.697* (1.792)
PF×CFO_age		-0.058** (2.499)		-1.134** (-2.261)		-0.733** (-2.002)
PF×CFO_age²		0.002** (-1.966)		0.014** (2.486)		0.009** (2.173)
CEO_age					0.001 (.373)	0.002 (0.402)
W_capital					0.000 (-0.602)	0.000 (-0.448)
Cash					0.073 (1.329)	0.072 (1.306)
State					-0.270** (-2.502)	-0.264** (-2.437)
Firm_age					-0.469*** (-4.057)	-0.466*** (-4.022)
Yangtze_RD					-0.440*** (-7.969)	0.055*** (-7.833)
Northeast_TP					-0.051 (-0.316)	0.160 (-0.253)
Ethnic_AR					-0.128 (-0.579)	0.221 (-0.479)
Municipality_DUCG					0.294*** (4.598)	0.064*** (4.679)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Year/Industry	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-2.760 (-1.551)	-1.819 (-.978)	-3.570* (-1.895)	-7.728** (-2.512)	2.051 (1.467)	-0.877 (-0.384)
N	5891	5891	3002	3002	5891	5891
F	74.008***	68.259***	37.436***	35.065***	62.143***	58.421***
Adj- R^2	0.303	0.303	0.298	0.301	0.314	0.315

Note: *, * *, and * * * represent the significance levels of 10%, 5%, and 1%, respectively; The Robust-corrected value of t is shown in parentheses.

5. Further Exploratory Research

The majority of the studies on the background characteristics of executive suggest a close relationship between age and tenure, suggesting that longer tenure often accompanies older executives.

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However, in recent years, the age and tenure characteristics of executives have become increasingly difficult to couple with each other. For instance, the experimental research of Barker III and Mueller [56] and Musteen, et al. [57] show that CEO age and CEO tenure have different effects on employees' turnover rates. In this case, is the decoupling effect of the age and tenure characteristics of CFO also reflected in enterprise R&D investment decisions? In other words, we want to explore the two questions: (1) Is there also an inverse U-shaped curve relationship between CFO tenure and R&D intensity? (2) Do female executives still play a negative moderating role in such a relationship between the two?

To explore whether the impacts of CFO age and CFO tenure exhibit a decoupling effect on R&D investment, CFO_Ten and CFO_Ten2 have been used to replace CFO_Age and CFO_Age2 of Model (1), and thus Model (4) has been constructed. The regression results are shown in Column I of Table 7. According to Column I of Table 7, the regression coefficient of CFO_Ten is significantly positive ($\beta1=0.091$, $p<0.05$), and the regression coefficient of CFO_Ten2 is significantly negative ($\beta2=-0.005$, $p<0.1$), confirming an inverted U-shaped relationship between CFO tenure and R&D intensity. The data suggests that both CFO age and CFO tenure significantly influence R&D investment, with no apparent decoupling effect between them. To further ensure the reliability of the result, by replacing RD1 in Model (4) with RD2 and RD3, the study has conducted the regression analysis once more. Columns II and III of Table 7 display the results. The inverted U-shaped curve relationship still exists.

In addition, this study further explores whether female executives have a moderating effect on the inverted U-shaped relationship between CFO tenure and R&D investment. By replacing CFO_Age and CFO_Age2 in Model (2) with CFO_Ten and CFO_Ten2, Model (5) has been constructed. In the light of Column IV of Table 7, it can be known that female executives do not have a moderating effect on the curve relationship between the CFO tenure and R&D expenditures. To ensure the reliability of the results, we draw on existing research by replacing the dependent variables from RD1 with RD2 and RD3,and conducting the regression analysis again. The results are shown in Columns V and Column VI of Table 7. The moderating effect remains untenable. Therefore, female executives' participation cannot moderate the curve relationship between CFO tenure and R&D investment. Such a fact is slightly different from the fact that there is a negative moderating effect of female executives' participation on the relationship between CEO age and R&D investment.

Table 7.
Empirical results on the relationship among female executives, CFO tenure, and R&D intensity.

Variables	*Curve relationship*			*Moderating effect*		
	RD1	**RD2**	**RD3**	**RD1**	**RD2**	**RD3**
	Column I	**Column II**	**Column III**	**Column IV**	**Column V**	**Column VI**
CFO_Tenure	0.091*** (2.633)	0.245*** (3.629)	0.028*** (2.807)	0.026 (.379)	0.099 (0.729)	0.008 (0.375)
CFO_Tenure^2	-0.005* (-1.879)	-0.015*** (-2.671)	-0.002* (-1.798)	0.000 (0.040)	0.000 (-0.018)	0.001 (0.329)
PF				-0.894 (-1.304)	-2.151 (-1.601)	-0.235 (-1.177)
PF×CFO_Tenure				0.285 (1.069)	0.640 (1.226)	0.090 (1.163)
PF×CFO_Tenure^2				-.025 (-1.158)	-.065 (-1.561)	-.009 (-1.443)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Year/Industry	Yes	Yes	Yes	Yes	Yes	Yes

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Variables	*Curve relationship*			*Moderating effect*		
	RD1	RD2	RD3	RD1	RD2	RD3
	Column I	Column II	Column III	Column IV	Column V	Column VI
Constant	2.142** (2.110)	-3.491* (-1.752)	-4.347*** (-14.696)	2.401** (2.330)	-2.809 (-1.390)	-4.281*** (-14.261)
N	4998	4998	4998	4998	4998	4998
F	62.987***	83.189***	357.768***	58.095***	76.919***	329.662***
Adj- R^2	0.303	0.365	0.714	0.302	0.362	0.714

Note: *, * *, and * * * represent the significance levels of 10%, 5%, and 1%, respectively; The Robust-corrected value of t is shown in parentheses.

6. Discussion

6.1. Research Conclusions

Holding a sustainability-oriented purpose, the study takes the data set of Chinese non-financial GEM listed companies over 2009-2021 as the research sample, and comprehensively investigates the impact of CFO age on R&D investment and the moderating effect of female executives on the link between the two. The research findings indicate that: (1) There is a significant inverted U-shaped curve relationship between CFO age and R&D intensity, namely, R&D investment shows an upward and then downward trend as CFO age increases. To be specific, with the age of 44 as the turning point, the relationship between CFO age and R&D intensity shows a positive correlation first and then a negative one; (2) female executives have a significant negative moderating effect on the inverted U-shaped relationship mentioned above; (3) further exploratory investigation shows that CFO tenure has a similar inverted U-shaped relationship with R&D intensity, while female executives cannot moderate such a relationship.

6.2. Theoretical Contributions and Practical Implications

There are at least three theoretical contributions in this paper. Firstly, the study enriches the relevant theoretical knowledge in the field of CFO research. At present, few scholars have explored the impact mechanism of individuals' age on enterprise R&D investment from the perspective of CFO, leaving the link between CFO age and R&D intensity in an unknown "black box." This study, by comprehensively drawing on the perspectives of Upper Echelons Theory, Signal Theory and Resource Dependency Theory, analyzes and verifies the inverted U-shaped effect of CFO age on R&D investment. The finding deepens the understanding of CFOs' R&D innovation preferences at different age stages and expands the research perspectives regarding the antecedents of R&D innovation. Secondly, the study adds new insights into the moderating roles of female executives, and further enriches the cross-disciplinary research results on gender diversity and technological innovation. Holding the contingency perspective, the paper explores the moderating effect of female executives on the inverted U-shaped relationship between CFO age and R&D intensity, considering their risk aversion tendencies and firm-serving motivations. The finding deeply reveals the role played by female executives in the R&D decision-making processes of CFOs who are at different age stages, enriching the theoretical knowledge regarding female executives. Thirdly, the study reveals, for the first time, that CFO tenure and CEO tenure have rather similar effects on R&D investment. The verified inverted U-shaped relationship between CFO tenure and R&D investment adds new empirical evidence to the Stage Theory of tenure on the one hand, and further adds new empirical support in the Chinese context to the Upper Echelon Theory on the other hand.

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The research conclusions provide the Chinese GEM-listed enterprises with rich theoretical guidance and practical implications for optimizing the allocation and motivation of executive talent, the career planning of CFOs, and the decision-making patterns of female executives.

(1) The implications for both shareholders and the board of directors are significant.

Technological innovation is a necessary source and driving force for the sustainable growth of companies. Consequently, the research findings hold vital significance for Chinese GEM-listed enterprises in their pursuit of long-term sustainability.

Firstly, when adjusting the composition of top management teams, the impact of CFO age and tenure on R&D investment should be fully considered, with the purpose of better matching CFO age or CFO tenure with the company's innovation strategy and supporting the implementation of the company's innovation strategy. For companies eager for more innovation advantages, shareholders may consider employing middle-aged CFOs more, as they have a higher risk tolerance and allow for innovation and failure; Secondly, when formulating executive compensation policies, enterprises should appropriately improve and adjust CFO's compensation packages by setting bonuses for CFOs who make better R&D investment decisions to motivate them to continue working with greater effort; Finally, the board of directors should establish a sound and reasonable recruitment and training mechanism for CFOs, analyze whether the age, tenure, abilities, awareness, and practical experiences of CFOs align with the enterprises' requirements, and provide appropriate training for CFOs based on the enterprises' strategies with the purpose of enabling them to smoothly integrate into the enterprise and make favorable decisions.

In addition, to mitigate or hedge the potential negative impact of CFO age on enterprise R&D investment, enterprises may consider using gender complementarity to improve decision-making quality and curb decision-making risks. Firstly, shareholders, the board, or CEO should fully recognize the importance of female executives' participation, promote, appoint, and maintain more capable and responsible female executives (especially female CFOs), and at least keep a stable proportion of female executives at all times; Secondly, in top executive teams, female executives' participation is suggested to be matched or adjusted according to CFO age, and greater power should be given to female executives in R&D decision-making processes, thereby ensuring the appropriateness of enterprise R&D investment; Thirdly, in terms of promotion mechanisms, enterprises should provide the non-executive female employees with equal opportunities for promotion instead of overlooking them, as they are the necessary reserve force for female executives; Finally, within the company, it is necessary to establish a gender-inclusive culture by consciously emphasizing the importance of female executives, providing timely and meticulous care to female executives, and ensuring that each employee recognizes the irreplaceable role of female executives.

(2) Implications for CFOs

As a value engineer and value integrator, the ultimate goal of the CFO is to secure the sustainable growth of corporate value. Against the backdrop of an aging population, the findings of this study affirm the career prospects of middle-aged CFOs in corporate R&D activities, which contribute to the attainment of core competitiveness for companies in contemporary society.

First, CFOs should recognize that their roles' importance is not inferior to that of CEOs for their enterprises. Hence, CFOs should be cautious in each decision they make; Second, it is necessary for CFOs to clarify their own stages of age or tenure and further recognize their attitudes towards risk. Accordingly, they should make conscious adjustments in response to the current strategic arrangements of the enterprises when making R&D investment decisions to ensure the appropriateness of the decisions; Finally, CFOs should actively cooperate with female executives. When female executives provide suggestions for their R&D decisions, CFOs should actively listen to them and attempt to co-develop appropriate and satisfactory decision outcomes in subsequent communication and discussion with female executives.

(3) Implications for female executives

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This research highlights the essential role of female executives in CFOs' decision-making about R&D investment. Therefore, it enhances companies' comprehension of the value of female human capital while simultaneously fostering the sustainable development of female executives' careers. Moreover, it also shows their potential for driving societal sustainability.

First, it is needed for female executives to recognize their importance in corporate governance practices, actively participate in corporate decision-making processes, and fully leverage their heterogeneous human and social capital relative to male executives; Second, female executives should actively cooperate with CFOs and take into account the actual strategic needs of the enterprises and the age of the CFOs in formulating R&D investment decisions. When CFOs make R&D investment decisions that do not align with the interests of the enterprises, female executives should intervene in a timely manner. For conservative CFOs, female executives should encourage them to invest more in R&D activities, and for aggressive CFOs, female executives should put forward suggestions for risk prevention in a timely manner when making R&D investment decisions, preventing aggressive CFOs from investing excessive R&D funds; Finally, female executives within an enterprise may regularly hold seminars to share their experiences in influencing R&D investment decisions, enhancing the R&D decision-making ability of the whole female executive group.

6.3. Research Limitations and Prospects

This study exhibits certain shortcomings that warrant further improvement and exploration in the future. First, this study has found that the age and tenure characteristics of CFOs have an inverted U-shaped impact on R&D investment, while future research can further explore the impact of other background characteristics of CFOs (such as educational background, party membership and overseas experience, etc.) on enterprises R&D activities; Second, this study takes the unbalanced panel data of Chinese GEM-listed companies as the research sample, and future research can further execute the cross-regional and cross-industry comparative research by adopting a wider sample of non-listed companies in China.

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The authors declare that they have no competing interests.

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All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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