

Effects of top female leaders on R&D activities under different executive pay gaps

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Abstract

Innovation is regarded as a crucial driver in achieving the vision of manufacturing power, and top female leaders play an increasingly important role in driving innovation. Based on a sample of 14,716 observations from Chinese manufacturing enterprises listed between 2010 and 2020, this study empirically examines the impact of top female leaders in different positions on (Research and Development) R&D intensity and investigates the moderating role of executive pay gap on this relationship. The results indicate that (1) female executive directors and female non-executive directors have a negative impact on R&D intensity, while female (Chief Finance Officer) CFO and female independent directors have a positive impact on R&D intensity, and there are no significant relationships between female supervisors, female (Chief Executive Officer) CEO, and female non-director executives and R&D intensity; (2) executive pay gap strengthens the negative effects of female executive directors and female non-executive directors on R&D intensity, weakens the negative effects of female CEO and female non-director executives on R&D intensity, and has no significant moderating role on the effects of female independent directors, female supervisors, and female CFO on R&D intensity.

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Executive pay gap
Female CEO
Female CFO
Female directors
Female supervisors
R&D intensity.

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1. Introduction

The strength of the manufacturing industry determines the national competitive advantage. China, which seeks to enhance its competitive advantage, is facing the need of upgrading its Manufacturing Industry and is seeking to transform into a "Manufacturing Power". This fact puts forward requirements for manufacturing

enterprises to carry out intensive R&D activities. In this context, the factors influencing the R&D activities of Chinese manufacturing enterprises have become a hot research topic and have achieved fruitful research contributions. At present, at least four streams of antecedents have received literature attention, namely, external environmental factors, organizational characteristics, operational characteristics, and corporate governance factors. Among them, corporate governance factors are considered more proactive and fundamental compared to the other three types of factors, and research results on their impact on R&D activities are more controversial. Consequently, an increasing number of scholars have focused their attention on this area. In this context, this paper takes the participation of top female leaders in corporate governance, an emerging corporate governance factor, as the research object, exploring its impact on manufacturing enterprises' R&D intensity. It is of theoretical frontier and practical necessity.

Numerous studies have examined the impact of top female leaders on enterprise R&D activities. First, [Chen, Leung, and Evans \(2018\)](#) and [Chen, Tong, Zhang, and Zhou \(2021\)](#) have investigated the effect of female directors on R&D expenditure and performance. Second, [Jean, Karpavičius, and Yu \(2021\)](#); [Lee and Chung \(2022\)](#); [Daniela, Patrick, and Jori \(2019\)](#) have examined the effect of TMT (i.e., top management team) gender diversity on R&D investment. Third, [Ronny and Doddy \(2021\)](#); [Keshab, Lee, and Ghafoor \(2022\)](#) and [Aric and Kevin \(2022\)](#) have discussed the effect of female CEO on R&D investment. In addition, some other studies [Ginesti, Spano, Ferri, and Caldarelli \(2021\)](#); [Wang and Fung \(2022\)](#) have discussed the effect of female CFO on R&D investment. However, up to now, we still know little about the different attitudes of top female leaders in different positions towards R&D activities in the same enterprise, especially in China. By applying a uniform sample and adopting the same statistical calibers and methods, systematic analysis and comparison of the links between top female leaders in different positions and R&D investment is significant for enriching the literature on gender diversity and technological innovation.

The effect of executive pay gap, a popular measurement indicator of tournament incentives, on R&D activities has also received widespread attention. Especially in recent years, more scholars have begun to pay attention to the indirect effect of executive pay gap as a moderating factor in affecting innovation investment decisions, leading to rich research results ([Fangfang, 2022](#)). In addition, a large number of studies argue that the effects of top female leaders on corporate governance practices have the nature of contingency ([Salma, Mbarek, & Haj-Salem, 2022](#)). Top female leaders are still in a relatively weaker position in the current upper echelons in China, and it is difficult to play a real decisive role in the decisions related to the core competitive advantage of enterprises (e.g., R&D decisions). Moreover, women's decision-making process is more easily affected by external contextual factors compared with men's ([De Paola, Gioia, & Scoppa, 2022](#)). Therefore, the authors expect that the impact of top female leaders on R&D investment decisions would logically be moderated by executive pay gap as a key contextual factor.

Based on the above discussion, the paper tries to investigate how each kind of top female leaders with different positions treat R&D investment decisions under the backgrounds of various executive pay gap based on the sample consisting of 14721 observations collected from Chinese manufacturing listed companies over 2010-2020. The expected theoretical contributions may be that: (1) to clarify and compare, for the first time, the differences in the attitudes of multiple top female leaders with different positions towards R&D activities, enriching the literature on gender diversity and technology innovation; (2) to prove the moderating effect of executive pay gap in determining the linkages between top female leaders with different positions and R&D intensity, contributing to the tournament theory and the contingency view of R&D determining mechanism.

2. Literature and Hypothesis

2.1. Tournament Theory

Tournament theory holds that competition exists amongst individuals in an organisation and that competition is a good motivator, so when there is a pay gap, it can motivate individuals to work hard and increase efficiency ([Lazear & Rosen, 1981](#)). It is important to note that the tournament theory points out that the pay gap is not an absolute gap but a relative gap. This is because relative gaps are more likely to give employees a longer-term perspective and a broader incentive to develop a promotion mentality than absolute gaps ([Connelly, Tihanyi, Crook, & Gangloff, 2014](#)). This theory holds that individuals at work are like sports competitions, where individuals place more emphasis on winning or losing the outcome of the competition, i.e. in comparison to others, rather than their own performance in the competition. Similarly, in management practice, there are extremely competitive relationships within organisations, and this phenomenon is more pronounced at the executive level ([Rosen, 1986](#)). Current research related to executive teams focuses on two main aspects, one of which is competition for self-protection and the other for further self-improvement. Specifically, on the one hand, although executives have a high status in the company, their agency nature determines that their position is not solid and immovable, and they are very likely to face the risk of dismissal if they perform poorly in the competitive process ([Ali & Zhang, 2015](#)). On the other hand, the pay gap is more pronounced for executives, so they will be keen to obtain higher pay by moving up the ladder when higher positions offer higher compensation ([Rosen, 1986](#)). Therefore, executives will actively participate in the competition, either passively or actively, and the higher the incentive stimulus, the more they will increase their propensity to take risks and perform more

risky tasks (Kato & Long, 2011). In summary, this paper will invoke tournament theory to explain the relationship between female executives and R&D intensity in the context of the pay gap.

2.2. Female Executives in Different Positions and R&D Intensity

Scholars have conducted relatively sizable studies on the relationship between female leaders and R&D intensity. Reviewing the above literature, it is not difficult to find that there are some insufficiencies in the existing studies on the relationship between female leaders in executive teams and R&D investment. Specifically: (1) the role of gender is not obvious, most of the studies are based on gender diversity, but do not explore the relationship between gender differentiation and R&D investment; (2) the mechanism is not uniform, the existing relationship between female leaders and R&D intensity is complex and diverse, and does not form a systematic logic; (3) the type of leader is not obvious, leaders can be differentiated into a variety of types according to their positions and characteristics, however, the existing studies mostly focus on a single leader. However, the existing studies are mostly from the perspective of a single level, such as female executives, female directors, female CEOs, and so on, and have not explored the differences in the relationship between different female leaders and R&D intensity in details. Considering the above shortcomings, this paper will explore the relationship between female leaders in different positions and R&D intensity in depth. The details are as follows:

First, regarding the link between female directors and R&D intensity, Griffin, Li, and Xu (2021) make a valuable contribution. Specifically, using a novel database of firm perspectives on patents and board characteristics from 45 countries, they examine the relationship between board gender diversity and firm innovation, concluding firms with gender-diverse boards are more R&D-intensive, have more patents, and are more innovatively efficient. Further analyses show that gender-diverse boards are correlated with CEO incentives that are more tolerance of failure and more innovative corporate cultures, which are conducive to higher R&D intensity and improved innovation performance. In addition, Almor, Bazel-Shoham, and Lee (2022) examine the relationship between board gender diversity and R&D investment in the UK. The study results indicate that board gender diversity has a positive impact on R&D intensity. Remarkably, this relationship is not affected by female board tenure. Chen, Ni, and Tong (2016) Firms with higher board gender diversity have lower negative impacts of R&D on the cost of debt. The results suggest that female directors improve board effectiveness in risk management of R&D investments. On the contrary, Some studies find that board gender diversity weakens firms' R&D investment intensity due to women's risk-averse tendencies.

Second, as a valuable contribution to the research on the relationship between top management teams and R&D investment, we found that gender diversity in TMT has a positive impact on firm innovation. Moreover, this finding is robust to female representation and other measures of innovation after accounting for the endogeneity of tournament incentives. Lee and Chung (2022) examine how TMT gender diversity (or women in TMT) affects corporate innovation. Using a data set of U.S. firms between 2005 and 2019, they exploited differences across U.S. states in supportive policies to protect the rights of women workers. The study finds that greater TMT gender diversity is associated with a higher number of innovations but a lower innovation impact. In additional, increased (Top Management Team) TMT gender diversity narrowed the breadth of searches (searches became more localised). The findings reveal multifaceted innovation outcomes of gender-diverse members of the TMT and emphasise the risk-reducing role of female members of the TMT in innovation. In contrast, Fang, Gozgor, Lau, Wu, and Yan (2020) confirm that TMT gender diversity is negatively associated with R&D investments due to women's risk-averse tendencies. However, Biga-Diambeidou, Bruna, Dang, and Houanti (2021) find no significant relationship between TMT gender diversity and R&D investment in start-ups, regardless of the number of female managers in the TMT, the firm's profitability, or the firm's stage of development and growth.

Third, concerning the linkage between the presence of female CEO and R&D investment, there are contradictory research results. Keshab et al. (2022) finds a zero relationship between the two, while Ronny and Doddy (2021) provides a positive relation. Yin, Hai, and Chen (2019) investigated the behavioural differences in R&D investment between CEOs with different characteristics under financial constraints. The empirical results show that compared with male CEOs, internal financial constraints have no significant limiting effect on the R&D investment of female CCEO firms, while external financial constraints have a significant limiting effect on the R&D investment of both groups of firms. Research through Fang, Razzaq, Mohsin, and Irfan (2022) shows that the gender of the CEO plays an important role in efficient investment decisions by improving governance and disciplining management. And female CEOs are positively associated with investment efficiency. The findings also suggest that in making investment decisions, female CEOs are more concerned with curbing underinvestment than male CEOs. However, female CEOs do not play a role in improving investment efficiency in State Owned Enterprises (SOEs). Moreover, Some studies has indicated that successful R&D activities require information sharing and knowledge cooperation among teams, having higher requirements for the cooperation of TMTs. Although the presence of female CEOs can improve the level of gender diversity in the TMTs, it is difficult for executives of different genders to reach a consensus, increasing internal differences and conflicts, reducing TMTs' cohesion and decision-making efficiency, and thus hindering enterprises' R&D investment.

Last but not least, Ginesti et al. (2021) provide the first insight into the impact of CFOs, as the most important C-suite executives, on the level of firms' investment in R&D activities, by using a regression analysis based on hand-collected data on CFOs of a sample of the largest European listed firms for the period 2013-2016

to empirically test the association between CFOs' association between gender and R&D intensity. Their findings suggest that the presence of female CFOs is positively associated with R&D investment intensity. Liu, Neely, and Karim (2022) were one of the first to examine whether the presence of female CFOs discourages firms from overinvesting. The potential positive impact of including female CFOs in the top management team extends to firms and investors. The existing literature is extended by examining how the gender of the CFO affects firms' investment practices, particularly the extent of overinvestment at the firm level. Using a sample of firms from 1994 to 2015, strong evidence is found that female CFOs are negatively associated with corporate overinvestment.

Though there are numerous studies investigating the effect of top female leaders on R&D activities, no research has systematically explored and compared the impacts of various top female leaders on R&D investment within a single study. Moreover, as a special type of top female leaders, female supervisors do not exist in most European and American companies, so their impact on R&D intensity is nearly unknown.

In Chinese listed enterprises, top female leaders occupy different positions, mainly including CEO, CFO, independent director, executive director, non-executive director, non-director executives, and supervisors. Even the same female leader in different positions will have different decision-making preferences and decision-making standards (Hernández-Lara, Gonzales-Bustos, & Alarcón-Alarcón, 2021). This study believes that the interaction between women's risk aversion, altruism, and other gender characteristics and the job requirements of each senior position will lead to their different innovation tendencies.

Based on the above discussion, the paper proposes the following hypothesis:

H1: Top female leaders in different positions, including CEO, CFO, independent director, executive director, non-executive director, non-director executives, and supervisors, would have distinct relations with R&D intensity.

2.3. The Moderating Role of Differences in Executive Compensation

Among the incentives for executives, pay incentives are the more prevalent ones. A larger pay gap exists as an additional reward for executives' hard work, which can make executives more self-confident and enable them to make decisions that are beneficial to the development of the firm from a long-term perspective and increase innovation, which in turn reduces the cost of the firm and improves the efficiency of the labour force (Wang & Fung, 2022). From the perspective of enterprise risk-taking, the executive compensation gap has a significant impact on the risk-taking attitude of executives, the larger the executive compensation gap, the stronger the risk-taking tendency, the longer the cycle of R&D activities and the higher the risk. The executive pay gap increases executives' willingness to carry out innovative activities and stimulates executives to increase risky investments. Therefore, a reasonable pay gap leads to internal competition among executives, reduces their risk aversion, and increases executives' investment in risky projects (Yang & Ji, 2023).

Due to gender discrimination and related occupational segregation, top female leaders, as the relatively more disadvantaged groups in the upper echelons, are difficult to directly determine strategic decisions without considering the influence of some critical conditional factors. An increasing number of studies have identified the critical moderating factors that can change the direct effects of top female leaders on some organizational variables. For example, Wang, Deng, and Alon (2021) has confirmed the moderating role of social capital on the relationship between female executives and the financing pecking order of GEM-listed companies; For another example, Gallucci, D'Amato, and Santulli (2015) has found the moderating role of shareholdings on the relationship between female directors and firm performance. Biswas, Chapple, Roberts, and Stainback (2023) using data from Australian organisations (2014-2019), we find that the contemporaneous relationship between female board representation and gender segregation is not significant, becoming significant and increasing in magnitude after lags of 1, 2 and 3 years. Critical mass analyses suggest that having only one woman on the board may not be sufficient to facilitate change, and instead two or more female directors, or holding 20% or more of the board seats, appear to be more effective in reducing gender segregation.

With regard to the relationship between top female leaders and R&D activities, it was found that the executive pay gap plays a moderating role as a tournament incentive. Tournament theory asserts that a larger pay gap creates strong incentives for high-calibre managers to be willing to put in more effort, thereby improving firm performance. The tournament theory applies to non-high-tech firms with low R&D intensity, and it encourages firms to increase the executive pay gap, not just executive pay, to improve firm performance. In contrast, for high-tech firms with high coordination needs, larger pay gaps do not necessarily improve firm performance, and a cautious approach should be taken when considering trade-offs between monetary incentives, bottom line performance, and mutually adaptive norms for top management teams (Lin, Yeh, & Shih, 2013). For example, Jean et al. (2021) suggest that the combined effect of tournament incentives and TMT gender diversity is detrimental to innovation. Existing literature suggests that wider executive pay gaps reduce the motivation and effort of non-CEO employees, which is consistent with pay equity theory (Chan, Kawada, Shin, & Wang, 2020). Moreover, when lower levels of motivation and effort are met with top female leaders who are more susceptible to negative emotions, this can have a detrimental effect on R&D investment and innovation performance. Amore and Failla (2020) analysed the impact of executive pay dispersion on innovation output in US firms and found that executive pay disparity is a double-edged sword. On the one hand, it can promote effort provision, coordination and good team dynamics among executives involved in the innovation process, with higher dispersion in variable pay associated with higher levels of innovation. On the other hand, it can also

trigger emotional conflicts that discourage executives from exerting effort, sharing knowledge and collaborating, and higher dispersion of fixed pay is associated with a lower level of innovation.

Furthermore, varying executive pay gaps may result in different promotions and monetary incentives. Top female leaders in different positions enjoy a distinct matching degree of position characteristics and female characteristics, and their possibilities of promotion and success are not equal. Therefore, the authors believe that the same executive pay gap has different moderating effects on the R&D investment tendency of top female leaders in different positions.

H₃: Executive pay gap would moderate, to varying degrees, the associations of top female leaders in different positions, including CEO, CFO, independent director, executive director, non-executive director, non-director executives, and supervisors with R&D intensity.

3. Method

3.1. Sample and Data

This paper takes manufacturing companies that disclose R&D investment data among China's A-share listed companies from 2010-2020 as the initial research framework, and selects the final sample according to the following steps: (1) excluding listed companies labelled with ST, * (Special Treatment) ST or (Particular Transfer) PT in the sampling year; (2) excluding listed companies with single data in the sampling year (e.g., companies with the gap between the CEO's and employees' salary less than 10,000 RMB, companies with the asset-liability ratio greater than 100%, etc.); (3) excluding listed companies in the sampling year that cannot fully access the data required for the study.

The data required in this paper mainly come from the CSMAR database, and a few data are collected manually from the annual report of enterprises. After the above steps of sample screening and data processing, a research sample consisting of 14716 unbalanced panel observations from the manufacturing industries were finally reached. In order to avoid the distortion effect of outliers on the final empirical results, the main continuous variables were Winsorized with 1% quantile and 99% quantile.

3.1.1. The Explained Variable: R&D Intensity

In reference to the existing literature on R&D investment, R&D intensity (RDI) is measured by the ratio of R&D expenditures to total sales. Considering the industry differences in R&D investment, industry-adjusted RDI (i.e., the difference between firms' RDI and the average RDI of the industry) is used as a proxy variable for robustness tests (Ana, Juan, & Amado, 2021)

3.1.2. The Explanatory Variables

Referring to the existing literature on female executives, the following variables were defined as explanatory variables. The number of female executive directors (FED_N) is used to measure the level of female executive director participation. The number of female non-executive directors (FNED_N) is used to measure the level of participation of female non-executive directors. The number of female independent directors (FID_N) is used to measure the level of participation of female independent directors. The number of female supervisors (FS_N) is used to measure the level of participation of female supervisors. (Female Chief Executive Officer) FCEO is a dummy variable to measure the presence of a female chief executive officer. FCFO is a dummy variable to measure the presence of a female chief financial officer. The number of female non-director executives (FNDE_N) is used to measure the extent of female non-director executive engagement (Chen et al., 2018; Chen et al., 2021).

3.1.3. The Moderating Variable

Referring to the existing literature on tournament theory, executive pay gap (EPG) is measured by the logarithm of the difference between the CEO's salary and the average salary of other executives (Chan et al., 2020; Zhao & Wang, 2019). In addition, the logarithm of the difference between the average salary of the top three executives and the average salary of other executives (EPG_A) is used as the alternative measure for the robustness test.

3.1.4. The Control Variables

Referring to related literature on the antecedents of R&D investment, the following variables are chosen as the control variables: executives shareholding ratio (ESR), firm size (FSIZE, the logarithm of total assets), firm age (FAGE), the state-owned nature of property rights (STATE), the ratio of the first largest shareholder's shareholdings (FSHARE), CEO duality (CEODUAL), equity balance degree (EBD), the size of the board of directors (BSIZE), independent directors proportion (IDP), the size of the supervisor board (SSB), return on investment (ROI), Tobin's Q (TQ), CEO's party membership (CEOPARTY), CEO education (CEOED, a dummy variable whether the CEO has a master or above degree), CEO tenure (CEOTENRUE), CEO age (CEOAGE), leverage ratio (LEV), business tax rate (BTR), and the logarithm of staff size (LNSS) (He & Jiang, 2019; Lee & Chung, 2022).

Moreover, 10 year dummy variables, 24 industry dummy variables, and 6 regional dummy variables are designed to control the fixed year effects, industry effects, and regional effects.

4. Description

Table 1 shows the descriptive statistical results. For manufacturing enterprises, the average number of female executive directors is about 0.31, the average number of female non-executive directors is about 0.94, the average number of independent directors is about 0.57, the average number of female supervisors is about 0.98, the average ratio of female CEOs is about 6%, the average ratio of female CFOs is about 32.5%, and the average number of non-director executives is about 0.898. In addition, the average R&D intensity is about 4.352, and the average executive pay gap is about 295 thousand Yuan.

The correlation analysis shows that correlation coefficients among explanatory, explained, and control variables are basically consistent with the expectations. The (Variance Inflation Factor) VIF test results show that the multicollinearity problem in this study is acceptable and will not harm the reliability of the empirical analysis results. The detailed results of correlation analysis are available on request.

Table 1. Descriptive statistics results.

Variables	Range	Minimum	Maximum	Mean	Standardized deviation	Skewness	Kurtosis
RDI	49.870	0.000	49.870	4.352	4.069	3.276	19.744
EPG	5.590	9.900	15.500	12.596	1.002	0.147	0.025
FED_N	4.000	0.000	4.000	0.310	0.555	1.843	3.536
FNED_N	6.000	0.000	6.000	0.940	0.915	0.864	0.570
FID_N	4.000	0.000	4.000	0.570	0.681	0.923	0.192
FS_N	5.000	0.000	5.000	0.980	0.877	0.637	-0.012
FCEO	1.000	0.000	1.000	0.060	0.239	3.681	11.548
FCFO	1.000	0.000	1.000	0.325	0.468	0.748	-1.440
FNDE_N	7.000	0.000	7.000	0.898	0.973	1.138	1.339
ESR	21.299	0.000	21.299	11.770	7.136	-0.817	-0.965
FSIZE	6.160	19.990	26.140	21.954	1.131	0.852	0.806
FAGE	28.000	1.000	29.000	8.980	6.832	0.754	-0.476
STATE	1.000	0.000	1.000	0.300	0.459	0.862	-1.257
FSHARE	0.661	0.088	0.748	0.341	0.142	0.510	-0.214
DUAL	1.000	0.000	1.000	0.330	0.468	0.746	-1.443
SBD	2.826	0.028	2.854	0.768	0.612	1.218	1.249
BSIZE	13.000	5.000	18.000	8.500	1.580	0.583	2.739
IDP	0.250	0.333	0.583	0.374	0.053	1.344	1.769
SSB	10.000	2.000	12.000	3.460	1.002	2.325	6.649
ROI	0.457	-0.214	0.242	0.064	0.062	-0.631	4.209
TQ	25.870	0.770	26.630	2.050	1.343	4.281	36.952
CEOPARTY	1.000	0.000	1.000	0.230	0.421	1.280	-0.361
CEOEDU	1.000	0.000	1.000	0.500	0.500	-0.001	-2.000
CEOTENURE	18.000	1.000	19.000	4.660	3.192	1.121	1.082
CEOAGE	55.000	25.000	80.000	49.750	6.821	-0.066	0.504
LEV	0.809	0.050	0.859	0.376	0.190	0.290	-0.751
BTR	0.327	0.000	0.327	0.010	0.016	7.215	64.924
LNSS	9.260	3.180	12.440	7.684	1.135	0.461	0.506

5. Models

To test H1, Model (1) is built as follows. If α_2 to α_8 are statistically different from each other, H1 holds.

To test H2, Model (2) is built as follows. If α_9 to α_{15} are statistically different from each other, H2 holds.

$$RDI_{it} = \alpha_{it} + \alpha_1 EPG_{it} + \alpha_2 FEDN_{it} + \alpha_3 FNEDN_{it} + \alpha_4 FIDN_{it} + \alpha_5 FSN_{it} + \alpha_6 FCEO_{it} + \alpha_7 FCFO_{it} + \alpha_8 FNDEN_{it} + \alpha_9 EPG_{it} * FEDN_{it} + \alpha_{10} EPG_{it} * FNEDN_{it} + \alpha_{11} EPG_{it} + \alpha_{12} EPG_{it} * FSN_{it} + \alpha_{13} EPG_{it} * FCEO_{it} + \alpha_{14} EPG_{it} * FCFO_{it} + \alpha_{15} EPG_{it} * FNDEN_{it} + \alpha_{16} CONTROL_{it} + \sum REGION + \sum YEAR + \epsilon_{it} \tag{1}$$

$$RDI_{it} = \alpha_{it} + \alpha_1 EPG_{it} + \alpha_2 FEDN_{it} + \alpha_3 FNEDN_{it} + \alpha_4 FIDN_{it} + \alpha_5 FSN_{it} + \alpha_6 FCEO_{it} + \alpha_7 FCFO_{it} + \alpha_8 FNDEN_{it} + \alpha_9 EPG_{it} * FEDN_{it} + \alpha_{10} EPG_{it} * FNEDN_{it} + \alpha_{11} EPG_{it} + \alpha_{12} EPG_{it} * FSN_{it} + \alpha_{13} EPG_{it} * FCEO_{it} + \alpha_{14} EPG_{it} * FCFO_{it} + \alpha_{15} EPG_{it} * FNDEN_{it} + \alpha_{16} CONTROL_{it} + \sum REGION + \sum YEAR + \epsilon_{it} \tag{2}$$

6. Findings and Discussion

6.1. Main Results

Column I of Table 2 reports the regression results of Model (1). The coefficient of FED_N on RDI is significantly negative ($B=-0.193$, $P=0.000$), indicating the existence of a detrimental effect of female executive directors on R&D intensity. In a similar vein, female non-executive directors have negative effects on R&D intensity, while female CFOs and female independent directors have positive effects on R&D intensity. In contrast, female supervisors, female CEOs, and female non-director executives do not have significant relationships with R&D intensity. Hence, H1 holds. Column II of Table 2 reports the regression results of Model (2). The coefficient of ZEPG*ZFED_N on RDI is significantly negative ($B=-0.141$, $P=0.000$), indicating that executive pay gap would enhance the negative linkage between female executive directors and R&D intensity. In a similar vein, executive pay gap would weaken the negative impacts of female CEOs and female non-director executives on R&D intensity, while executive pay gap has no moderating effect on the associations of female independent directors, female supervisors, and female CFOs with R&D intensity. Hence, executive pay gap plays different moderating roles in determining the relationships between top female leaders with different positions and R&D intensity. H2 holds. Concerning the effects of the control variables on R&D intensity, the findings in this paper are largely consistent with previous studies. It is worth emphasizing that financial leverage ratio and firm age have a significant and stable restraining effect on R&D intensity, the proportion of executives' shareholding and CEO education background have a significant and stable promoting effect on R&D intensity, while the proportion of independent directors and CEO duality has no significant effect on R&D intensity.

Table 2. The results of empirical test and robustness test.

Variables	I	II	III	Variables	IV
	Model(1)	Model(2)	Model(3)		Model(4)
	RDI	RDI	RDI_IA		RDI
EPG	0.079** (2.253)	0.086** (2.451)	0.088*** (2.646)	EPG_A	0.113**** (3.720)
FED_N	-0.193*** (-2.751)	-0.166** (-2.359)	0.086 (1.288)	FED_N	0.069 (1.027)
FNED_N	-0.256*** (-4.903)	-0.243*** (-4.648)	-0.266*** (-5.345)	FNED_N	-0.265*** (-5.312)
FID_N	0.186*** (2.680)	0.183*** (2.645)	0.227*** (3.443)	FID_N	0.227*** (3.444)
FS_N	-0.021 (-.581)	-0.017 (-0.481)	-0.022 (-0.651)	FS_N	-0.028 (-0.833)
FCEO	-0.049 (-0.324)	-0.067 (-0.441)	-0.426*** (-2.932)	FCEO	-0.434*** (-3.012)
FCFO	0.145* (1.870)	0.132* (1.684)	0.162** (2.174)	FCFO	0.155** (2.088)
FNDE_N	0.000 (0.010)	-0.021 (-0.473)	-0.117*** (-2.778)	FNDE_N	-0.102** (-2.454)
ZEPG*ZFED_N		-0.141*** (-3.781)	-0.172*** (-4.844)	ZEPG_A*ZFED_N	-0.144*** (-4.072)
ZEPG*ZFED_N		-0.108** (-2.260)	-0.081* (-1.757)	ZEPG_A*ZFED_N	-0.078* (-1.741)
ZEPG*ZFID_N		0.023 (0.492)	0.053 (1.192)	ZEPG_A*ZFID_N	0.053 (1.202)
ZEPG*ZFS_N		-0.009 (-0.301)	0.006 (0.195)	ZEPG_A*ZFS_N	0.047 (1.607)
ZEPG*ZFCEO		0.057* (1.652)	0.073** (2.211)	ZEPG_A*ZFCEO	0.056* (1.810)
ZEPG*ZFCFO		0.056 (1.517)	0.007 (0.201)	ZEPG_A*ZFCFO	-0.007 (-0.212)
ZEPG*ZFND_N		0.082** (2.010)	0.169*** (4.366)	ZEPG_A*ZFND_N	0.124*** (3.355)
Controls	Yes	Yes	Yes	Controls	Yes
Year/Industry/Region	Yes	Yes	Yes	Year/Industry/Region	Yes
(Constants)	-19.283*** (-16.823)	-19.176*** (-16.686)	-6.816*** (-7.315)	(Constants)	-6.700 (-7.244)
F	103.070	90.380	50.136	F	50.898
Adj.R ²	0.263	0.266	0.168	Adj.R ²	0.168
N	14716	14716	14716	N	14716

Note: a. *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively. the same hereinafter.

EPG(executive pay gap); FED_N (The number of female executive directors); FNED_N(The number of female non-executive directors); FID_N(The number of female independent directors); FS_N(The number of female supervisors); FCEO(Female Chief Executive Officer); FCFO(Female Chief Financial Officers); FNDE_N(The number of female non-director executives).

6.2. Robustness Test

The four robustness tests have been executed to ensure the validity of the empirical results. First, to replace RDI in Model (2) with RDI_IA, Model (3) has been built. Column III of Table 2 reports the regression results of Model (3). Second, to replace EPG in Model (2) with EPG_A, Model (4) has been built. Column IV of Table 2 reports the regression results of Model (4). Third, considering the potential time lagging effect, the paper replaces RDI_t in Model (1) and Model (2) with RDI_(t+1) and executes the same empirical analyses. Finally, considering the potential endogenous problem of top female leaders, this study has executed the residual regression analysis method based on Model (1).

7. Conclusion and Contribution

This paper seeks to examine how top female leaders with different positions determine R&D intensity, and how executive pay gap moderates the linkages between multiple kinds of top leaders and R&D intensity, based on the data consisting of 14716 firm-year observations collected from Chinese A-share manufacturing enterprises over 2010–2020. It was found that for manufacturing enterprises, (1) top female leaders in different positions, including CEO, CFO, independent director, executive director, non-executive director, non-director executives, and supervisors, have distinct relationships with R&D intensity. The analysis of the empirical results shows that female executive directors and female non-executive directors have a negative impact on R&D intensity, while female CFOs and female independent directors have a positive contribution to the R&D intensity of an company, in contrast to female supervisors, female CEOs, and female non-director executives who do not have a significant relationship with R&D intensity; (2) executive pay gap would moderate the impact of top female leaders in different positions with R&D intensity to varying degrees. For female chief executive directors and female non-executive directors, the executive pay gap strengthens the negative impact on R&D intensity; for female chief executive officers and female non-director executives the negative impact on R&D intensity is weakened by executive pay; and the executive pay gap does not have a significant moderating effect on the impact on R&D intensity of female independent directors, female supervisors, and female chief financial executives.

The main theoretical contributions of this paper are as follows. Firstly, the paper explains the relationship between senior female leaders in different positions and R&D intensity. Although previous studies have explored the relationship between female leaders and R&D intensity, they have mostly discussed it from a single perspective, ignoring the possible differential impact of diverse positions. On this basis, this paper combines the positional characteristics and female characteristics of top female leaders in different positions in the context of manufacturing industry, and analyses and compares them in a multi-level and multi-angle way, enriching the decision-making mechanism of R&D activities from the perspective of the executive pay gap within the company. Secondly, based on the tournament theory, this paper confirms the different effects played by female leaders in different positions in the process of R&D investment from the perspective of competition. Previous research has examined women and corporate behaviour from the perspectives of women's individual characteristics, motivation, and leadership styles, but few studies have explored the relationship between women leaders and R&D intensity in the context of the pay gap from a competitive perspective. The results of this study not only provide a new theoretical perspective to explain the research related to female executives, but also enrich the application of tournament theory in related research. Finally, this study explores the boundary effect between female executives and R&D investment by integrating gender diversity, executive pay gap and technological innovation into a complete research framework, and further expands the research boundaries by introducing executive compensation as a moderating variable and exploring the different sensitivities of female executives in different functions in the same firm to the relationship between female executives and R&D intensity as explained by the pay gap perspective.

Our findings also have implications for organisations' management practices. Firstly, as mentioned above, high-level female leaders have a differential impact on R&D intensity. Therefore, organisations should rationally view the value of female leaders in the management process and rationally arrange the gender ratio in the management structure in order to carry out R&D activities more effectively. In addition, the role of female leaders in different positions on R&D intensity is also inconsistent. Companies should strengthen the analysis of job characteristics and help female leaders better understand R&D through training and exchanges to ensure the success rate of R&D while improving R&D intensity. For example, a female independent board of directors positively affects R&D intensity, while executive and non-executive directors decrease the company's R&D intensity. Therefore, there should be more exchanges of views between directors to come up with reasonable solutions through multiple efforts. Secondly, pay gap can effectively improve the relationship between female leaders and R&D intensity, so companies should control the pay gap between executives. This can give leaders a higher sense of fairness, enhance their initiative and effort, and thus improve R&D intensity. At the same time, it should be noted that in the process of regulating the pay gap, it should not be different because of the gender structure, otherwise it may reduce the incentive effect brought by the pay difference.

Although this paper has made many contributions, it still has some deficiencies. Firstly, although this paper breaks the limitation of the previous single perspective research and explains the influence of different female leaders on R&D intensity, the study only starts from female leaders and does not combine male leaders, so it

cannot analyse what kind of gender ratio can enhance R&D intensity more effectively. The follow-up study can introduce male leaders and conduct a study based on the differences between male and female leaders to explore the differences in gender structure on R&D intensity in different leadership positions. Secondly, this paper explores the boundary effect between female leaders and R&D intensity based on the pay gap perspective, but there are many more factors that can influence female leaders' decision-making. For example, the cultural environment, female leader traits, and the leader's informal position in the organisation. Therefore, in the future, more perspectives can be explored to improve the boundary conditions between the two. Finally, this paper emphasises the relationship between female leaders and R&D intensity, but willingness to make R&D investment does not mean that R&D can be successful. So are female leaders successful after making R&D investment decisions? This paper does not explain it. Therefore, future research needs to delve further into the impact of female leaders' decisions on R&D success after R&D investment.

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