



The Impact of Chairman-Senior Management Team's Vertical Dyad Differences on R&D Intensity in the Context of Big Data Management

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Abstract. Big data technology has a profound impact on enterprise management. In the context of big data management, we used the 2010–2019 Shanghai and Shenzhen A-share manufacturing listed companies as samples, examined the relationship between the chairman-senior management team's vertical dyad differences, risk-taking and R&D intensity. The results showed that the vertical dyad differences of the chairman-senior management team's age, tenure, and professional experience are positively correlated with enterprise R&D intensity; the vertical dyad differences of the chairman-senior management team's age and tenure are negatively related to corporate risk taking, while the vertical dyad differences of professional experience are positively correlated with corporate risk-taking. Further research found that corporate risk-taking completely concealed the positive impact of the vertical dyad differences of the chairman-senior management team's age and tenure in R&D intensity, while the vertical dyad differences of professional experience played a part of the mediating effect on R&D intensity. Therefore, the accurate management of human capital through big data technology can improve the scientificity and rationality of enterprise management decisions, and then create a good environment for enterprise innovation and development.

Keywords: Vertical dyad differences · Risk-taking · R&D intensity · Big data management

1 Introduction

As China enters a stage of high-quality development, it is particularly important to adhere to innovation-driven development and comprehensively shape new advantages of development. The application of big data technology is also one way. As the basis of the real economy, manufacturing industry is the lifeblood of China's economic development, and also an important basis for participating in international competition and enhancing competitive advantages. Since the reform and opening up, China's manufacturing industry has developed rapidly, but it still faces the problem of "large but not strong, complete but not excellent". The independent research and innovation ability of enterprises are

not strong, which is closely related to the high risk of R&D project investment and the risk-taking of management. As the maker and implementer of corporate decisions, the management has the right to decide R&D investment, but may make non-optimal innovation investment decisions due to the influence of personal interests and the structural characteristics of the whole team. Previous studies based on managers as a whole ignored that managers' behavior would be affected by the differences between upper and lower levels within the team. In recent years, the study of vertical dyad differences within groups based on demographic characteristics and the influence of intra-group interactions under such differences has gradually attracted academic attention. At the same time, big data technology provides convenient conditions for precise management of human capital. Therefore, based on the background of big data management, this paper explores the impact of the age, tenure and professional experience of the chairman-senior management team on the R&D intensity of manufacturing enterprises from the perspective of vertical dyad differences. Since R&D is a high-risk and high-yield activity, once the failure of R&D will bring some losses to enterprises, enterprises need to weigh the possible gains and losses and make appropriate investment decisions. In order to pursue the sustainable development of enterprises and improve their R&D and innovation capabilities, enterprises generally need to have high risk-bearing capacity to promote them to seize development opportunities and pursue risk premium. Therefore, this paper further examines whether the chairman-senior management team vertical dyad differences has an impact on R&D intensity through firm risk-taking level.

Encouraging enterprises to increase R&D investment and comprehensively enhance their independent innovation capabilities is an inherent requirement for the implementation of the national innovation-driven development strategy in the new era. This paper studies the effect of chairman-senior management team vertical dyad differences on enterprise R&D intensity from the perspectives of age, tenure and professional experience, reveals the relationship and mechanism between the internal composition and interaction of senior management team and R&D investment intensity. It provides theoretical basis for innovation-driven development of manufacturing enterprises. The contribution of this paper is as follows: first, it explores the impact of demographic characteristics of the internal structure and interaction of top management team on the R&D intensity of manufacturing firms, which enriches the research on the vertical dyad differences and firm innovation development; Second, based on the research on the effect of chairman-senior management team vertical dyad differences on R&D intensity, this paper introduces the variable of risk-taking, and tries to explore the role of risk-taking as a mediating variable, reveals the masking effect of risk-taking on the positive impact of age and tenure on R&D intensity. It provides ideas for the cultivation and innovative development of senior management team in manufacturing enterprises.

2 Research Hypotheses

2.1 The Vertical Dyad Differences and R&D Intensity

The research of the upper echelons theory on managers ignores the interaction within the senior management team due to the rank difference and team structure, and only considers the impact of the demographic characteristics of the senior management, such

as age and gender, on organizational behavior decisions and corporate performance. According to the similarity attraction theory of, the more similar team members are, the more likely they are to attract each other, because when they have some similar life attitudes, living environments and beliefs, it will be easier to communicate [1]. At the same time, working with others with similarity will increase the intimacy of the relationship, thus enhancing the cohesion of the team. With the deepening of research, scholars' research on similarity attraction theory has gradually shifted from belief and attitude to demographic variables that are easier to identify and measure. Tsui et al. studies the interaction between the upper and lower levels of the management team based on the similarity of demographic characteristics, and proposes the research paradigm of the vertical dyad differences of the senior management team [7]. The research introduces the position hierarchy of management team members, and finds that the more obvious the demographic difference between the supervisor and the subordinate, the less attractive the supervisor is to the subordinate. However, when the supervisor has higher education level and longer tenure than the subordinate, the subordinate is more attracted to the supervisor. This suggests that it is not just similar characteristics in senior management teams that can produce positive results, but that differences in certain characteristics can also have beneficial effects. The further studies point out that this difference can produce positive effects because it conforms to certain social norms [8]. Due to the difference in nature of each group, there are corresponding norms, and individuals in the group should show obedience to the norms, and keep consistent with the group. This informal mechanism will affect individual behavior. Once the social norms are violated, there may be inconsistencies and disunity within the team.

By introducing the social norm theory, the study explains the positive effect of vertical dyad differences. When scholars explain the impact of such differences, they usually take emotional factors into consideration. However, in Chinese enterprises, senior management teams often avoid adverse conflicts and maintain harmonious interpersonal relationships out of consideration of their own interests. Although the concept of modern corporate governance has been popularized and applied, influenced by the traditional bureaucratic culture, China's society has a distinct cultural background, and the enterprise management team is prone to the constraints of power and rank and more abide by social norms. In Chinese society, people's interactions are more easily affected by status and are more sensitive to authority and high-ranking figures [2]. And in China's listed companies, the chairman of the board has the greatest authority and represents the highest decision-making power. It is also clearly stated in the Company Law that the chairman is the highest person in charge of an enterprise and plays an important role in the operation of the company. Therefore, when the vertical dyad differences between chairman and top management team members conforms to certain social norms, it is beneficial to reduce the conflict within the team, and has a positive impact on the internal interaction of the team, thus affecting the company's decision.

Innovation is the driving force for the sustainable development of enterprises, which helps enterprises gain advantages in the industry competition and occupy a leading position. However, due to the influence of many factors, the R&D intensity of enterprises varies greatly. The senior management team as the epitome of an enterprise, and the formulation and implementation of corporate strategic decisions were deeply influenced

by the cognition or preference of the senior management team [3]. As a high-risk investment project, R&D investment is formulated and implemented by the senior management team, which is also affected by demographic differences within the senior management team. The chairman represents the interests of shareholders and will actively promote the continuous innovation of the enterprise from the perspective of long-term development of the company. When the vertical dyad differences of the chairman and senior management team is bigger, relative to the senior management team, the chairman is older and has longer term and richer professional experience, is more advantageous to the innovation of the company to make the optimal decision, and actively provides information and resources for senior management team. At the same time, the chairman has the greatest power in the senior management team. Due to his high ability and rich experience, the chairman can establish a higher authority and win the support and respect of the senior management team. In addition, when the average age, tenure and career experience of the senior management team is lower than that of the chairman, out of consideration for career, they are more motivated to work and are willing to improve corporate performance through active investment in research and development, so as to show their abilities and get career promotion opportunities. Vertical dyad differences also reflect on the characteristics of the chairman of the board of directors and senior management team cognition and the differences of values. Harmonious internal atmosphere and cooperation mechanism formed based on social norms can promote internal communication and thinking integration of team members. The greater vertical dyad difference is more advantageous to the formulation and implementation of the optimal investment decision. Based on the above analysis, this paper proposes hypotheses:

H1: The vertical dyad differences of the chairman-senior management team are positively correlated with the R&D intensity.

2.2 The Mediating Role of Risk-Taking

According to the similarity attraction theory and social norm theory, in addition to the characteristics of individuals or teams, the interaction within a team can also affect the outcome of enterprise decision-making, which may have an impact on enterprise risk-taking. On the one hand, managers' age, tenure, professional experience and other personal characteristics will make them have richer experience and experience, higher comprehensive quality, a good understanding of enterprise risks, a strong ability to deal with high-risk projects, and a strong tolerance for high-risk behaviors. On the other hand, managers with older, longer tenure and rich professional experience tend to accumulate more social resources, have greater power and prestige, and are more likely to win the trust and respect of subordinates. When the age, tenure and professional experience of the chairman-senior management team are more different, it will promote the exchange of views, improve the risk awareness level of the senior management team, and enhance the tolerance of risk.

Enterprises have to take certain risks when making various strategic decisions. The performance and development obtained by taking risks are their risk returns. From the perspective of sustainable development, enterprises should have high risk tolerance to pursue the risk premium brought by R&D activities and cultivate core competitiveness.

The R&D and innovation activities of enterprises require a large amount of capital investment, which affects the cash flow status of enterprises. However, due to the high risk, R&D investment does not necessarily bring benefits to enterprises, which requires enterprises to have a high risk-taking capacity. At the same time, higher risk-taking capacity will also encourage enterprises to actively grasp investment opportunities, enhance the enthusiasm of R&D investment, conducive to enterprise innovation. Combined with the above assumptions, this paper believes that when the vertical dyad differences between chairman and senior management team are greater, the senior management team is more inclined to take risks out of adhering to social norms and respecting and obeying the chairman's ability and authority, so as to improve the R&D intensity of the enterprise. Therefore, this paper proposes the hypothesis:

H2: Risk-taking is the mediating variable of the vertical dyad differences and enterprise R&D intensity.

3 Research Design

3.1 Definition of Variables

3.1.1 Explanatory Variables

In this paper, the explanatory variable is the vertical dyad differences of chairman-senior management team. Referring to previous studies, the senior management team is defined as chairman, general manager, manager, president, secretary of the board of directors, chief financial officer and other personnel stipulated in the company's articles of association [10]. And the vertical dyad differences between chairman and senior management team is measured from three aspects of age, tenure and professional experience [6]. In accordance with CSMAR database classification standard, professional experience divided into production, research and development, design, market, finance, human resources, management, finance, law, and other 10 class, if the chairman or senior manager have certain professional experience, the 1 of the assignment, or 0, numerical measure of the aggregation degree of rich professional experience. If the age of the chairman is bigger than the average age of the senior management team, the vertical dyad difference of age between the chairman and the senior management team (DIFA) is set to 1; otherwise, it is set to 0. If the chairman's tenure is greater than the average tenure of the senior management team, the vertical dyad difference of tenure between the chairman and the senior management team (DIFT) is set to 1; otherwise, the DIFT is set to 0. If the chairman has more professional experience than the average senior management team, the vertical dyad difference of professional experience between the chairman and the senior management team (DIFF) is set to 1; otherwise, the DIFF is set to 0.

3.1.2 Explained Variable

Research and development intensity (RD) is widely used by domestic and foreign scholars by referring to existing literature and measuring the proportion of R&D investment in the current year in the enterprise's operating income [5].

3.1.3 Mediator

Take Risk-taking as the mediator. Earnings volatility is widely used in all measures of risk-taking, so this paper also uses earnings volatility measure. The specific method is to adjust the annual corporate return on assets (Roa) minus the average industry return on assets (Roa) to obtain the adjusted corporate return on assets (Adj_Roa). Formula (1) is used to calculate the standard deviation of Adj_Roa in a three-year cycle (t – 1 to t + 1). Referring to the treatment method of He Ying et al., the risk-taking was multiplied by 100 during regression so that the dimension could be changed without affecting its significance [4].

$$Risk_{i,t} = \sqrt{\frac{1}{T - 1} \sum_{t=1}^T \left(Adj_Roa_{i,t} - \frac{1}{T} \sum_{t=1}^T Adj_Roa_{i,t} \right)^2} \tag{1}$$

3.1.4 Control Variables

Considering the influence of other variables on R&D intensity and risk-taking, in this paper, the number of board members (Board), ownership concentration (Top1), asset-liability ratio (Lev), growth of operating revenue (Growth), the size of company (Size) and the age of company (Age) are selected as control variables from three aspects of corporate governance, financial status and basic characteristics of the company. At the same time, the effects of industry and year variables were controlled.

3.2 Research Model

In order to verify the hypothesis mentioned above, this paper constructed model (2) to investigate the relationship of vertical dyad differences and firm R&D intensity, and (3) to investigate the relationship of vertical dyad differences and firm risk-taking. Finally, model (4) from the perspective of risk-taking, the path analysis of the impact of the vertical dyad differences on enterprise R&D intensity is conducted. Controls stand for control variables. DIF stand for explanatory variables.

$$RD_{i,t} = \beta_0 + \beta_1 DIF_{i,t} + \beta_2 Controls + \varepsilon_{i,t} \tag{2}$$

$$Risk_{i,t} = \beta_0 + \beta_1 DIF_{i,t} + \beta_2 Controls + \varepsilon_{i,t} \tag{3}$$

$$RD_{i,t} = \beta_0 + \beta_1 DIF_{i,t} + \beta_2 Risk_{i,t} + \beta_3 Controls + \varepsilon_{i,t} \tag{4}$$

3.3 Sample Selection and Data Sources

In this paper, A-share manufacturing listed companies in Shanghai and Shenzhen from 2010 to 2019 were selected as the initial research samples, and the samples were screened as follows: ST and *ST samples were removed; Annual observed values with missing values were removed; Eliminate the sample of companies that have been in existence

for less than five years. The data mainly came from the CSMAR database, in which the missing values of chairman's career experience were manually queried and supplemented by Sina Financial network, and 9517 samples observed values of 1181 companies were finally obtained. In order to reduce the deviation caused by extreme values to test results, Winsorize the upper and lower 1% of all continuous variables and use STATA 16.0 for data processing.

4 Empirical Test

4.1 Descriptive Statistics

The descriptive statistical results of main variables are shown in Table 1. Among them, the mean value and standard deviation of RD is 4.35 and 3.67, indicating that the R&D intensity of manufacturing enterprises is at a low level as a whole, and there is a large gap in R&D investment between enterprises. The mean of the DIFA is 0.84, and the median is 1, indicating that the age of the chairman of most listed companies was larger than the average age of the senior management team. The mean of the DIFT is 0.69, and the median is 1, indicating that the tenure of the chairman of most listed companies was longer than that of the average executive team. The mean of the DIFF is 0.30, and the median is 0, indicating that the chairman's professional experience of most listed companies is not as rich as the average level of senior management team. The mean of Risk is 0.03, indicating that the overall level is low.

4.2 Correlation Analysis

Pearson correlation coefficient was used for correlation analysis of main variables. According to Table 2, the DIFA, DIFT, DIFF and the RD are all positively correlated at the level of 1%, which preliminarily verifies that the vertical dyad differences of the chairman-senior management team may have a positive impact on the enterprise's R&D intensity. The Risk has a positive correlation with the RD and DIFF, while it has a negative correlation with the DIFA and DIFT.

Table 1. Descriptive statistics of variables.

Variable	Mean	Median	Max	Min	Standard Deviation
RD	4.350	3.620	25.44	0.02	3.670
DIFA	0.840	1	1	0	0.370
DIAT	0.690	1	1	0	0.460
DIFF	0.300	0	1	0	0.460
Risk	0.030	0.020	0.250	0	0.030

Table 2. The correlation analysis of main variables.

Variable	RD	DIFA	DIFT	DIFF	Risk
RD	1				
DIFA	0.054 ^{***}	1			
DIFT	0.109 ^{***}	0.257 ^{***}	1		
DIFF	0.053 ^{***}	-0.054 ^{***}	-0.060 ^{***}	1	
Risk	0.049 ^{***}	-0.042 ^{***}	-0.065 ^{***}	0.086 ^{***}	1

Note: * p < 0.1, ** p < 0.05, *** p < 0.01.

Table 3. Vertical dyad differences and R&D intensity.

Variable	RD	RD	RD
DIFA	0.403 ^{***} (4.54)		
DIFT		0.480 ^{***} (6.66)	
DIFF			0.169 ^{**} (2.17)
Controls	Yes	Yes	Yes
N	9517	9517	9517
Adj_R ²	0.204	0.206	0.203
F	139.842	144.943	138.850

Note: t statistics in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01. The regression results were corrected by Whited heteroscedasticity. The following table is the same.

4.3 Regression Analysis

4.3.1 The Vertical Dyad Differences and R&D Intensity

In this paper, model (2) is used to test the relationship between the vertical dyad differences of the chairman-senior management team and enterprise R&D intensity, and the regression results are shown in Table 3. We can find that, the regression coefficient of the DIFA, DIFT, DIFF with the RD was 0.403, 0.48 and 0.169 respectively, significance level of 1%, 1% and 5% respectively, indicating that the greater the vertical dyad differences of age, tenure and professional experience, the greater the R&D intensity of the enterprise, the assume H1 is verified.

4.3.2 The Mediating Effect of Risk-Taking

According to Table 4 and Table 5, the method of Wen Zhonglin et al. on mediating effect was used to test the mediating effect of risk taking [9]. If the independent variable X affects the dependent variable Y through the mediator M, then the model $Y = cX +$

Table 4. Vertical dyad differences and risk.

Variable	Risk	Risk	Risk
DIFA	-0.206** (-2.28)		
DIFT		-0.413*** (-5.81)	
DIFF			0.430*** (5.93)
Controls	Yes	Yes	Yes
N	9517	9517	9517
Adj_R ²	0.093	0.096	0.096
F	31.295	31.902	31.928

1, $M = aX + \varepsilon_2$, $Y = c'X + bM + \varepsilon_3$ can be tested in sequence. In the relationship between the DIFA, Risk and RD, $c = 0.403$, $a = -0.206$, $b = 0.048$, $c' = 0.413$, and all are significant, and the sign of indirect effect $a \times b$ is opposite to that of direct effect c' , indicating that Risk plays a masking role in the DIFA and RD, and $c' > c$, shows that risk-taking can completely hide the positive influence of vertical dyad difference of age on the enterprise R&D intensity, and the absolute value of proportion of the cover effect and the direct effect is $lab/c' = 2.39\%$. Similarly, risk-taking also can completely cover the DIFT on the RD. However, in the relationship between the DIFF, Risk and RD, $c = 0.169$, $a = 0.43$, $b = 0.045$, $c' = 0.149$, the coefficients are significant. The sign of indirect effect $a \times b$ is the same as the direct effect c' , and the mediating effect is established. And the mediation effect of total effect is $lab/c = 11.45\%$. Risk-taking therefore, in the relationship between the vertical dyad difference of professional experience and the enterprise R&D intensity has partial mediating effect.

4.4 Robustness Test

In order to enhance the reliability of the existence of mediating effect, the Bootstrap method was further used to test the effect of risk-taking on the relationship between vertical dyad differences and enterprise R&D intensity. Bootstrap method was used for 500 iterations, and the test results are shown in Table 6. As can be seen from Table 6, the indirect effect of the DIFA, DIFT, DIFF on the RD through Risk is in the 95% confidence interval do not contain 0, indicating that the indirect effect is significant, and the mediating effect and masking effect of risk-taking are still valid.

Table 5. The mediating effect.

Variable	RD	RD	RD
DIFA	0.413*** (4.63)		
DIFT		0.501*** (6.90)	
DIFF			0.149* (1.92)
Risk	0.048**** (3.48)	0.051*** (3.72)	0.045** (3.27)
Controls	Yes	Yes	Yes
N	9517	9517	9517
Adj_R ²	0.205	0.207	0.204
F	132.957	137.839	131.971

Table 6. The test results of bootstrap.

Variable	effect	coefficient	95% confidence interval	
DIFA	indirect	-0.0098	-0.0190	-0.0006
	direct	0.4129	0.2382	0.5875
DIFT	indirect	-0.0211	-0.0340	-0.0082
	direct	0.5008	0.3653	0.6363
DIFF	indirect	0.0194	0.0060	0.0327
	direct	0.1492	0.0029	0.2955

5 Conclusions

Based on research of enterprise human capital and R&D under the background of big data management, the following conclusions can be drawn from the research results: (1) the vertical dyad differences of age, tenure, and professional experience have a positive impact on the decision-making of senior management team, which is conducive to the innovation and development of manufacturing enterprises and the intensities of R&D investment; (2) The vertical dyad differences of age and tenure will reduce the level of enterprise risk-taking, while the vertical dyad difference of professional experience will improve the level of enterprise risk-taking; (3) Risk-taking does not play a mediating role between the vertical dyad differences of age and tenure of the chairman-senior management team and enterprise R&D intensity. However, it completely hides the positive effect vertical dyad differences of age and tenure on R&D intensity, while the vertical dyad difference of professional experience will make the decision prone to take risks, thus improving enterprise R&D intensity.

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