

## How TMT affects the innovative performance: the mediating role of R&D investment

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**ABSTRACT:** As values and cognitive basis, characteristics of top management team (TMT) attract much attention, but there are quite few research examining whether and how these exert any influence on firm innovative performance through R&D investment. Hence we examine the mechanism of TMT characteristics affecting firm innovative performance through R&D investment with a sample of A-share listed firms in Shanghai and Shenzhen from 2012 to 2017. We find that the proportion of female executives and the average age have a significant and negative impact on innovative performance, while the average tenure, the proportion of professional background and overseas background have a significant and positive effect on innovative performance. In addition, the average age, average tenure, proportion of professional background and proportion of overseas background are also intermediary variable factors to innovative performance through R&D investment. The findings of our study have some positive implications for the optimization of TMT structures, R&D investment resources allocation and firm innovative performance improvement.

**KEY WORDS:** characteristics of top management team (TMT); R&D investment; firm innovative performance; mediating effect

### I. INTRODUCTION

Innovation is not only an important endogenous variable of national economic growth, but also an effective way to promote the continuous development of enterprises. The 18th National Congress of the Communist Party of China clearly states that it is necessary to implement an innovation-driven development strategy and place innovation at the core of the overall development of the country [1]. Enterprise is the micro-unit of social and economic development. The factors influencing firm innovation performance have been widely concerned by the society. At present, most of the scholars' research on the factors influencing firm innovation performance is based on the assumption that managers are completely rational and homogeneous, and discuss the external factors such as industrial policy, government subsidies, national culture, or internal factors such as venture capital, firm size, and shareholding structure. These researches ignore the influence of limited rational managers. As a decision-making behavior led by enterprise managers, innovation must be directly influenced by TMT's management concept and risk awareness. According to the Upper Echelons, managers are the subjects of corporate strategic decision-making, and their management behaviors are the reflection of characteristics such as age, education, experience and so on. By observing the characteristics of managers, we can objectively study their impacts on corporate strategic choices and performance. This theory provides a scientific perspective to study the mechanism of characteristics of TMT on firm innovative performance. In addition, there have been some studies on TMT characteristics and enterprise innovation, which mainly based on the level of R&D investment to measure corporate innovation activities, and to examine whether the TMT influence the company's innovation trends and actions. There are a few scholars who study the direct impact of TMT on firm innovative performance, but few studies focus on the mediating effects of characteristics of TMT on firm innovative performance.

Based on the theoretical framework of “characteristics of TMT—strategic choice—enterprise performance”, this paper takes China's Shanghai and Shenzhen A-share listed companies as the research subject, and empirically tests the mechanism of interaction between TMT characteristics, R&D investment and firm innovative performance. The mediating effect model of TMT characteristics on firm innovative performance through R&D investment is put forward, which provides empirical support for further improving firm innovative performance.

## **II. LITERATURE REVIEW**

Scholars' research on the relationship between characteristics of TMT and corporate innovation is mainly based on the innovative behavior of R&D investment. Wally (2001) believes that the higher the average level of education of TMT is, the broader the management perspective will be, and the more innovative strategies will be developed to increase R&D investment of the company [2]. Wen Fang and Hu Yuming (2009) take Chinese listed companies as the research object and conclude that executives' technical experience and education level have a significant positive impact on R&D investment. The influence of executive tenure on R&D investment varies with executive age [3]. Guo Baochun and Zhang Dan (2013) take the GEM listed companies as a sample and find that the average age of TMT has a significant negative impact on the R&D investment, while the average education level, tenure and technical experience are positively correlated with R&D investment. In recent years, some scholars have begun to pay attention to the direct influence of characteristics of TMT on firm innovative performance. Zhu Guojun et al. (2013) use the GEM listed companies as a research sample and conclude that the average age, education level and tenure of TMT significantly inhibit the improvement of firm innovative performance, while technical experience of TMT has no significant influence on firm innovative performance[4]. With the sample of listed companies in the information technology industry from 2011 to 2014, Yang Guozhong and Yang Mingzhu (2016) find that the average age, education level and participation of female executives of TMT have no significant influence on firm innovative performance[5]. Dang Jianmin et al. (2017) use A-share wind power industry listed companies in Shanghai and Shenzhen from 2012 to 2017 as a research sample, and discover that the proportion of female executives has a significant positive impact on firm innovative performance [6].

Liu Fengchao et al. (2017) study A-share listed companies in China's computer, communication and other electronic equipment manufacturing industry, and the empirical results show that the proportion of overseas background executives in TMT has a positive effect on firm innovative performance [7]. These above-mentioned research focus on the direct impact of characteristics of TMT on R&D investment or innovative performance, but unfortunately the possible mediating role is placed in the back of their mind. Yang Lin et al. (2018) take the GEM listed companies as the research object and find that the overseas functional experience and industry experience of TMT have a direct impact on firm innovative performance, while R&D investment does have some moderating effect between the overseas functional experience and industry experience of TMT and firm innovative performance [8]. Using the sample of GEM listed companies from 2013 to 2015 as panel data, Hu Yanhua et al. (2018) demonstrate that there is a significant positive correlation between CEO education level, professional technical background and firm innovative performance, in which R&D investment exerts a partial mediating effect [9]. These studies provide a basis for this paper to examine the mediating effect of R&D investment between characteristics of TMT and firm innovative performance. Furthermore, the above research only considers the single characteristics of TMT or the individual CEO, and doesn't comprehensively analyze the mediating mechanism of TMT's characteristics on firm innovative performance. Therefore, based on Upper Echelons theory, this paper studies whether the proportion of female executives, average age, average tenure, average education level, proportion of professional background, and proportion of overseas background executives in TMT have any impacts on firm innovative performance, and how R&D investment plays a role in the relationship.

### III. THEORETICAL ANALYSIS AND RESEARCH HYPOTHESIS

#### **Characteristics of TMT and firm innovative performance**

**The proportion of female executives and firm innovative performance:** Gender differences in managers often lead to differences in management behavior. Compared with male executives, female executives are more sober-minded and cautious, when making decisions, and their expectations for market and corporate development are often lower showing obvious risk aversion. Li Linlin (2018) points out that female executives are more conservative in innovation decision-making, and tend to maintain the existing development scale and product technology level<sup>[10]</sup>. In addition, female managers are relatively poor in strategic thinking and may be more inclined to the stable growth of enterprises. Male managers are more likely to view issues from a long-term perspective and are more willing to take risks when faced with innovation investments that may get high returns. Enterprise innovation is a process of continuous trial. Faced with great uncertainty and risk, male executives may have more overall views and be able to make risky decisions from the strategic level of the enterprise, so that they can promote the organizational strategic change and improve the enterprise innovation. Accordingly, we put forward the following hypothesis:

**Hypothesis 1a:** The proportion of female executives has a negative influence on firm innovative performance.

**The average age of TMT and firm innovative performance** Age mainly affects managers' behavior choices from two aspects: the way you treat and risk tendency. On the one hand, the knowledge structure of older managers is gradually aging, and their learning ability is declining, which leads to the solidification of cognitive structure, and makes it easier to do things with experience. Therefore, older managers are less likely to make changes, discern new changes, seize new opportunities and solve new problems, which poses threat to the efficiency of innovative decision-making and the overall innovation ability of enterprises. On the other hand, Hambrick and Mason (1984) think that young managers are more willing to take risks, while older managers tend to avoid risks[11]. Innovation activities are generally long-term strategic investments with high risks and uncertain returns. Older managers prefer low-risk decisions and may be away from innovation activities. However, young managers have the courage to take risks, and they hope to obtain a sense of accomplishment in the development of enterprises. They are more likely to choose innovative strategies, improve innovation efficiency, and promote the improvement of firm innovative performance[12]. Accordingly, we propose the following hypothesis:

**Hypothesis 1b:** The average age of TMT has a negative influence on firm innovative performance.

**The average tenure of TMT and firm innovative performance** Tenure is an important factor influencing team operation process and managers' experience. Eisenhardt (1990) suggests that a longer team tenure could make the cooperation more coordinated among members. There is not enough time for communication among TMT members with short tenure, and there is a high possibility of friction when making decisions about the company's innovation strategy. While the long-tenure executive team members communicate and work together for a longer period of time, which helps to reduce internal conflicts and enhance team collaboration, thereby improving the efficiency of innovation decision-making and promoting enterprise innovation. Moreover, there is a lack of comprehensive understanding of the operating environment of the enterprise among managers with shorter tenure, so radical exploration and innovation is avoided and potential risks that companies may bear is reduced to some degree. With the increase of tenure, manager's knowledge level, social experience and management ability will be greatly improved, so it will be possible to judge maturely on the company's future innovation strategy and the future development direction of the industry and they are more likely to implement mature innovation strategies, which will improve firm innovative performance. Accordingly, we propose the following hypothesis:

**Hypothesis 1c:** The average tenure of TMT has a positive influence on firm innovative performance.

**The average education level of TMT and firm innovative performance** the manager's education level determines the individual's cognitive ability and professional level [13]. The higher the manager's education level is, the more complex the cognitive structure and the richer the knowledge reserve are. Well-educated managers can take full advantage of their knowledge to collect, identify and integrate effective information, and they are better in adapting to environmental changes, and seizing development opportunities. Enterprise innovation has high requirements for managers' opportunity recognition and cognitive ability, which requires managers to quickly obtain information and process it accurately. Managers with higher education have a more complete knowledge system and stronger information processing ability. They can identify market changes more quickly, acquire new knowledge and new technologies, formulating innovation strategies timely according to changes in market environment and situation, and improve enterprise innovation. Block et al. (2013) conclude that managers with

high degree are better in discovering, identifying, and creating opportunities to provide an enabling environment for knowledge to be transformed into innovation outcome. Accordingly, we put forward the following hypothesis:

**Hypothesis 1d:** The average education level of TMT has a positive influence on firm innovative performance.

**The proportion of professional background in TMT and firm innovative performance** The professional experience of managers in the professional field is an important factor affecting the strategic decision of managers. Managers are influenced by their previous work experience because they tend to deal with problems based on that and make relevant strategic decisions. Therefore, the more members with production or research professional background in TMT are, the more attention they pay to product innovation. In addition, managers with production or research professional backgrounds master the core technologies and competitiveness of industry, and have a better understanding of the development status and direction in the industry. Relying on their good command of professional knowledge and product technology, they are more likely to provide a broader perspective on the enterprise's technological innovation and increase the likelihood of innovation success. Accordingly, we propose the following hypothesis:

**Hypothesis 1e:** The proportion of production or research professional background in TMT has a positive influence on firm innovative performance.

**The proportion of overseas background in TMT and firm innovative performance** the overseas background plays an active role in optimizing the knowledge base and social network of TMT. Managers with overseas backgrounds have an international vision and can better absorb and learn from the advanced management experience of foreign high-quality enterprises through their study or work experience abroad, so as to make a more accurate assessment of the market environment and provide possibilities for strengthening the product upgrading and improving innovation ability of enterprises. From the perspective of social networks, managers with overseas background have a access to resources through dual social networks at home and abroad, which undoubtedly is a huge innovation advantages compared to other ones. Xu Chen and Lu Ping (2013) point out that the international networks of executives with overseas background provide convenience for enterprises innovate internationalization behavior, which has a positive impact on enterprise innovation. Therefore, the social relationship network of executives with overseas background is conducive to integrate domestic and foreign resources for innovation. Based on these above analyses, we propose the following hypothesis: Hypothesis 1f: The proportion of overseas background in TMT has a positive influence on firm innovative performance.

#### **Characteristics of TMT and R&D investment**

**The proportion of female executives and R&D investment:** Female executives are more delicate, cautious and sensitive, tend to avoid risks, and pursue stable development, while male executives are more adventurous and confident in decision-making. Facing high-risk and highly uncertain R&D investment, male executives are more confident in their ability to control risks and more willing to take on R&D risks to achieve possible high returns and long-term development of the company. On the other hand, female executives are more conservative and less risk-tolerant, which may avoid high-risk R&D activities and reduce R&D investment. Accordingly, we propose the following hypothesis: Hypothesis 2a: The proportion of female executives has a negative influence on R&D investment.

**The average age of TMT and R&D investment** Older managers with declining learning ability and self-adjustment ability, are susceptible to their reputation and retirement insurance and are more likely to choose a low-growth strategy. They tend to avoid risks, and are less willing to take risks from long-term R&D projects with uncertain returns. Younger executives have better learning ability and stronger sense of innovation so that their stronger risk tolerance, and ability to take a long-term view on their career development. Promote R&D investment. Accordingly, we offer the following hypothesis: Hypothesis 2b: The average age of TMT has a negative influence on R&D investment.

**The average tenure of TMT and R&D investment** Managers with long tenure possess a more comprehensive grasp of the internal and external information of the enterprise., enhanced ability to handle problems and respond to risks, and pay more attention to the long-term development of enterprises. Thus, when faced with high-risk activities as R&D investment, executives in long-term position have greater tolerance. Executives with short tenure are lack of work experience, and relatively lack of ability to deal with risks and make decisions. They need to invest more energy and pay more private costs when making R&D investment decisions, which may result in less enthusiasm for innovation. Accordingly, we offer the following hypothesis: Hypothesis 2c: The average tenure of TMT has a positive influence on R&D investment.

**The average education level of TMT and R&D investment** R&D activities are risky and have a long cycle, requiring managers to have higher risk identification ability and operational management ability in the R&D process. Highly educated managers are more confident in their ability to manage and respond to risks in R&D project. From the perspective of occupational safety, managers with high education level have great competitive advantages and low work conversion costs, so the short-term performance decline has a relatively less negative impact on work for them. They are more likely to abandon short-term gains and make decisions with long-term development. Accordingly, we offer the following hypothesis:

**Hypothesis 2d:** The average education level of TMT has a positive influence on R&D investment.

**The proportion of professional background in TMT and R&D investment** Managers with production or research professional backgrounds pay more attention to the technological development of enterprises and are more willing to increase R&D investment in products. Such managers have professional technical skills and have a keen insight into the effective information of R&D decisions. They can use the professional knowledge and skills to solve some of the technical bottlenecks and problems encountered in the R&D process. Based on these technologies and capabilities, managers with production or research professional backgrounds are more confident in making decisions on R&D activities and are more likely to increase R&D investment. Accordingly, we offer the following hypothesis: Hypothesis 2e: The proportion of production or research professional background in TMT has a positive influence on R&D investment.

**The proportion of overseas background in TMT and R&D investment** Song Jianbo and Wen Wen (2016) suggest that if managers overseas studied or worked before, it will help to have a deeper understanding of the importance of independent innovation and more willing to accept, absorb and transform new ideas [14]. In addition, because executives with overseas backgrounds are often better able to master international technology and management concepts, they always show higher self-expectations. Thus,

they are more likely to increase R&D investment and apply accumulated overseas experience to current corporate strategy decisions. Accordingly, we offer the following hypothesis:

**Hypothesis 2f:** The proportion of overseas background in TMT has a positive influence on R&D investment.

**The mediating effect of R&D investment** According to the analysis framework of “characteristics of TMT--strategic choice--enterprise performance”, executives with different demographic characteristics will have different perceptions of the internal and external environment of the enterprise, thus making different strategic decisions, which will affect corporate performance. Yang Lin et al. (2018) propose that the improvement of firm innovative performance mainly depends on R&D innovation, and R&D investment activities are the basis of R&D innovation. The differences in the demographic characteristics of TMT make their cognitive abilities and values different, and form different understandings of the importance of innovation activities, thus affecting R&D investment behavior and innovative performance. The results of Lee & Park (2008) show that the experience of TMT often indirectly affect corporate performance, by influencing corporate strategic decisions [15]. Therefore, this paper argues that there is a link between the characteristics of TMT and firm innovative performance. Both TMT characteristics and the strategic decision-makings of innovation activities are different, which affects R&D investment and ultimately leads to differences in firm innovative performance. R&D investment plays a mediating role in the relationship between characteristics of TMT and firm innovative performance. Hence, we propose the following hypothesis: Hypothesis 3: R&D investment plays a mediating role between the proportion of female executives (H3a), average age (H3b), average tenure (H3c), average education level (H3d), proportion of production or research professional background (H3e), proportion of overseas background (H3f) in TMT and firm innovative performance.

#### IV. DATA AND METHODS

**Sample** Our study uses the data of Shanghai and Shenzhen A-share listed companies from 2012 to 2017. The reason for choosing this interval is that the measurement of innovation performance requires patent application data, while China does not impose mandatory disclosure on the number of patent applications of listed companies. A large number of data before 2012 are missing, and 2017 is the latest annual data available for our study. The sample is screened by excluding ST\* and ST companies, financial and insurance listed companies, companies with unclear information on executives and related financial data. Finally, 5093 sample observations are obtained and STATA14.0 analysis software is



used for data processing. In order to eliminate the influence of outliers, 1% Winsorize tailing for all continuous variables is performed.

**Measures**

**Dependent variable:** Our dependent variable is firm innovative performance. There are two main indicators for measuring firm innovation performance at home and abroad: (1) the number of patent applications, patents granted, new products and services, and other research and development results indicators; (2) the profit rate of new products and services, market share of new products, proportion of new product sales revenue, and other financial results indicators. Based on the information disclosure of the listed company's annual report, we adopt the number of patent applications to measure firm innovative performance.

**Independent variable :** Independent variables are the characteristics of top management team. Based on relevant studies at home and abroad, we demonstrate that top management team include president general manager, vice president, deputy general manager, chief financial officer, chief accountant, chief engineer and top managers with other titles disclosed in the company's annual report. The characteristics of top management team include the proportion of female executives, average age, average tenure, average education level, proportion of production or research professional background, and proportion of overseas background.

**Mediating variable** Relative value and absolute value indicator are used to measure R&D investment. In order to improve comparability, relative value index, which is R&D input divided by operation revenue of the sample company, is used for measuring R&D investment

**Control variables** Other factors that may affect firm innovation performance are controlled in my study, including company size, growth opportunities, profitability, asset-liability ratio, and fixed asset ratio. In addition, Year and Industry are also control variables. The industry variables refer to “Guidelines for the Classification of Listed Companies in the Industry” revised by the CSRC in 2012.

Table 1 summarizes the specific definition of variables.

**Table 1 Definition of variables**

Property	Name	Label	Definition
Dependent variable	Firm innovative performance	LnPatent	The natural logarithm of the number of patent applications plus 1
Independent variable	Proportion of female executives	Female	The number of female executives divided by the total number of executives in TMT
	Average age	Age	Sum of executive age divided by the total number of executives in TMT
	Average tenure	Time	Sum of executive tenure divided by the total number of executives in TMT
	Average education level	Degree	Sum of executive education level divided by the total number of executives in TMT. Among them, 1 for high school or technical secondary school, 2 for junior college, 3 for bachelor's degree, 4 for master's degree and 5 for doctor's degree

	Proportion of production or research professional background	Career	The number of executives with background in production or research divided by the total number of executives in TMT
	Proportion of overseas background	Oversea	The number of executives with overseas background divided by the total number of executives in TMT
Mediating variable	R&D investment	R&D	R&D input divided by operation revenue and multiplied by 100
Control variables	Company size	Size	The natural logarithm of total assets of a listed company at the end of year
	Growth opportunities	Growth	Tobin q value
	Profitability	ROA	Net profit divided by total assets
	Asset-liability ratio	Lev	Total liabilities divided by total assets
	Fixed asset ratio	PPE	Fixed assets divided by total assets
	Year	Year	Based on 2012, set up 5 dummy variables
	Industry	Indu	According to a type of code, exclude industries without selected companies, divide into 14 industries and set up 13 dummy variables

**Model explanation :** We establish model (1) to test the influence of characteristics of top management team on firm innovative performance. Where M is the characteristic variable of TMT, Controls present the control variables.

$$\text{Patent}_{it} = \alpha_0 + \alpha_1 M_{it} + \alpha_2 \text{Controls}_{it} + \varepsilon_{it} \quad (1)$$

We establish model (2) to test the influence of characteristics of TMT on R&D investment.

$$R \& D_{it} = \beta_0 + \beta_1 M_{it} + \beta_2 \text{Controls}_{it} + \mu_{it} \quad (2)$$

We establish model (3) to test mediating role of R&D investment between characteristics of TMT and firm innovative performance.

$$\text{Patent}_{it} = \gamma_0 + \gamma_1 M_{it} + \gamma_2 R \& D_{it} + \gamma_3 \text{Controls}_{it} + \eta_{it} \quad (3)$$

## V. ANALYSIS AND RESULTS

**Descriptive statistics and correlation analysis:** Table 2 presents the descriptive statistics and correlative statistics of variables used in this paper. The mean and standard deviation of variables in Table 2 are close to those of the domestic study indicating the reliability and validity of the data. From correlation analysis, the characteristic variables of TMT are significantly correlated with R&D investment and firm innovative performance with the exception of average academic qualifications. Except that the correlation coefficient between firm size and asset-liability ratio is 0.55, the correlation coefficient between other variables is less than 0.5. The test of variance inflation factor (VIF) shows that the maximum VIF for each variable is 2.48, and the average VIF is 1.58, which is far less than 10, indicating that there is no significant multicollinearity problem among variables. In order to avoid the influence of heteroscedasticity, we use the ordinary least squares (OLS) method of robust standard error for regression.

**Table 2 The descriptive statistics and correlative statistics of variables**

Variable	Mean	Std	Patent	R&D	Female	Age	Time	Degree	Career	Oversea	Size	Growth	ROA	Lev	PPE
Patent	3.98	1.74	1												
R&D	4.57	4.28	0.11 ***	1											
Female	0.15	0.16	-0.10 ***	0.05 ***	1										
Age	46.91	3.58	0.05 ***	-0.12* **	-0.17 ***	1									
Time	53.23	21.81	0.08 ***	0.01	-0.08 ***	0.34* **	1								
Degree	3.25	0.51	0.02	-0.01	-0.02	0.03* *	-0.003	1							
Career	0.33	0.23	0.07 ***	0.20 ***	-0.15 ***	0.09* **	0.02	0.01	1						
Oversea	0.06	0.11	0.05 ***	0.14 ***	0.04 ***	-0.03* **	0.001	-0.03*	0.04 ***	1					
Size	21.97	1.09	0.36 ***	-0.25* **	-0.14 ***	0.23* **	0.13 ***	0.06 ***	-0.13 ***	-0.01	1				
Growth	2.48	1.94	-0.16 ***	0.30 ***	0.15 ***	-0.12* **	-0.04 ***	-0.04 ***	0.02* **	0.09 ***	-0.47 ***	1			
ROA	0.04	0.05	0.07 ***	0.04 ***	0.07 ***	-0.05* **	0.03 **	0.03 **	0.004	0.04 ***	-0.04 ***	0.32 ***	1		
Lev	0.39	0.19	0.16 ***	-0.33* **	-0.13 ***	0.14* **	0.02	0.05 ***	-0.13 ***	-0.06 ***	0.55 ***	-0.46 ***	-0.38 ***	1	
PPE	0.21	0.13	-0.04 ***	-0.23* **	-0.11 ***	0.14* **	0.05 ***	0.03 **	0.06 ***	-0.06 ***	0.08 ***	-0.18 ***	-0.21 ***	0.15* **	1

Note: \*\*\*, \*\* and \* indicate significant levels at 1%, 5% and 10% respectively. The sample size N = 5093



**Regression analysis of characteristics of TMT and firm innovative performance:** We use model (1) to test the relationship between characteristics of TMT and firm innovative performance. In a gesture to better examine the impact of the characteristics of TMT on firm innovative performance, we first put the individual characteristic variables of TMT into the model separately, and finally put all the characteristic variables together into the model. The regression results of model 2 and 3 show that the proportion of female executives, average age and firm innovative performance are significantly negatively correlated ( $\beta=-0.324$ ,  $p<0.05$ ;  $\beta=-0.022$ ,  $p<0.01$ ), so H1a and H1b are supported. The regression results of models 4, 6, and 7 show that the average tenure, proportion of production or research professional background, and proportion of overseas background are significantly positively correlated with firm innovative performance ( $\beta=0.002$ ,  $p<0.10$ ;  $\beta=0.529$ ,  $p<0.01$ ;  $\beta=0.627$ ,  $p < 0.01$ ), thus, H1c, H1e and H1f are supported. The regression result of Model 5 shows that there is a negative correlation between the average education level and firm innovative performance, but it is not significant ( $\beta=-0.015$ ). H1d is not supported. In the full model 8, the positive effect of average tenure are significantly increased from 10% to 1%, and the direction and significance level of the regression coefficients of remaining independent variables don't change.

**Table 3 The return results of characteristics of TMT and firm innovative performance**

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Size	0.590*** (19.16)	0.585*** (18.98)	0.602*** (19.43)	0.586*** (19.01)	0.590*** (19.15)	0.602*** (19.54)	0.585*** (19.04)	0.605*** (19.54)
Growth	-0.052*** (-3.19)	-0.050*** (-3.08)	-0.053*** (-3.27)	-0.051*** (-3.10)	-0.052*** (-3.19)	-0.046*** (-2.85)	-0.056*** (-3.44)	-0.048*** (-2.97)
ROA	2.195*** (4.40)	2.214*** (4.43)	2.186*** (4.43)	2.155*** (4.30)	2.204*** (4.41)	2.193*** (4.42)	2.228*** (4.47)	2.165*** (4.37)
Lev	0.191 (1.20)	0.182 (1.15)	0.191 (1.21)	0.204 (1.28)	0.193 (1.22)	0.251 (1.59)	0.203 (1.28)	0.281* (1.79)
PPE	-1.497*** (-7.96)	-1.518*** (-8.07)	-1.451*** (-7.69)	-1.512*** (-8.06)	-1.496*** (-7.95)	-1.545*** (-8.23)	-1.477*** (-7.84)	-1.511*** (-8.04)
Female		-0.324** (-2.35)						-0.287** (-2.05)
Age			-0.022*** (-3.49)					-0.034*** (-5.07)
Time				0.002* (1.79)				0.003*** (3.04)
Degree					-0.015 (-0.35)			-0.013 (-0.30)

Career						0.529*** (5.39)		0.540*** (5.44)
Oversea							0.627*** (3.34)	0.565*** (3.02)
Constant	-10.331*** (-15.54)	-10.159*** (-15.22)	-9.548*** (-13.74)	-10.328*** (-15.52)	-10.287*** (-15.28)	-10.735*** (-16.04)	-10.243*** (-15.42)	-9.277*** (-13.16)
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Indu	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj-R <sup>2</sup>	0.243	0.244	0.245	0.244	0.243	0.247	0.245	0.254
F	63.78	61.11	61.62	61.23	61.12	63.25	61.86	53.89

Note: \*\*\*, \*\* and \* indicate significant levels at 1%, 5% and 10% respectively. The sample size N = 5093

**Regression analysis of characteristics of TMT and R&D investment:** We use model (2) to test the relationship between characteristics of TMT and R&D investment. In order to better examine the impact of various characteristics of TMT on R&D investment, we first put each characteristic variable of TMT into the model separately, and finally put all the characteristic variables into the model for regression. The regression results of Model 2 shows that the proportion of female executives is negatively correlated with R&D investment ( $\beta=-0.548$ ,  $p<0.10$ ). When adding other independent variables, the negative effect of the proportion of female executives decreases significantly from 10% to insignificant. H2a isn't supported. The regression results of model 4, 5, 6, and 7 show that the average tenure, average education level, proportion of production or research professional background, proportion of overseas background and R&D investment are significantly positively correlated ( $\beta=0.006$ ,  $p<0.10$ ;  $\beta=0.236$ ,  $p<0.05$ ;  $\beta=3.033$ ,  $p<0.01$ ;  $\beta=3.464$ ,  $p<0.01$ ). H2c, H2d, H2e and H2f are supported. The regression result of Model 3 shows that there is a negative correlation between the average age and R&D investment, but it isn't significant ( $\beta=-0.011$ ). When adding other independent variables, the negative effect of average age increases significant to the level of 1%. H2b is supported.

**Table 4 The return results of characteristics of TMT and R&D investment**

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Size	0.234*** (3.64)	0.226*** (3.52)	0.240*** (3.70)	0.220*** (3.42)	0.232*** (3.60)	0.303*** (4.72)	0.208** * (3.28)	0.284*** (4.45)
Growth	0.451*** (9.31)	0.454*** (9.36)	0.451*** (9.26)	0.455*** (9.37)	0.453*** (9.33)	0.484*** (10.13)	0.426** * (8.88)	0.465*** (9.81)
ROA	- 14.331** *	- 14.299** *	- 14.335** *	- 14.460** *	- 14.483** *	- 14.343** *	- 14.144* **	- 14.499** *

	(-9.44)	(-9.41)	(-9.44)	(-9.51)	(-9.50)	(-9.66)	(-9.41)	(-9.78)
Lev	-5.114*** (-13.53)	-5.13*** (-13.57)	- 5.114*** (-13.53)	- 5.071*** (-13.40)	- 5.144*** (-13.59)	- 4.768*** (-13.01)	- 5.047** * (-13.47)	- 4.683*** (-12.86)
PPE	-4.334*** (-11.04)	- 4.369*** (-11.12)	- 4.312*** (-10.98)	- 4.399*** (-11.23)	- 4.353*** (-11.06)	- 4.612*** (-11.76)	- 4.226** * (6.53)	- 4.518*** (-11.60)
Female		-0.548* (-1.65)						-0.030 (-0.09)
Age			-0.011 (-0.71)					- 0.046*** (-2.85)
Time				0.006*** (2.65)				0.008*** (3.14)
Degree					0.236** (2.32)			0.237** (2.40)
Career						3.033*** (12.07)		3.019*** (12.08)
Overse a							3.464** * (6.53)	3.211*** (6.14)
Consta nt	-0.025 (-0.02)	0.266 (0.20)	0.344 (0.24)	-0.015 (-0.01)	-0.717 (-0.52)	-2.345* (-1.71)	0.460 (0.34)	-0.947 (-0.64)
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Indu	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj-R <sup>2</sup>	0.296	0.296	0.296	0.297	0.296	0.319	0.304	0.328
F	96.59	91.23	91.38	92.14	91.62	94.15	92.53	78.28

Note: \*\*\*, \*\* and \* indicate significant levels at 1%, 5% and 10% respectively. The sample size N = 5093 5.4 Analysis of the mediating effect of R&D investment Model (3) is utilized to test the mediating effect of R&D investment. and the Bootstrap method is applied to test the mediating effect. When examining a certain TMT's

characteristic variable, other characteristic variables are put into the model as control variables to verify whether the coefficient product is significantly 0 with the sample size of 5000. Table 5 shows the results of the mediating effect test of R&D investment. Indirect means the indirect influence of the mediating path and Direct indicates the direct influence of the dependent variable on the independent variable after controlling the mediating variable. When the independent variable is the proportion of female executives, the confidence interval of the coefficient product term is between -0.051 and 0.026, including 0, indicating that the indirect effect is not significant. After controlling mediating variable, the direct effect of the proportion of female executives on innovative performance is significant. The confidence interval is between -0.746 and -0.183, excluding 0, which indicates that the proportion of female executives has a significant negative impact on innovative performance, but not through R&D investment. H3a is not supported and the reason may be that after adding other characteristic variables, the impact of the proportion of female executives on R&D investment is offset. When the other characteristic variables are removed, the confidence interval of the coefficient product term is [-0.095, -0.005], and the indirect effect is significant, which confirms the above conjecture. When the independent variable is the average age, the confidence interval of the coefficient product term is between -0.008 and -0.002, and doesn't contain 0, indicating that the indirect effect is significant. After controlling the mediating variables, the direct effect of average age on innovative performance is significant.

The confidence interval is between -0.042 and -0.014, excluding 0, indicating that R&D investment plays a partial mediating role between the average age and innovative performance. Consequently, H3b is supported. When the independent variable is the average tenure, the confidence interval of the coefficient product term is between 0.0001 and 0.001, excluding 0, indicating that the indirect effect is significant. After controlling the mediating variables, the direct effect is significant, the confidence interval is between 0.001 and 0.005, and doesn't include 0, indicating that R&D investment plays a partial mediating role between the average tenure and innovative performance. So, we can draw the conclusion that H3c is supported. When the independent variable is the average education level, the indirect effect and the direct effect are not significant, and the confidence intervals are [-0.003, 0.024] and [-0.113, 0.057] respectively, including 0, indicating that the average education level doesn't affect firm innovative performance, which is consistent with the test result of H1d. H3d is not supported unfortunately. When the independent variable is the proportion of production or research professional background in TMT, the confidence interval of the coefficient product term is between 0.076 and 0.225, excluding 0, indicating that the indirect effect is significant. After controlling the mediating variables, the direct effect is significant, and the confidence interval is between 0.186 and 0.594, which doesn't include 0, indicating that R&D investment plays a partial mediating role between the proportion of production or research professional background and innovative performance. H3e is supported. When the independent variable is the proportion of overseas background, both the indirect effect and the direct effect are significant. The confidence intervals are [-0.081, 0.280] and [-0.015, 0.753], excluding 0, indicating that R&D investment plays a partial mediating role between the proportion of overseas background and innovative performance. H3f is supported.

**Table 5 The results of the mediating effect of R&D investment**

		Observed Coef.	BS S.E.	z	p	[95% Conf.Interval]	
Female	Indirect	-0.0126	0.020	-0.64	0.525	-0.051	0.026
	Direct	-0.465	0.144	-3.24	0.001	-0.746	-0.183
Age	Indirect	-0.005	0.001	-3.24	0.001	-0.008	-0.002
	Direct	-0.028	0.006	-4.01	0.000	-0.042	-0.014
Time	Indirect	0.0005	0.0002	2.45	0.014	0.0001	0.001
	Direct	0.003	0.001	2.83	0.005	0.001	0.005
Degree	Indirect	0.010	0.007	1.51	0.130	-0.003	0.024
	Direct	-0.028	0.043	-0.64	0.521	-0.113	0.057

Career	Indirect	0.150	0.038	3.96	0.000	0.076	0.225
	Direct	0.390	0.104	3.76	0.000	0.186	0.594
Oversea	Indirect	0.181	0.051	3.56	0.000	0.081	0.280
	Direct	0.384	0.188	2.04	0.041	0.015	0.753

In order to make the results robust, we adopt the following methods: (1) empirically test the case where the

number of patent applications lags behind one year; (2) remove some control variables such as profitability and asset-liability ratio; (3) transform the regression method, and use the fixed-effect model to analyze model (1) and (2). The regression results of the robustness analysis are not significantly different from the previous major regression results.

## VI. CONCLUSION

With the data of Shanghai and Shenzhen A-share listed companies during 2012-2017, this paper empirically tests the relationship among characteristics of TMT, R&D investment and firm innovative performance. The findings are as follows. First, The characteristics of TMT have a direct impact on firm innovative performance. Among them, the proportion of female executives and average age have a significant negative impact on firm innovative performance. The average tenure, proportion of production or research professional background, and proportion of overseas background in TMT have a significant positive impact on firm innovative performance, while the impact of the average education level doesn't pass the significant test. Secondly, the characteristics of TMT have a significant impact on R&D investment. Among them, the average age of TMT has a significant negative impact on R&D investment. The average education level, average tenure, proportion of production or research professional background, and proportion of overseas background in TMT have a significant positive impact on R&D investment, while the impact of the proportion of female executives on R&D investment doesn't pass the significant test. Last but not least, R&D investment plays a part of mediating role between the average age, average tenure, proportion of production or research professional background, and proportion of overseas background in TMT and firm innovative performance. Based on above research discoveries and the situation of China's capital market, the following suggestions could be given due heed. In the first place, it is in urgent need to improve the stability of top management team members. The executive team has a longer average tenure, and members know each other better. They are more willing to communicate and cooperate. It is easier to reach an agreement when making decisions, which is conducive to the improvement of firm innovative performance. Second, on the premise of guaranteeing the stability of TMT, try to make TMT "younger". Managers should not only have rich management experience and strong social network, but also be challenging and innovative. Proper introduction of young managers can bring new business ideas to enterprises and become the driver of innovation decision-makings. Thirdly, overseas and production or research professional background in top management team should be given enough attention. Executives with overseas study or work experience can learn advanced foreign business concepts, and have a broader perspective on issues, which can open up new ideas for enterprises in the traditional business model. Executives with production or research professional background will lay emphasis on R&D. Their previous professional background and work experience are more conducive to understanding the technological frontiers and development trends in the field of the company, and stimulate their greater enthusiasm for innovation.

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