Research on the Influence of Executive Characteristics on the Innovation Capability of Listed Companies

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Abstract. Innovation is an important means to achieve national core competitiveness and sustainable development, and it is also a powerful driving force for corporate transformation and upgrading. As important decision-makers and managers of enterprises, the characteristics of top executives largely determine the direction and strategy of the company's development. This article selects data from the executive teams of A-share listed companies in China from 2015 to 2021, establishes an empirical research model, and comprehensively analyzes the impact of executive characteristics on the innovation ability of listed companies from two dimensions: homogeneity and heterogeneity of the executive team. The empirical results show that in terms of homogeneity, executives with higher average education level in TMT, higher proportion of executives with R&D and design backgrounds, and higher proportion of executives with overseas backgrounds are more conducive to corporate innovation. In terms of heterogeneity, the higher the level of heterogeneity in age, education level, tenure, and professional background of TMT members, the more it can promote the improvement of corporate innovation ability.

Keywords: Characteristics of senior management, enterprise innovation ability, top management team.

1. Research Background

In the second year of Donald Trump's presidency as the 45th President of the United States, the U.S. unilaterally announced tariff increases on Chinese imported goods, triggering the Sino-U.S. trade war. It also declared that it would no longer sell key components and technologies to ZTE Corporation for the following eight years, which instantly plunged ZTE, the second-largest communications equipment company in China and the fourth-largest globally, into deep trouble. Subsequently, the U.S. adopted a series of trade protection measures that significantly altered China's economy and even the global economy. The various events during this trade war, especially the "ZTE incident," have taught us that only through independent innovation and mastery of core technologies can China navigate rough waters and achieve long-term success. They also show that competition among nations over core innovative technologies is becoming increasingly fierce. As the economic structure changes, China must continuously innovate and steadily enhance its innovation capacity to maintain a strong competitive advantage. Innovation is a crucial means to achieve national core competitiveness and sustainable development, and it is also a powerful engine for corporate transformation and upgrading. To improve the country's overall strength and build an innovative nation, China must place independent innovation at the core of its current development strategy.

As major participants in the market economy, listed companies' innovation capability is not only vital to their own development but also significantly influences the entire economic system and innovation-driven growth. Therefore, exploring the relevant factors affecting the innovation capability of listed companies has substantial research and practical value. Executives, as key decision-makers and managers, largely determine the firm's development direction and strategies through their characteristics. When studying the innovation capability of listed companies, executive characteristics are also regarded as an important influencing factor. Executives' background traits, experience, and decision-making styles all have a considerable impact on corporate innovation capability. Such research not only helps reveal the internal mechanisms of innovation capability in listed companies but also provides a scientific basis for the selection and training of corporate executives, thereby enhancing firms' innovation capacity and core competitiveness. Currently, domestic and international scholars have begun to pay attention to the impact of executive characteristics on the innovation capability of listed companies. Some studies suggest that firm innovation capability is influenced by top managers' age, personality, and other traits, though the results remain controversial. Therefore, it is necessary to delve deeper into the mechanisms through which executive characteristics affect the innovation capability of listed companies, so as to broaden and deepen research in this field.

2. Literature Review

2.1. Internal Factors Affecting the Innovation Capability of Listed Companies

Through reviewing relevant international literature, it is found that scholars both at home and abroad have mainly studied the factors influencing corporate innovation capability from different perspectives such as corporate culture, internal management systems, and organizational structure.

Corporate culture plays a non-negligible role in enterprise development, particularly in innovation activities. Tatikonda [1] showed that corporate culture has a significant positive relationship with innovation. A positive corporate culture that encourages employees to take risks and innovate facilitates innovation activities, whereas a culture that emphasizes authority, conservatism, and stability inhibit innovation. The influence of management systems on innovation is mainly reflected in the following aspects: First, Amabile [2] proposed that a sound internal management system can enhance a firm's innovation capability; second, Laursen [3] found that flexible internal management systems are also beneficial to innovation, and listed companies adopting flat organizational structures perform better in innovation performance than those with traditional hierarchical structures. Corporate governance structure, as an internal governance mechanism, has received extensive attention for its impact on listed companies' innovation capability. Fama and Jensen [4] pointed out that larger board sizes weaken control over the company, thus making it easier to engage in innovative activities. Yermack [5] found that R&D expenditure increases with the proportion of independent directors on the board. Executive stock ownership can help mitigate agency problems; Finkelstein et al. [6] argued that executive shareholding can improve the balance between short-term and long-term interests, thereby increasing corporate innovation activities.

2.2. External Factors Affecting the Innovation Capability of Listed Companies

In recent years, researchers have begun to focus on the impact of the external environment on the innovation capability of listed companies. Here, the external environment refers to the macro environment in which the firm operates, including market competition, policy environment, technological development, and other factors.

Market competition is one of the main drivers of corporate innovation. Studies by Xiang and Wang [7] indicate that corporate innovation capability improves as market competition intensifies. The policy environment also has a significant impact on firms' innovation capability. Sun and Yang [8] showed that policy environment can positively affect corporate innovation capability; with policy support, firms find it easier to obtain funding and resources, thus enhancing innovation capability. Of course, the policy environment can also have negative effects; overly strict or incomplete policies may hinder corporate innovation. In the study of innovation policies, Guo [9] argued that innovation subsidy policies can significantly improve corporate innovation performance and effectively promote the number of patent outputs. However, Chen et al. [10] pointed out that subsidy policies represented by "government science and technology activity funding" do not help improve corporate innovation performance. Chen et al. [11] indicated that both government fiscal subsidies and tax incentives can stimulate firms' exploitative and exploratory innovation capabilities, but when formulating policies, the firm's development stage must be considered to determine the appropriate measures.

2.3. Homogeneity of Top Management Teams and Innovation Capability of Listed Companies

Team homogeneity refers to the average level of TMT members in terms of gender, age, education, etc., which to some extent reflects the overall internal characteristics based on cognition and values. O'Reilly [12] stated that teams with high homogeneity communicate more easily and more frequently, leading to a high level of behavioral integration. In this regard, Amazon et al. [13] argued that in novel environments, TMT members need to interact openly and frequently through rich face-to-face channels; the more similar team members' characteristics are, the smoother the communication.

TMT size is a key factor in group demography because it represents the structure and composition background of a team. Research on the relationship between TMT size and proactive orientation remains unclear. Bantel and Jackson[14] proposed that as TMT size grows, the diversity of opinions, values, and interests increases. Accordingly, Wen Fang et al. [15] suggested that larger groups possess more cognitive resources, which may help improve the group's knowledge, creativity, and performance. However, larger teams may also face greater conflicts, as potentially divergent views may prevail.

In addition, larger groups may encounter issues related to control and coordination, resulting in decreased performance. As Knight et al. [16] pointed out, as team size expands, the quality and quantity of communication among members tend to decline. Some studies show that younger managers promote innovation more than older ones. Hambrick et al.[17] indicated that they are more open to new ideas and have received more up-to-date education, which is therefore more relevant. Herrmann and Datta [18] argued that older managers have less ability to grasp new ideas and have limited capacity to handle challenging situations, which may explain their adoption of more conservative stances; such behaviors may restrict the firm's ability to cope with economic stagnation. According to Lu Xin [19], as top managers age, their risk tolerance declines, and their attitudes toward strategic choices change. Li Tao [20] showed that TMT average age is negatively correlated with corporate innovation capability; younger managers are generally agile and innovative, while older managers tend to be more comprehensive and conservative.

Research on the impact of gender on innovation yields mixed results. Herrmann et al. [18] found that women in decision-making positions have a positive effect on firm performance to some extent. Knight et al. [16] showed that, even after controlling for numerous firm characteristics and the direction of causality, the proportion of women in top management positions tends to positively affect corporate innovation. Chinese scholar Li Jinglin [21] stated that women on boards bring unique perspectives, experiences, and working styles different from men; they bring diverse knowledge and expertise, and this broader range of ideas and views helps teams integrate different knowledge and experience and discover new innovation opportunities.

Wiersema et al. [22] showed that top managers with higher education are more likely to use complex and diversified approaches to problem-solving and decision-making. Moreover, Camelo [23] argued that because the novelty of innovation generates uncertainty, these managers' greater ability to obtain information to reduce such uncertainty will promote innovation; in addition to enhancing the ability to generate creative solutions to complex problems, education also plays an important role in stimulating acceptance of new ideas, innovation needs, and creating a favorable environment for implementing innovation.

Executive tenure length affects innovation preferences. Barker et al. [24] found that over time, managers become more inclined to accept the status quo of their position and support fewer innovations and changes. Similarly, managers with longer tenure in an organization are more likely to be socialized to accept the organizational status quo and less likely to initiate and adopt new ways of doing things, whereas newly appointed top managers are more receptive to innovation because they bring fresh perspectives to their work. Mousa and Chowdhury [25] argued that with extended tenure, CEOs' business and management capabilities and familiarity with the internal and external environments also improve, which enhances the initiative to conduct innovation activities, increases R&D investment, and thus improves innovation capability.

Scholars have also studied executives' professional and overseas backgrounds. Finkelstein and Hambrick [26] proposed that experience accumulated by managers in other companies or industries is associated with more innovative ideas and with the breadth and diversity of perspectives managers hold within the organization. Wang et al. [27] showed that executives with R&D backgrounds have a significant positive impact on the quality of corporate technological innovation. Liu et al. [28] found that executives with overseas backgrounds significantly promote corporate innovation, especially breakthrough innovation, and that returnee chief technology officers have an even more prominent promoting effect. Yuan and Wen [29] pointed out in their study on executives' overseas experience that executives with overseas study or work experience are more proactive and contribute significantly to corporate innovation. However, Lin et al. [30], based on a sample of small and medium-sized high-tech companies, investigated the link between returnee executives and corporate innovation activities and found that firms with returnee CEOs did not show significantly improved innovation capability.

2.4. Heterogeneity of Top Management Teams and Innovation Capability of Listed Companies

Based on upper echelons theory, the heterogeneity of TMT characteristics is emphasized as an important factor affecting long-term firm operations. This heterogeneity refers to differences in individual backgrounds of team members, specifically in age, tenure, education level, and other background attributes. However, the impact of TMT heterogeneity on corporate innovation capability remains controversial. Some scholars argue that heterogeneity implies that management team members, based on their different cognitions, have multiple solutions and resources when facing problems, which facilitates organizational learning and performance improvement. Others contend that heterogeneity may undermine the identification of TMT members, inhibit the transfer of professional skills within the team, increase the likelihood of conflict, and generate greater divergence in strategic formulation and strategic goal behaviors.

Regarding age heterogeneity, according to Wu et al. [31], older executives may be relatively less receptive to new things and find it difficult to make innovative decisions in response to changing times. Sun et al. [32] pointed out that, in general, younger executives in TMTs tend to be creative and willing to take risks, while older managers possess rich experience and extensive networks and can integrate well. Therefore, increasing age heterogeneity in TMTs provides more diversified problem-analysis perspectives, offering more feasible solutions for corporate innovation and thus enhancing innovation capability. Wiersema and Bantel [22] also stated that age diversity increases different views on strategic issues facing the firm, stimulating consideration of change and thereby making the team less risk-averse. However, as age heterogeneity increases, this benefit gradually diminishes.

In terms of gender heterogeneity, Adams et al.[33] showed that GEM companies, compared to older and more structurally established firms, are more dynamic, passionate, and inclusive; thus, gender stereotypes within TMTs may be less prevalent, and increased gender heterogeneity is conducive to improving team decision-making and management efficiency. Wang et al. [34] indicated that members of different genders possess different thinking styles and perspectives; gender-diverse TMTs are beneficial to improving corporate innovation capability, and they also found that female executives play an even more positive role in promoting corporate innovation.

Reg] suggestedtion level heterogeneity, Knight et al. [16] suggested that TMT members, based on their own mindsets, believe they have succeeded in their careers (i.e., reached executive levels) and are more likely to trust their own approaches and persist with them. Therefore, higher education background heterogeneity increases conflict, makes it difficult to reach consensus on strategic decisions, reduces decision-making efficiency, and negatively affects innovation performance. Li et al. [35] argued that when team members have similar educational backgrounds, especially when all have relatively high education levels, the probability of endogenous conflicts is lower.

There are two different views in studies on TMT tenure heterogeneity. West and Anderson [36] indicated that TMT tenure has a positive effect on innovation, especially when TMT members have long-term cooperation; tenure heterogeneity positively affects innovation, but it is highly dependent on different contexts. Elenkov [37] showed that tenure heterogeneity positively moderates the relationship between strategic leadership behavior and product-market innovation as well as administrative innovation. Liu et al. [38] found that although longer TMT tenure stabilizes relationships and cooperation among members, and such good collaboration promotes innovation, excessive tenure differences reduce team cohesion and decision-making efficiency and negatively affect firm value.

Professional background heterogeneity refers to differences among TMT members in professional knowledge resources, experience and skills, and thinking styles due to different job tasks and professions. Bantel and Jackson [14] found that TMT heterogeneity in professional background is associated with a firm's ability to provide new services. Hambrick and Mason [17] suggested that background diversity may provide TMTs with broader information sources, skill sets, and social cognitive frameworks than homogeneous TMTs; they also argued that TMT professional background diversity affects the firm's ability to utilize its R&D investments and related new technology development capabilities. Ma et al. [39] showed that functional diversity leads to conflicts in work-related aspects and topics; such conflicts generate rich problem analysis and diverse solutions, positively affecting innovation.

Regarding overseas background heterogeneity, Liu et al. [20] pointed out that members from different countries bring extensive knowledge and experience from diverse institutional environments. When multinational teams strive to integrate and reconcile their different institutionally embedded experiences, they engage in in-depth discussions, consider various alternatives, and generate new creative ideas. Nielsen et al. [40] showed that because strategic decision-making is a task of high complexity, uncertainty, and lack of routine, nationality diversity improves the comprehensiveness and quality of TMT strategic decision-making, thereby affecting corporate innovation capability. Zheng[41] demonstrated that executives' overseas backgrounds can increase firms' R&D investment intensity, thereby promoting technological innovation and improving innovation capability.

3. Theoretical Foundations and Research Hypotheses

3.1. Upper Echelons Theory

Upper echelons theory was proposed by Hambrick and Mason [17], and it holds that the top management team consists of individuals responsible for disclosing information to external stakeholders. Overall, the importance of the TMT in firms has been fully affirmed, both in terms of the strategic decision-making process and its impact on firm performance. In subsequent studies, researchers have supplemented and revised upper echelons theory, arguing that the TMT is composed of individuals who are most deeply involved in decision-making and execution, and they have begun to pay more attention to the important role of the TMT in strategic decision-making and performance improvement.

3.2. Social Network Theory

Social network theory is a theory that studies the interconnections and interactions among individuals. It holds that individuals in society are not isolated but are linked and influenced through certain relationships, forming a network structure. These connections and influences can take many forms, such as kinship, friendship, work relationships, and knowledge exchange. In the field of innovation, social network theory has also been widely applied. Research shows that connections and interactions among individuals are crucial for the generation and promotion of innovation. In a closely connected social network, people are more likely to share information, learn from each other, and cooperate, thereby facilitating the occurrence of innovation. Enterprises can also cultivate relationships and open communication channels among TMT members to promote cross-departmental and cross-field knowledge exchange and collaboration, thereby accelerating innovation and improving corporate innovation capability.

3.3. Principal-Agent Theory

Principal-agent theory refers to the relationship and interaction between principals and agents within an organization. The origin of principal-agent theory can be traced back to the early 1970s. This theory holds that there is an agency relationship within the firm: shareholders, as principals, hire managers as agents to manage the company. Principal-agent theory can be used to explain the relationship between corporate executives and the innovation capability of listed companies. Executive characteristics affect a firm's innovation capability, but executives may incur agency costs—for example, they may pursue their own interests rather than those of shareholders, thereby undermining innovation capability. Therefore, how to reduce agency costs and enable executives to better fulfill their agency duties has become an important issue for improving the innovation capability of listed companies. Principal-agent theory proposes various methods to reduce agency costs. It can be used to explain the relationship between executive characteristics and innovation capability and to propose measures to reduce agency costs, thereby providing theoretical support for improving the innovation capability of listed companies.

3.4. Hypotheses on the Relationship between TMT Characteristics and Innovation Capability of Listed Companies

3.4.1. TMT Size and Innovation Capability of Listed Companies

TMT size refers to the number of team members. Generally, firms with larger TMTs possess more cognitive resources, which contribute to the group's knowledge, creativity, and performance [14]. However, larger teams may also face greater conflicts, as potentially divergent views may dominate. From the perspective of social networks, more team members also mean more social resources, greater capacity to raise funds, and better access to market dynamics, all of which are conducive to enhancing innovation capability. Therefore, we propose the following hypothesis:

H1: TMT size is significantly positively correlated with the innovation capability of listed companies.

3.4.2. TMT Age and Innovation Capability of Listed Companies

Manager age reflects their past professional experience, bounded rationality, and risk tolerance, thereby influencing their behavioral choices. Generally, younger managers tend to make risk-taking and innovative business decisions driven by passion, whereas older managers focus more on financial and career security and tend to avoid risks. Firms with higher average TMT age tend to adopt more conservative strategies and thus may miss market opportunities [24]. Compared with more homogeneous teams, age heterogeneity implies broader intellectual assets, richer information sources, and stronger abilities to solve novel problems. Therefore, we propose:

H2a: TMT average age is significantly negatively correlated with the innovation capability of listed companies.

H2b: TMT age heterogeneity is significantly positively correlated with the innovation capability of listed companies.

3.4.3. TMT Gender and Innovation Capability of Listed Companies

Generally, men and women have different risk preferences and risk perceptions. Traditionally, women are perceived as having lower risk tolerance than men, leading to conservative decision-making and difficulty in innovation. However, women can bring different viewpoints and ideas from men. Female managers are skilled in emotional expression, which helps create a positive innovation climate and enhance team creativity. Gender heterogeneity implies additional differences in experience, knowledge, and abilities associated with a particular gender. For example, based on the risk-taking propensity of male executives, they may initiate more innovations because they are more willing to change the status quo and more readily decide to adopt and allocate resources to innovation. On the other hand, female executives may have a greater influence on implementation than male executives, because they tend to use participative leadership styles, are socialized to show care and consideration, and better establish rapport with organizational members. Therefore, we propose:

H3a: The proportion of female executives in the TMT is significantly positively correlated with the innovation capability of listed companies.

H3b: TMT gender heterogeneity is significantly positively correlated with the innovation capability of listed companies.

3.4.4. TMT Education Level and Innovation Capability of Listed Companies

Education level reflects an individual's knowledge base, cognitive ability, information integration capacity, and decision-making skills[23]. It is also closely related to their openness to new ideas, adaptability to environmental changes, and information processing ability [27]. People with higher education have higher cognitive abilities to process and analyze information than those with lower education; therefore, executives with higher education can implement more complex decisions to manage ill-structured situations and make higher-quality decisions. However, higher education background heterogeneity may increase conflict, make it difficult to reach consensus on strategic decisions, reduce decision-making efficiency, and negatively affect innovation performance. Therefore, we propose:

H4a: TMT average education level is significantly positively correlated with the innovation capability of listed companies.

H4b: TMT education heterogeneity is significantly negatively correlated with the innovation capability of listed companies.

3.4.5. TMT Tenure and Innovation Capability of Listed Companies

Tenure is an important determinant of TMT functioning. We argue that longer-serving managers are more familiar with the firm, have richer management experience, and are less likely to make mistakes in corporate decisions. Good communication among members is based on tenure length; excessive tenure differences reduce team cohesion and decision-making efficiency and negatively affect firm value. Based on principal-agent theory, managers are agents employed by shareholders to manage the firm. Longer tenure and management experience enable managers to understand the firm's operating environment and internal conditions, thus making sound decisions for the company. Shorter tenure may not allow managers to fully understand the firm's long-term strategy and corporate culture, hindering good innovative decisions. Therefore, we hypothesize:

H5a: TMT average tenure is significantly positively correlated with the innovation capability of listed companies.

H5b: TMT tenure heterogeneity is significantly negatively correlated with the innovation capability of listed companies.

3.4.6. TMT Professional Background and Innovation Capability of Listed Companies

Professional background refers to whether executives have prior experience in R&D and design. Executives with R&D and design experience have a clearer understanding of the firm's technology development direction, thereby reducing investment risks and improving innovation efficiency, which is of great significance for corporate innovation. Firms with a higher proportion of executives with rich R&D and design experience tend to have more prominent innovation capability. Although TMT functional background heterogeneity may cause friction and conflict within the team, cross-professional experience can effectively enhance the team's decision-making and problem-solving capabilities. Based on this, we propose:

H6a: The proportion of executives with R&D and design backgrounds in the TMT is significantly positively correlated with the innovation capability of listed companies.

H6b: TMT professional background heterogeneity is significantly negatively correlated with the innovation capability of listed companies.

3.4.7. TMT Overseas Background and Innovation Capability of Listed Companies

Executives' overseas experience, as an important personal characteristic of the TMT, has a profound impact on the agglomeration and optimal allocation of innovation resources. Overseas study experience gives executives broader international perspectives and solid professional knowledge, which can compensate for managerial myopia. However, because they have lived abroad for a long time, they may lack in-depth understanding of the domestic market; thus, firms also need local executives to assist returnee executives in domestic operations. Therefore, overseas background heterogeneity is conducive to achieving integration of Chinese and foreign elements, drawing on foreign innovative technologies based on the local international market, and achieving sustainable development. In summary, we propose:

H7a: The proportion of executives with overseas backgrounds in the TMT is significantly positively correlated with the innovation capability of listed companies.

H7b: TMT overseas background heterogeneity is significantly positively correlated with the innovation capability of listed companies.

4. Research Design

4.1. Sample Selection and Data Sources

This paper selects A-share listed companies from 2015 to 2021 as the sample. We exclude listed companies in the financial industry, remove firms with abnormal financial status (ST and ST*), and eliminate companies with severe missing data. To avoid the influence of extreme values, we winsorize the main continuous variables at the 1% level. All data sources used in this paper come from the CSMAR database, with some individually missing data manually supplemented from company annual reports and the RESSET database. Finally, we obtain 15,136 observations and use Excel and Stata 17.0 for descriptive, correlation, and empirical analyses.

4.2. Variable Selection

Based on the foregoing discussion and referring to existing literature, we select variables and define their measurement methods, as detailed in Table 1.

4.2.1. Dependent Variable

The dependent variable in this paper is the innovation capability of listed companies. In measuring corporate innovation capability, following Xiao et al.[42], among the constructed indicators, six indicators including patent quality and R&D investment as a proportion of operating revenue have relatively high weights. After comparison, we refer to Li Tao et al.[26] and use the natural logarithm of (1 + the number of patent applications in the current year), (1 + the number of patent grants), and (1 + the number of patent citations) as dependent variables, and then conduct empirical analyses separately for each of the three dependent variables.

4.2.2. Independent Variables

The independent variables are TMT characteristics. Based on upper echelons theory and the studies of domestic and international scholars, following Li Tao [26] and Li Jinglin [27], we select seven variables: TMT size, age, gender, education level, tenure, professional background, and overseas background. We describe the impact of TMT characteristics on the innovation capability of listed companies from two dimensions—homogeneity and heterogeneity—resulting in a total of 13 variables, as shown in Table 1.

4.2.3. Control Variables

Existing research indicates that, in addition to TMT characteristics, corporate innovation capability is also affected by other factors. To control for the interference of these factors, we select the following control variables based on a summary of numerous studies and include them in the regression models to enhance the reliability of the results. The details are shown in Table 1.

Table 1. Variable Definitions.

Variable Type	Name	Symbol	Measurement
Dependent Variable	Innovation Capability of Listed Companies	*Pat1*	Ln (1 + number of patent applications in the reporting period)
		Pat2	Ln (1 + number of patent grants in the reporting period)
		Pat3	Ln (1 + number of patent citations in the reporting period)
Independent Variables	Team Size	*Tsize*	Total number of TMT members
	Average Age	*Aage*	Sum of members' ages / total number of team members
	Age Heterogeneity	*Dage*	Standard deviation of age / average age
	Proportion of Female Executives	*Agen*	Number of female executives / total team members
	Gender Heterogeneity	*Dgen*	$1 - \Sigma P_i^2$, where P_i is the proportion of each gender
	Average Education Level	*Aedu*	Average education level: 1 = below junior college; 2 = junior college; 3 = bachelor; 4 = master; 5 = doctor
	Education Heterogeneity	*Dedu*	$1 - \Sigma P_i^2$, where P_i is the proportion of each education level
	Average Tenure	*Aten*	Average tenure (in months)
	Tenure Heterogeneity	*Dten*	Standard deviation of tenure / average tenure
	Proportion of R&D/Design Background Executives	*Afunc*	Number of executives with R&D/design background / total team members
	Professional Background Heterogeneity	*Dfunc*	$1 - \Sigma P_i^2$, where P_i is the proportion of each professional background
	Proportion of Overseas Background Executives	*Aove*	Number of executives with overseas background / total team members
	Overseas Background Heterogeneity	*Dove*	$1 - \Sigma P_i^2$, where P_i is the proportion of each overseas background category
Control Variables	Firm Size	*Size*	Natural logarithm of total assets
	Firm Age	*Age*	Natural logarithm of the number of years since establishment to the end of period t
	Capital Structure	*Lev*	Total liabilities / total assets
	Profitability	*ROA*	Net profit / average total assets
	Ownership Concentration	*Cn*	Shareholding ratio of the largest shareholder
	Executive Equity Incentive	*Sto*	Executive shareholding ratio
	Government Support	*Gov*	Government subsidies / total assets
	Nature of Property Rights	*Own*	State-owned enterprise = 1, non-state-owned = 0
	Industry Dummy	*Ind*	High-tech enterprise = 1, non-high-tech = 0

Note: Herfindahl coefficient $H = 1 - \Sigma P_i^2$, where P_i is the proportion of the i-th category in the TMT. Larger H indicates greater differentiation.

4.3. Model Specification

Following the econometric models in previous literature, we construct the following multiple linear regression models. Model 1 tests the relationship between TMT homogeneity and listed companies' innovation capability; Model 2 tests the relationship between TMT heterogeneity and innovation capability; Model 3 tests the relationship between all TMT characteristics and innovation capability; Model 4 includes only control variables to analyze their impact on innovation capability.

$$\text{Model 1:}Y_i = \beta_0 + \beta_1 * \text{Explanatory VariabiesA}_i + \beta_2 * \text{Control Variabies}_i + \mu_i \quad (1)$$

$$\text{Model 2:}Y_i = \beta_0 + \beta_1 * Explanatory\ VariabiesD_i + \beta_2 * Control\ Variabies_i + \mu_i \quad (2)$$

$$\text{Model 3:}Y_i = \beta_0 + \beta_1 * Explanatory\ Variabiesi + \beta_2 * Control\ Variabies_i + \mu_i \quad (3)$$

$$\text{Model 4:}Y_i = \beta_0 + \beta_1 * Control\ VariabiesD_i + \mu_i \quad (4)$$

Where Y_i is the dependent variable, including *Pat1, Pat2,* and *Pat3*; Explanatory VariablesA represents a series of homogeneity variables, including Tsize, Aage, Agen, Aten, Aedu, Afunc, and Aove; Explanatory VariablesD represents a series of heterogeneity variables, including Dage, Dgen, Dedu, Dten, Dfunc, and Dove; Explanatory Variables includes all homogeneity and heterogeneity variables; Control Variables includes Size, Age, Lev, ROA, Cn, Sto, Gov, Own, and Ind; $\mu_i$is the random error term.

5. Empirical Analysis

5.1. Descriptive Statistical Analysis

5.1.1. Descriptive Statistics of the Dependent Variable (Full Sample)

Table 2. Descriptive Statistics of Innovation Capability of Listed Companies (Full Sample).

Variable	N	Mean	Std. Dev.	Min	Median	Max
pat1	15136	2.975	1.839	0	3.135	9.702
pat2	15136	2.753	1.767	0	2.944	9.212
pat3	15136	2.626	1.830	0	2.639	10.14

From Table 2, the means of the three indicators measuring corporate innovation capability range from 2.62 to 2.98, indicating that firms' innovation capability needs further improvement. The minimum values are all 0; the maximum for Pat3 reaches 10.14, while the other two are above 9.21; the standard deviations are around 1.80, indicating considerable differences in innovation capability among Chinese firms.

5.1.2. Descriptive Statistics of the Dependent Variable (Sub-samples)

Table 3. Descriptive Statistics of Innovation Capability by Sub-samples

Variable		N	Mean	Std. Dev.	Min	Median	Max	Variable
State-owned enterprises	*Pat*1	5983	2.988	2.051	0	3.135	9.613	
	*Pat*2	5983	2.769	1.967	0	2.944	8.978	
	*Pat*3	5983	2.666	2.039	0	2.639	10.03	
Non-state-owned enterprises	*Pat*1	9153	2.966	1.685	0	3.178	9.702	
	*Pat*2	9153	2.743	1.622	0	2.944	9.212	
	*Pat*3	9153	2.599	1.679	0	2.708	10.14	
High-tech enterprises	*Pat*1	6457	3.464	1.454	0	3.526	8.697	
	*Pat*2	6457	3.206	1.409	0	3.258	8.456	
	*Pat*3	6457	3.123	1.535	0	3.135	10.03	
Non-high-tech enterprises	*Pat*1	8679	2.610	2.003	0	2.708	9.702	
	*Pat*2	8679	2.416	1.923	0	2.485	9.212	
	*Pat*3	8679	2.255	1.941	0	2.079	10.14	

As shown in Table 3, there are 5,983 state-owned enterprise observations and 9,153 non-state-owned observations; 6,457 high-tech and 8,679 non-high-tech observations. ① In terms of means, both state-owned and non-state-owned firms have patent application and grant numbers (ln+1) around 2.9 and 2.7, respectively, with little difference, but state-owned firms are slightly higher; the patent citation indicator for state-owned firms is noticeably higher than for non-state-owned firms, indicating that state-owned enterprises have a higher overall innovation capability. High-tech enterprises have innovation capability indicators above 3.12, much higher than non-high-tech firms, which aligns with reality—high-tech firms focus more on technological innovation, thus generating more patent applications, grants, and citations. ② In terms of standard deviations, all three indicators for state-owned enterprises are higher than for non-state-owned ones, and non-high-tech firms have higher standard deviations than high-tech firms, indicating greater disparities in innovation capability among state-owned firms and among non-high-tech firms. ③ In terms of extremes, the minimum is 0 for all sub-samples; non-state-owned firms have larger maximum values than state-owned ones, indicating that there are highly innovative non-state-owned firms. Moreover, from the high-tech classification, this firm is non-high-tech, suggesting that although state-owned and high-tech enterprises have higher overall levels, there are relatively few outstanding ones.

5.1.3. Descriptive Statistics of Independent Variables

Table 4. Descriptive Statistics of TMT Characteristics.

Variable	N	Mean	Std. Dev.	Min	Median	Max
Tsize	15136	18.47	3.683	9	18.000	38
Aage	15136	49.82	3.121	35.62	49.933	62.88
Dage	15136	0.157	0.0405	0.0429	0.154	0.318
Agen	15136	0.193	0.120	0	0.182	0.833
Dgen	15136	0.287	0.127	0	0.298	0.500
Aedu	15136	3.514	0.392	1.500	3.529	5
Dedu	15136	0.631	0.0817	0	0.643	0.800
Aten	15136	50.93	18.74	7.048	48.650	184.1
Dten	15136	0.758	0.226	0	0.749	2.272
Afunc	15136	0.197	0.148	0	0.174	1
Dfunc	15136	0.744	0.0544	0.227	0.753	0.856
Aove	15136	0.0811	0.0921	0	0.059	0.667
Dove	15136	0.126	0.126	0	0.105	0.500

Table 4 displays the relevant TMT characteristics of the selected listed firms. First, TMT size has a mean of 18.47, with a minimum of 9 and maximum of 38, indicating considerable variation across firms. Second, average TMT age has a mean of 49.82 years, suggesting that TMT members are generally middle-aged, with rich professional experience and management capabilities, making them more competent for executive positions. In terms of gender, the average proportion of female executives is about 0.2, indicating that female representation is relatively low overall. The gender H coefficient has a mean of 0.287 and a maximum of 0.5, indicating a generally low level of differentiation in the selected sample. In terms of education, the average TMT education level is 3.514, indicating that the average executive holds at least a bachelor's degree and that the overall education level is relatively high. However, the education H coefficient is 0.631 and the maximum is 0.8, indicating considerable variation in education levels among TMT members. In terms of tenure, the average TMT tenure is 50.93 months, with a maximum of 184 months, and the mean tenure coefficient of variation is 0.758, indicating large tenure differences among members. Furthermore, the proportion of executives with R&D/design backgrounds is only 0.2, suggesting a shortage of such members in TMTs. The average proportion with overseas backgrounds is 0.126, indicating relatively few executives with overseas study or work experience. The overseas background H coefficient has a mean of 0.758, indicating a high degree of differentiation in overseas background.

5.2. Correlation Test

To ensure the validity of multiple linear regression results, we use Pearson correlation coefficients to test the correlations among variables. As shown in the tables, the absolute values of correlation coefficients among independent variables and between independent and dependent variables are generally below 0.4, preliminarily ruling out multicollinearity problems. The specific results are shown in Table 6(presented below).

From the correlations between TMT characteristics and the three innovation indicators, the variables Agen, Dage, and Dgen are significantly negatively correlated with Pat1, Pat2, and Pat3 at the 1% level; Dten is negatively correlated with patent applications but shows mixed correlations with grants and citations, all insignificant at the 10% level; all other TMT characteristics are significantly positively correlated with innovation capability at the 1% level. However, these do not imply causality, so further empirical analysis is needed.

Pearson correlation coefficients range from –1 to 1; negative values indicate negative correlation, positive values indicate positive correlation, and larger absolute values indicate stronger correlations.

5.3. Empirical Results Analysis

5.3.1. Multicollinearity Test

Table 5. Multicollinearity Test among Variables.

Variable	Model 1		Model 2		Model 3		Model 4	
	VIF	Tolerance	VIF	Tolerance	VIF	Tolerance	VIF	Tolerance
Tsize	1.250	0.799			1.280	0.783		
Aage	1.390	0.718			1.510	0.663		
Agen	1.140	0.879			3.770	0.210		
Aedu	1.170	0.856			1.200	0.832		
Aten	1.180	0.846			1.300	0.771		
Afunc	1.120	0.897			1.390	0.720		
Aove	1.090	0.916			4.960	0.300		
Dage			1.230	0.814	1.350	0.742		
Dgen			1.100	0.910	4.890	0.204		
Dedu			1.010	0.992	1.010	0.989		
Dten			1.060	0.942	1.190	0.842		
Dfunc			1.030	0.973	1.290	0.778		
Dove			1.070	0.930	4.100	0.199		
Size	1.760	0.569	1.500	0.667	1.770	0.564	1.380	0.726
Age	1.130	0.887	1.100	0.908	1.160	0.859	1.060	0.942
Lev	2.840	0.352	2.820	0.355	2.850	0.351	2.800	0.357
ROA	2.610	0.384	2.600	0.384	2.610	0.383	2.590	0.385
Cn	1.130	0.888	1.120	0.890	1.170	0.857	1.080	0.926
Gov	1.030	0.968	1.030	0.967	1.040	0.961	1.030	0.973
Sto	1.060	0.946	1.060	0.946	1.070	0.936	1.030	0.967

To avoid multicollinearity that would render regression results meaningless, we use the variance inflation factor (VIF) to test for multicollinearity. The VIF values are the same for different dependent variables; Table 5 presents the results with Pat2 as the dependent variable. All VIF values are below 10, confirming no multicollinearity among variables.

5.3.2. Full-Sample Empirical Analysis

To test the impact of TMT characteristics on innovation capability, we use TMT characteristics and the three dependent variables (Pat1, Pat2, Pat3) in multiple linear regression. We compare the results of each regression to summarize the effects. The data results are shown in Tables 7, 8, and 9.

Table 6. Correlation Test of Dependent and Independent Variables (Full Sample)

Variable	Pat1	Pat2	Pat3	Tsize	Aage	Aedu	Aten	Agen	Afunc	Aove	*Dage*	*Dgen*	*Dedu*	*Dten*	*Dfunc*	*Dove*
*Pat*1	1															
*Pat*2	0.901***	1														
*Pat*3	0.770***	0.735***	1													
Tsize	0.189***	0.181***	0.179***	1												
Aage	0.153***	0.168***	0.119***	0.229***	1											
Aedu	0.104***	0.106***	0.128***	0.089***	0.059***	1										
Aten	0.084***	0.083***	0.076***	0.029***	0.288***	-0.167***	1									
Agen	-0.171***	-0.162***	-0.171***	-0.203***	-0.257***	-0.077***	0.00100	1								
Afunc	0.277***	0.267***	0.279***	0.064***	0.066***	0.090***	0.079***	-0.140***	1							
Aove	0.099***	0.095***	0.108***	-0.038***	0.021***	0.223***	0.023***	0.029***	0.098***	1						
Dage	-0.059***	-0.055***	-0.076***	-0.258***	-0.361***	-0.168***	-0.047***	0.231***	-0.00100	0.128***	1					
Dgen	-0.181***	-0.172***	-0.181***	-0.199***	-0.288***	-0.070***	0.00100	0.888***	-0.140***	0.039***	0.257***	1				
Dedu	0.017**	0.020**	0.016**	0.00500	-0.046***	-0.043***	0.00200	0.00900	0.022***	0.015*	0.029***	0.0130	1			
Dten	-0.00600	0.0120	0.00600	0.095***	-0.019**	0.119***	-0.306***	-0.021***	-0.111***	-0.022***	-0.030***	-0.015*	-0.027***	1		
Dfunc	0.153***	0.177***	0.102***	-0.031***	-0.115***	0.031***	-0.065***	0.019**	0.411***	0.085***	0.087***	0.032***	0.00100	0.027***	1	
Dove	0.110***	0.107***	0.118***	-0.040***	-0.0120	0.212***	0.026***	0.040***	0.119***	0.947***	0.160***	0.052***	0.00700	-0.016**	0.117***	1

N=15136,*P<0.1,**P<0.05,***P<0.01

Table 7. TMT Characteristics and Corporate Patent Applications.

Variable	Model 1	Model 2	Model 3	Model 4
Tsize	0.004		0.007*	
	(0.96)		(1.80)	
Aage	-0.004		0.008	
	(-0.76)		(1.58)	
Aedu	0.015		0.066*	
	(0.42)		(1.87)	
Aten	0.006***		0.006***	
	(7.31)		(8.19)	
Agen	-1.083***		-0.059	
	(-9.37)		(-0.25)	
Afunc	3.146***		2.594***	
	(34.13)		(26.04)	
Aove	0.437***		-1.055**	
	(2.85)		(-2.28)	
Dage		1.267***	2.297***	
		(3.45)	(6.33)	
Dgen		-1.845***	-1.270***	
		(-16.94)	(-5.64)	
Dedu		0.439***	0.425***	
		(2.74)	(2.75)	
Dten		-0.273***	0.027	
		(-4.36)	(0.42)	
Dfunc		5.825***	3.028***	
		(22.96)	(11.31)	
Dove		0.518***	0.978***	
		(4.67)	(2.91)	
Size	0.591***	0.612***	0.593***	0.622***
	(42.89)	(47.43)	(43.20)	(48.38)
Age	-0.033***	-0.045***	-0.034***	-0.050***
	(-12.43)	(-16.40)	(-12.89)	(-17.43)
Lev	-0.459***	-0.612***	-0.451***	-0.612***
	(-6.52)	(-8.31)	(-6.58)	(-7.90)
ROA	-0.378***	-0.454***	-0.367***	-0.453***
	(-3.80)	(-3.74)	(-3.81)	(-3.44)
Cn	-0.876***	-0.988***	-0.801***	-0.989***
	(-8.88)	(-9.83)	(-8.07)	(-9.57)
Gov	8.162***	11.190***	10.136***	9.557***
	(3.93)	(5.30)	(4.91)	(4.28)
Sto	0.105	0.158	0.100	0.187
	(0.99)	(1.15)	(0.98)	(1.22)
Constant	-9.879***	-13.501***	-13.464***	-9.474***
	(-29.93)	(-36.57)	(-31.17)	(-33.08)
N	15136	15136	15136	15136
R^2	0.253	0.223	0.264	0.175
F	379.5	317.5	286.4	409.9

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively; t-values in parentheses.

Table 8. TMT Characteristics and Corporate Patent Grants

Variable	Model 1	Model 2	Model 3	Model 4
Tsize	0.001		0.003	
	(0.23)		(0.72)	
Aage	-0.007		-0.022***	
	(-1.39)		(-4.51)	
Aedu	0.014		0.073**	
	(0.40)		(2.15)	
Aten	0.005***		0.006***	
	(6.71)		(8.33)	
Agen	-0.880***		0.054	
	(-7.81)		(0.24)	
Afunc	3.001***		2.302***	
	(34.00)		(24.26)	
Aove	0.371**		-1.434***	
	(2.45)		(-3.14)	
Dage		1.516***	2.677***	
		(4.28)	(7.64)	
Dgen		-1.687***	-1.207***	
		(-16.06)	(-5.53)	
Dedu		0.532***	0.546***	
		(3.45)	(3.66)	
Dten		-0.174***	0.122**	
		(-2.91)	(2.01)	
Dfunc		6.351***	3.933***	
		(26.25)	(15.43)	
Dove		0.454***	1.179***	
		(4.20)	(3.59)	
Size	0.557***	0.580***	0.559***	0.585***
	(40.42)	(44.88)	(41.02)	(45.35)
Age	-0.022***	-0.033***	-0.024***	-0.038***
	(-8.74)	(-12.71)	(-9.60)	(-13.78)
Lev	-0.343***	-0.498***	-0.334***	-0.499***
	(-4.75)	(-6.58)	(-4.78)	(-6.29)
ROA	-0.303***	-0.380***	-0.288***	-0.382***
	(-3.39)	(-3.50)	(-3.38)	(-3.25)
Cn	-0.845***	-0.891***	-0.745***	-0.919***
	(-8.75)	(-9.11)	(-7.71)	(-9.12)
Gov	5.435***	8.719***	8.060***	6.583***
	(2.86)	(4.61)	(4.32)	(3.29)
Sto	0.095	0.140	0.094	0.170
	(0.97)	(1.13)	(0.99)	(1.20)
Constant	-10.022***	-13.925***	-14.678***	-9.195***
	(-30.97)	(-38.36)	(-34.83)	(-32.38)
N	15136	15136	15136	15136
R^2	0.240	0.220	0.258	0.165
F	348.2	300.4	274.3	358.6

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively; t-values in parentheses.

Table 9. TMT Characteristics and Corporate Patent Citations

Variable	Model 1	Model 2	Model 3	Model 4
Tsize	0.014***		0.014***	
	(3.27)		(3.15)	
Aage	-0.012**		-0.011**	
	(-2.46)		(-2.13)	
Aedu	0.212***		0.220***	
	(6.14)		(6.30)	
Aten	0.006***		0.007***	
	(7.93)		(9.15)	
Agen	-1.197***		-0.045	
	(-10.58)		(-0.20)	
Afunc	2.941***		2.754***	
	(31.88)		(27.51)	
Aove	0.616***		-0.778	
	(3.88)		(-1.61)	
Dage		-0.595*	0.485	
		(-1.66)	(1.36)	
Dgen		-1.834***	-1.302***	
		(-16.71)	(-5.86)	
Dedu		0.318**	0.296*	
		(1.98)	(1.91)	
Dten		-0.043	0.247***	
		(-0.70)	(3.97)	
Dfunc		4.071***	1.006***	
		(16.11)	(3.78)	
Dove		0.895***	1.061***	
		(7.76)	(3.05)	
Size	0.478***	0.496***	0.474***	0.531***
	(31.75)	(34.21)	(31.52)	(36.46)
Age	-0.050***	-0.062***	-0.050***	-0.065***
	(-18.63)	(-22.94)	(-18.73)	(-23.96)
Lev	-0.360***	-0.516***	-0.358***	-0.512***
	(-4.50)	(-6.23)	(-4.58)	(-5.90)
ROA	-0.391***	-0.469***	-0.384***	-0.470***
	(-4.36)	(-4.66)	(-4.43)	(-4.36)
Cn	-0.830***	-1.033***	-0.774***	-0.997***
	(-8.46)	(-10.20)	(-7.76)	(-9.74)
Gov	19.359***	21.900***	20.245***	21.431***
	(7.09)	(7.39)	(7.21)	(7.13)
Sto	-0.048	0.030	-0.036	0.020
	(-1.62)	(0.43)	(-1.12)	(0.29)
Constant	-7.859***	-9.490***	-8.953***	-7.531***
	(-22.92)	(-24.07)	(-19.79)	(-24.44)
N	15136	15136	15136	15136
R^2	0.227	0.184	0.231	0.149
F	298.6	226.0	215.7	301.5

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively; t-values in parentheses.

As shown in Tables 7, 8, and 9, these are regression results for TMT characteristics on different dependent variables. Four multiple linear regression models are used to examine the effects of TMT homogeneity, heterogeneity, and both together on innovation capability.

(1) Homogeneity characteristics. Model 1 introduces homogeneity variables on top of Model 4 to analyze the effect of TMT homogeneity on innovation capability. From the regression results in the three tables, after adding homogeneity variables, the R^2 values of all three models increase, indicating that homogeneity characteristics affect innovation capability, and the F-values are large, suggesting good model fit. TMT average size, average age, and average education are not significant for patent applications and grants, but average size and average education are positively associated, while average age is negatively associated. For patent citations, the following relationships are significant at the 1% level: citations increase with larger TMT size and higher average education, and decrease with higher average age, supporting H1, H2a, and H4a. This indicates that larger teams have more cognitive resources, which enhances innovation capability; higher average education leads to higher-quality decisions beneficial to innovation; higher average age leads to more conservative strategies, which is detrimental. Average tenure, the proportion of R&D/design executives, and the proportion of overseas-background executives are all significantly positively correlated with all three indicators, supporting H5a, H6a, and H7a. This suggests that longer tenure gives executives better understanding of the environment for sound innovative decisions; R&D/design background helps direct technological development and improve innovation efficiency; overseas background provides broader international perspectives and expertise. The proportion of female executives is significantly negatively correlated with innovation capability, indicating that although female managers have unique management styles, their innovation awareness needs improvement.

(2) Heterogeneity characteristics. From the regression results in the three tables, Model 2 adds heterogeneity variables to Model 4, and R^2 values increase for all models, indicating that heterogeneity affects innovation capability. The results show that greater heterogeneity in education, professional background, and overseas background is conducive to innovation capability. These can be explained by diversity in personal experiences, which brings cognitive diversity—various professional knowledge, skills, and perspectives; cross-professional collisions effectively enhance team decision-making and problem-solving, thus benefiting innovation, supporting H6b and H7b. Age heterogeneity is significantly positively related to patent applications and grants, but negatively related to citations at the 10% level, indicating that age diversity positively affects innovation, supporting H2b. Gender heterogeneity is significantly negatively related to innovation capability, suggesting that decision-making differences between male and female managers still hinder strategy formulation, not supporting H3b. Overseas background heterogeneity is significantly positively related to innovation capability, indicating that it plays an important role in grasping innovation opportunities, supporting H7b.

(3) Considering both homogeneity and heterogeneity **simultaneously.** Model 3 introduces both types of variables on top of Model 4; R^2 values increase and F-values are large, indicating better fit. The results in Model 3 across the three tables are generally consistent with Models 1 and 2. Therefore, in the sub-sample descriptive analysis, Model 3 is used for regression, with the dependent variable being Pat2 (patent grants +1, ln), as it shows relatively more significant results.

Table 10. Hypothesis Test Results

No.	Hypothesis	Result
H1	TMT size is significantly positively correlated with innovation capability	Supported
H2a	TMT average age is significantly negatively correlated with innovation capability	Supported
H2b	TMT age heterogeneity is significantly positively correlated with innovation capability	Not supported
H3a	Proportion of female executives is significantly positively correlated with innovation capability	Not supported
H3b	TMT gender heterogeneity is significantly positively correlated with innovation capability	Not supported
H4a	TMT average education is significantly positively correlated with innovation capability	Supported
H4b	TMT education heterogeneity is significantly negatively correlated with innovation capability	Not supported
H5a	TMT average tenure is significantly positively correlated with innovation capability	Supported
H5b	TMT tenure heterogeneity is significantly negatively correlated with innovation capability	Supported
H6a	Proportion of R&D/design background executives is significantly positively correlated with innovation capability	Supported
H6b	TMT professional background heterogeneity is significantly positively correlated with innovation capability	Supported
H7a	Proportion of overseas background executives is significantly positively correlated with innovation capability	Supported
H7b	TMT overseas background heterogeneity is significantly positively correlated with innovation capability	Supported

5.3.3. Heterogeneity Analysis

We conduct sub-sample regressions based on firm nature and industry characteristics. Given the full-sample results, we use Pat2 (patent grants +1, ln) as the dependent variable and employ Model 3 (including both homogeneity and heterogeneity variables) for the sub-sample regressions. The results are shown in Table 11. All R^2 values exceed 0.2 and F-statistics are large, indicating good model fit.

Table 11. Sub-sample Regression Results for Patent Grants

Variable	State-owned	Non-state-owned	High-tech	Non-high-tech
Tsize	0.005	0.018***	-0.000	0.004
	(0.84)	(3.43)	(-0.09)	(0.71)
Aage	0.051	-0.016***	-0.015***	0.043***
	(0.90)	(-2.80)	(-2.61)	(5.94)
Agen	0.706**	-1.079***	-0.983***	0.266
	(2.03)	(-3.52)	(-2.97)	(0.95)
Aedu	0.397***	0.022	0.113***	0.209***
	(6.13)	(0.57)	(2.70)	(4.43)
Aten	-0.002	0.009***	0.005***	0.002*
	(-1.13)	(10.22)	(5.17)	(1.83)
Afunc	2.992***	1.627***	0.272**	2.845***
	(20.38)	(13.57)	(2.43)	(19.61)
Aove	-2.574***	-0.292	-1.285**	-1.149**
	(-3.48)	(-0.51)	(-1.98)	(-1.98)

Variable	State-owned	Non-state-owned	High-tech	Non-high-tech
Dage	4.092***	0.390	0.254	2.385***
	(5.96)	(0.92)	(0.63)	(4.64)
Dgen	-2.469***	0.232	0.377	-1.731***
	(-7.74)	(0.79)	(1.27)	(-6.29)
Dedu	0.815***	0.355*	-0.162	0.663***
	(3.46)	(1.91)	(-0.84)	(3.34)
Dfunc	3.281***	4.196***	2.518***	3.446***
	(8.44)	(12.55)	(7.85)	(10.31)
Dove	1.362**	0.289	0.806*	0.930**
	(2.46)	(0.71)	(1.76)	(2.21)
Dten	0.190*	0.144*	0.293***	-0.004
	(1.92)	(1.90)	(3.68)	(-0.05)
Size	0.621***	0.477***	0.676***	0.541***
	(29.27)	(26.28)	(33.46)	(30.97)
Age	-0.013***	-0.025***	0.007**	-0.022***
	(-2.84)	(-8.34)	(2.56)	(-6.04)
Lev	-0.670***	-0.118	0.376***	-0.438***
	(-5.66)	(-1.63)	(3.58)	(-4.24)
ROA	-0.323	-0.105	0.212	-0.404***
	(-1.27)	(-1.53)	(0.93)	(-3.38)
Cn	-1.075***	-0.306**	0.069	-0.951***
	(-6.85)	(-2.40)	(0.59)	(-7.29)
Gov	10.327***	7.000***	13.302***	6.507***
	(4.00)	(2.85)	(6.20)	(3.10)
Sto	2.111***	0.030	0.552***	0.006
	(3.12)	(0.41)	(6.04)	(0.11)
Constant	-18.300***	-12.640***	-15.650***	-15.324***
	(-26.14)	(-22.67)	(-27.24)	(-27.12)
N	5,983	9,153	6,457	8,679
R^2	0.358	0.201	0.302	0.295
F	195.4	114.4	125.5	191.4

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively; t-values in parentheses.

(1) Homogeneity aspects. In terms of TMT size, larger size improves innovation capability for both state-owned and non-state-owned firms, but the effect is significant only for non-state-owned firms at the 1% level; for high-tech and non-high-tech firms, the relationship is insignificant at the 10% level. Average age: for state-owned firms, innovation capability increases with age but insignificantly; for non-state-owned firms, it is significantly negative at the 1% level, indicating that state-owned executives are generally older. For both high-tech and non-high-tech firms, innovation capability decreases with average age, and this relationship is more significant for high-tech firms, supporting H2a. Female proportion: in state-owned firms, higher female proportion improves innovation but insignificantly; in non-state-owned firms, it is significantly negative; in high-tech firms, significantly negative; in non-high-tech firms, positive but insignificant. Average education: higher education improves innovation for all four groups, significant at the 1% level except for non-state-owned firms, supporting H4a. Average tenure: for state-owned firms, negative but insignificant; for non-state-owned, positive and significant; for high-tech and non-high-tech, positive and significant. R&D/design background: higher proportion always improves innovation for all groups at the 5% level, supporting H6a. Overseas background: higher proportion is detrimental to innovation for all groups at the 10% level, not supporting H7a.

(2) Heterogeneity aspects. Age heterogeneity: for state-owned and non-high-tech firms, higher heterogeneity improves innovation at the 1% level; for non-state-owned and high-tech firms, positive but insignificant. Gender heterogeneity: for state-owned and non-high-tech firms, higher heterogeneity reduces innovation at the 1% level; for non-state-owned and high-tech firms, negative but insignificant. Education heterogeneity: for both state-owned and non-state-owned firms, greater heterogeneity improves innovation, more significantly for state-owned; for high-tech firms, negative; for non-high-tech, positive and significant. Tenure heterogeneity: for both state-owned and non-state-owned, positive and significant at the 10% level; for high-tech, positive and significant; for non-high-tech, negative but insignificant. Professional background heterogeneity: higher heterogeneity always improves innovation for all groups at the 1% level. Overseas background heterogeneity: higher heterogeneity improves innovation for all groups except non-state-owned firms, where it is insignificant; significant for state-owned, high-tech, and non-high-tech.

The above sub-sample regressions indicate that whether a firm is state-owned or high-tech affects the relationship between TMT characteristics and innovation capability, but only for some characteristics. Most variables have similar signs and significance levels across groups, largely consistent with the full-sample results, confirming the robustness and validity of the overall conclusions.

6. Research Conclusions

Based on upper echelons theory, this paper selects data from the TMTs of A-share listed companies in China from 2015 to 2021, establishes an empirical research model, and explores the impact of TMT characteristics on innovation capability from two dimensions—homogeneity and heterogeneity. We further conduct sub-sample regressions by firm nature and industry. The main conclusions are as follows:

First, from the homogeneity perspective: TMT size is positively correlated with innovation capability, especially significant for non-state-owned firms, but insignificant for state-owned, high-tech, and non-high-tech firms. Overall, TMT average age is negatively correlated with innovation capability, but this does not hold for state-owned firms. In state-owned firms, a higher proportion of female executives is beneficial, but the opposite holds for non-state-owned and high-tech firms. Average education is significantly positively related to innovation capability for all groups except non-state-owned firms. Average tenure is positively related to innovation capability, with insignificant effects for state-owned firms. The proportions of R&D/design and overseas-background executives are positively related to innovation capability for all groups.

Second, from the heterogeneity perspective: TMT age heterogeneity positively affects innovation capability, significant for state-owned and non-high-tech firms at the 1% level. Gender heterogeneity is positively related to innovation for state-owned firms but negatively for non-state-owned and high-tech firms. Education heterogeneity is positively related to innovation capability, significant for state-owned and non-high-tech firms. Tenure heterogeneity is negatively related overall but not significant; it is positively significant for high-tech firms. Professional background heterogeneity is positively related to innovation in both full-sample and sub-sample regressions. Overseas background heterogeneity is positively related to innovation capability, but this effect is not significant for non-state-owned firms.

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