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Article

The role of board heterogeneity on corporate sustainable innovation: Research from the perspective of scientific and technological innovation corporates

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Abstract: Sustainable innovation is crucial for addressing social and environmental challenges and is a key driver of enterprise competitiveness and economic growth. This study examines how board heterogeneity influences sustainable innovation in enterprises, particularly within the context of China's Science and Technology innovation board. Findings reveal that diverse boards enhance sustainable innovation and impact M&A activities, which in turn mediate the relationship between board diversity and corporate sustainability. The research aims to understand the optimal board composition for scientific and creative enterprises, analyze the mechanisms behind board heterogeneity's effect on innovation, and assess M&A's role in this process. The study's outcomes underscore the importance of board diversity for fostering sustainable innovation and suggest that M&A can be a critical pathway to enhancing corporate sustainability.

Keywords: heterogeneity of the board of directors; sustainable innovation of enterprises; mergers and acquisitions of enterprises; scientific and creative enterprises

1. Introduction

In recent years, sustainable innovation has become particularly important in addressing the increasingly severe social and environmental issues and has garnered increasing attention from academia, business, and policymakers. The 18th National Congress of the Communist Party of China proposed the innovation-driven strategy, transitioning from an investment-driven development model to an innovation-driven one. In May 2016, the Central Committee of the Communist Party of China and the State Council issued the "National Strategy Outline for Innovation-Driven Development", specifically outlining a three-step strategy for China's innovation-driven development. First, by 2020, China will join the ranks of innovation-driven nations, by 2030 it will be among the top, and ultimately by 2050, China will be built into a world leader in science and technology. To consolidate the existing market position of enterprises and even to capture new markets for healthy and sustainable development, it is necessary to harness the solid advantages of competition, which often depends on sustainable innovation. Sustainable innovation not only helps enterprises gain short-term competitive advantages but is also an important source of sustainable development, crucial for the survival and growth of the enterprise.

Scholars both at home and abroad have explored factors that inhibit or affect sustainable innovation in enterprises. The results indicate that national or regional

social capital (Akcomak and Terweel, 2009), intellectual property protection (Chen and Puttitanun, 2005), financial regulation and banking competition (Chava et al., 2013; Cornaggia et al., 2015), asset size (Acs and Audretsch, 1988; Zhu, 2006), business risk (Caggese, 2012), litigation risk and judicial protection (Pan Yue et al., 2015), micro-level political connections of enterprises (Yuan et al., 2015), executive incentives (Baranchuk et al., 2014), and corporate governance factors (Li et al., 2010; Lin et al., 2011; Wen et al., 2012) will impact the sustainable innovation capability of enterprises. Ultimately, the innovation activities of an enterprise originate from its decision-making, and the core of the enterprise's decision-making is inevitably the board of directors. According to the upper echelons theory (Hambrick and Mason, 1984), the demographic characteristics of top managers' cognitive bases and their values (such as age, career path, educational background, status, etc.) will influence their decision-making. As the core of corporate governance, the board of directors bears significant responsibility for the company's development. A diverse board can enable a company to access a variety of information resources. Through the integration, application, and processing of these information resources, various innovation decisions are generated, which will affect the strategic decisions of the enterprise and ultimately impact its sustainable innovation capability.

As an important way for enterprises to invest, mergers and acquisitions (M&A) have been widely applied and considered in both the theoretical and business communities. In order to continue innovating, companies must proceed with caution in the face of illusions or myths generated by M&A. In the M&A decision-making process, the characteristics of the board of directors, as the decision-making body of the company, are crucial for scientific and effective decision-making. A diverse board can enable an enterprise to obtain a variety of information resources. Through the integration, application, and processing of these information resources, various innovation decisions are generated, allowing the enterprise to gain more competitive advantages that are harder for competitors to replicate. However, the diversity of the board leads to an increase in the diversity of board members. As the diversity of board members increases, the heterogeneity among board members will inevitably intensify, directly affecting the strategic decisions of the enterprise and the development of sustainable innovation. Therefore, studying the impact of board heterogeneity on sustainable innovation has significant practical significance.

Based on the above research background, this paper reviews the literature on board heterogeneity and the sustainable innovation capability of enterprises, and in combination with the current situation of M&A in China's science and technology innovation board-listed companies and the factors affecting the completion of M&A, seeks to identify the influencing factors of the board of directors, M&A, and the sustainable innovation capability of enterprises.

In summary, this study aims to delve into the impact mechanism and key factors of board heterogeneity on sustainable innovation and development in technology enterprises, play the mediating role of M&A, establish the connotation of board heterogeneity management in technology enterprises, construct the path of sustainable innovation, and provide theoretical and practical support for the sustainable development of technology enterprises. The value of this research lies in providing practical recommendations for board optimization, innovation development strategies,

and practical support for technology enterprises, as well as contributing valuable research to social and economic development.

2. Theory and literature review

2.1. Theory

The contemporary society is an era marked by the rapid rise of high technology, and the importance of scientific and technological innovation to the economy is self-evident. However, it was the Austrian economist Joseph Schumpeter who began to systematically study the theory of technological innovation. In his 1934 book "The Theory of Economic Development", Schumpeter first introduced the concept of "innovation". According to Schumpeter (1990), innovation involves the transfer of the production function or the recombination of the production function to capture potential super-profits. Thus, Schumpeter's concept of innovation encompasses all activities that can improve the efficiency of resource allocation.

Corporate governance theory has evolved from the emergence of corporate governance to the present, resulting in two main theories of separation of powers: the principal-agent theory and the stakeholder theory. The principal-agent theory is a governance theory developed to address principal-agent problems. According to this theory, governance measures that promote the convergence of interests between principals and agents can resolve principal-agent issues (Chen et al., 2016). However, in the process of corporate development, scholars have realized that corporate issues are not limited to principal-agent problems but also include "holder" issues that require resolution through other governance theories. Thus, the stakeholder theory came into being.

As early as ancient China, operations research and decision-making were skillfully applied. However, the study of decision analysis and theory as a discipline originated in the West in the 17th century, with its initial theoretical formulas proposed by Cramer and Bernoulli. In the 20th century, von Neumann and Morgenstern put forward the axiomatic expression of the Expected Utility Theory (EU Theory) of risky decision-making. Moreover, the later extension of subjective expected utility is one of the most important and influential theories in decision science. Due to the rapid development and popularization of computer technology, the maturity of information processing and data storage technology, as well as the advancement of retrieval capabilities, coupled with in-depth research into decision theory and the achievement of some results, statistical data and research materials have been rapidly updated, and decision models have become increasingly sophisticated. The birth and development of decision support systems have solved the helplessness of decision-makers facing complex problems and have automated the resolution of some routine decision-making issues.

2.2. Literature review

2.2.1. Board heterogeneity

Board heterogeneity can be divided into professional and social aspects. Professional heterogeneity primarily refers to the heterogeneity of board members in

terms of professional experience, educational background, and tenure, which are work-related. In contrast, social heterogeneity includes factors like gender, age, and race, which are socially related. Both types of board heterogeneity have a significant impact on corporate performance and strategic decision-making.

2.2.2. Corporate mergers and acquisitions

Corporate mergers and acquisitions (M&A) refer to the merging and acquiring of companies, which are forms of routine and capital operations. Currently, the motivations behind corporate M&A largely focus on how M&A can enhance corporate value. Hambrick and Sanders (2007) suggest that M&A can create long-term corporate value, and a rational choice behavior oriented towards M&A objectives enables companies to acquire development capabilities not available under current technological conditions. Zhang (2003) studied the impact of M&A events on the value of Chinese listed companies and found that while M&A can create value for companies, it may harm the interests of shareholders in the acquiring company. However, whether M&A can add value to a company is a matter of debate, as indicated by the findings of Barkema and Schijven (2008).

2.2.3. Corporate sustainable innovation

Corporate sustainable innovation refers to the emphasis on sustainability in corporate operations, where companies innovate their production, management, and operational models to enhance their sustainability and competitiveness in economic, environmental, and social domains. Research on corporate sustainable innovation focuses on sustainability, innovation, organization, and strategic management. Boons and Ludeke-Freund (2013) point out that the business model is one of the most critical areas of research in corporate sustainable innovation, as it can balance a company's commercial and sustainable goals. The diversity and sustainability of business models are fundamental factors of sustainable innovation.

2.2.4. Impact of board heterogeneity on corporate sustainable innovation

The board of directors is one of the highest decision-making bodies in a corporation, and the number, composition, and heterogeneity of its members have a crucial impact on the company's innovative capacity and performance. The heterogeneity among board members is one of the key factors in corporate development and innovation, significantly affecting a company's innovative capability and performance. Some studies have found that board member heterogeneity has a positive impact on corporate innovation consciousness and performance. Research indicates that the diversity of board members can bring a wider range of knowledge sources and experiences to the company, effectively avoiding collective cognitive blind spots and thus better promoting corporate innovation performance (Hunt et al., 2016; Santos-Vijande et al., 2012). Additionally, some research has found that the age and gender diversity of board members has different impacts on corporate innovation performance. For instance, studies have shown that female board members can bring higher visibility and a richer perspective, which helps improve the company's social responsibility performance (Kassinis et al., 2019). Similarly, younger board members are more receptive to new innovation ideas and technologies, which also has a positive impact on the company's innovation

performance (Lee and Ocker, 2018). In terms of the impact of board member diversity on corporate innovation, research has found that different thinking styles among board members also have a profound impact on the company's innovation performance. For example, studies have shown that integrating adaptive and innovative thinking can enhance the board's recognition and support for innovation, thereby improving the company's innovation performance (Sipahi and Yayla, 2020). In summary, the impact of board diversity on corporate sustainable innovation is complex and varied. Companies need to create a favorable atmosphere for board diversity and implement targeted board diversity management to maximize the company's innovation performance and long-term development while maintaining the diversity of board members.

2.2.5. Board heterogeneity and corporate mergers

From the perspective of M&A capability, M&A behavior must have the corresponding M&A capability to be successfully achieved. However, many domestic listed companies currently overlook the stages of self-capability assessment and self-capability enhancement, focusing all their attention on selecting target companies and conducting due diligence on the selected target companies. Consequently, many companies engage in M&A activities blindly due to neglecting their own M&A capabilities, ultimately leading to the failure of M&A transactions (Tao et al., 2012). A company's M&A capability refers to its ability, within a specific external environment (such as the policy and industry environment), to make reasonable M&A strategic choices and develop sound M&A plans, as reflected in the valuable and scarce resources, as well as the unique product or management advantages, that the company owns or controls (Chen, 2006). This is the focus of this paper—the unique cognitive foundation resulting from the board's background characteristics at the decision-making level. Based on this, some scholars have begun to study the relationship between board heterogeneity and the success of M&A transactions, finding that the greater the board heterogeneity, the more significant the board's social and functional heterogeneity, the more likely it is to reach an M&A deal (Li et al., 2014), which gradually enriches the research content on the relationship between M&A transactions and internal governance structures.

2.2.6. Mergers and acquisitions and sustainable innovation

Ahuja (2001) believes that M&A can improve a company's innovation performance in the short term. Mao et al. (2019) argue that M&A is crucial for transferring knowledge and integrating it through M&A for innovation. For companies, it is also vital to fill technological gaps and rapidly enhance R&D capabilities. Liu (2022) points out that through M&A, companies can quickly acquire scarce knowledge and human resources from the outside, avoiding the rigidity of breakthrough innovation capabilities due to a single knowledge source and repeated utilization. Wang (2022) considers M&A as a micro-process of knowledge spillover, which not only expands the channels for the transmission of explicit knowledge from the target company to the acquiring company but also promotes the exchange between the technological M&A parties, accelerating the transmission of tacit knowledge. Existing research shows that M&A provides a shortcut for companies to quickly gain advantages in industry-leading technologies, acquiring the core technological

resources of the target company. It not only directly fills technological gaps and optimizes existing technologies but also significantly shortens internal R&D cycles and reduces innovation risks, prompting companies to increase R&D investment and technological innovation intensity, thereby enhancing their sustainable innovation capabilities.

2.2.7. Research summary

There is a close relationship between board heterogeneity and corporate sustainable innovation capabilities. Research on board background characteristics mainly analyzes financial restatement, financial fraud, corporate risk, and economic effects. Research on corporate sustainable innovation mainly focuses on external.

3. Research design

3.1. Research hypothesis and conceptual model

3.1.1. The impact of board heterogeneity on the sustainable innovation capability of enterprises

This study divides board heterogeneity into five categories: gender heterogeneity, age heterogeneity, tenure heterogeneity, functional background heterogeneity, and professional heterogeneity. Theoretical perspectives and sources of board heterogeneity are shown in **Table 1**. More and more scholars have found that board heterogeneity is conducive to improving enterprises' sustainable innovation ability, and member heterogeneity can increase cognitive diversity. Members have different viewpoints, can interpret information through multiple channels, and provide various action plans for solving related problems. Therefore, high heterogeneity can positively impact team innovation and creative decision-making. Based on this, the central hypothesis of this paper is put forward:

MH: The heterogeneity of the board of directors has a significant positive impact on enterprises' sustainable innovation ability.

Based on the above analysis, this paper proposes hypothesis 1–5:

H1: Board gender heterogeneity has a significant positive impact on enterprises' sustainable innovation ability.

H2: Board age heterogeneity has a significant positive impact on sustainable innovation capability.

H3: Board tenure heterogeneity has a significant positive impact on sustainable innovation capability.

H4: Board of directors has a significant positive impact on the sustainable innovation capability of enterprises.

H5: Board of directors has a significant positive impact on the sustainable innovation ability of enterprises.

Table 1. Theoretical perspectives and sources of board heterogeneity.

	Literature Sources	Opinions	Theoretical perspective
1	Wu Dejun et al. (2013)	The gender of senior executives has a great impact on the innovation behavior of enterprises, and the innovation performance of enterprises with female senior executives will be relatively better	Gender heterogeneity
2	Kollmuss et al. (2002)	Compared with male executives, female executives will be more receptive to new things	
3	Lin Yuen et al. (2018)	The majority decision-making behavior of female directors can play a good regulating role in corporate decision-making	
4	Lee Wai Tin (2015)	Young executives are more energetic and are more inclined to invest in companies with high risks and high returns	Age heterogeneity
5	Yukaio et al. (2019)	The larger the proportion of senior executives, the less likely companies are to break the rules	
6	Su Kun (2020)	Heterogeneity of board age helps to improve governance efficiency and thus reduce corporate risk	
7	Hambrick et al. (1993)	The tenure of team members will affect individual cognition. The longer the tenure, the more rigid the cognitive structure of directors will be, and it will be more difficult to break the past behavior and cognitive mode, especially the company innovation	Tenure heterogeneity
8	Katz (1982)	Therefore, a board composed of members with diverse tenure may give multiple interpretations of the same information	
9	Li Xiaoqing (2012)	A diverse board of directors brings diverse knowledge and rich perspectives	
10	Xie Zhihua et al. (2011)	It is generally believed that in order to ensure the correctness of the decisions of the board of directors, the board of directors should be composed of experts from at least five aspects: law and policy, technology, finance, market and operation experts	Functional background heterogeneity
11	Li Xiaoqing (2012)	A team with high heterogeneity of professional experience usually has a diverse skill set and can provide the board with the knowledge, experience and ability needed for innovation	
12	Hitt Tyler (1991)	Educational background can affect the process and output of strategic decision making	Professional heterogeneity
13	Wiersema and Bantel (1992)	The choice of courses can affect an individual's personality, attitude and cognitive style	

3.1.2. The mediating role of M&A

For board members, different roles will lead to other social identities. The heterogeneity of the board of directors is caused by the different cognitive characteristics (education level, functional background, and tenure of directors) and structural characteristics (whether the members are executive directors or independent directors) of the board of directors. At the same time, the different relationships and attitudes among board members can form the social dynamics within the board of directors, which is conducive to the board of directors to integrate strategic decision-making resources, strengthen the identification, acquisition, and utilization of director resources, timely and effective participation and supervision strategies, and then positively affect the merger and acquisition of enterprises. When making decisions, the board of directors faces not only the uncertainty from the external environment but also the differences in trust and familiarity among the internal members of the board. When the trust and communication among board members increase, the board members' heterogeneity will enhance team members' cohesiveness. At the same time,

the heterogeneity of board members may provide different plans for team decision-making, thus improving the exploration of opportunities by the board of directors and also playing an essential role in the flexibility of the team's strategic positioning so that it can have a positive impact on the occurrence of enterprise mergers and acquisitions. M&A strategy, as an intermediary variable, conveys the impact of board heterogeneity on the sustainable innovation ability of enterprises, and the launching of M&A can improve the sustainable innovation ability of enterprises.

The proportion of gender heterogeneity in the board of directors of H6 is positively correlated with M&A.

The age heterogeneity of the board of directors of H7 is positively correlated with M&A.

H8: Board tenure heterogeneity is positively correlated with M&A.

The functional background heterogeneity of the board of directors of H9 is positively associated with M&A.

The professional heterogeneity of the H10 board of directors is positively associated with M&A.

H11: M&A is positively correlated with sustainable innovation capability.

H12: M&A plays a significant mediating role in the relationship between the heterogeneity of the board of directors and the sustainable innovation ability of enterprises.

3.1.3. Conceptual model

Figure 1 illustrates the research conceptual model regarding the proposed hypothesis. In this model, board heterogeneity is the explanatory variable, firm sustainable innovation ability is the explained variable, and assertive M&A behavior is the intermediary variable. The heterogeneity of the board of directors is subdivided into five dimensions: gender heterogeneity, age heterogeneity, tenure heterogeneity, functional background heterogeneity, and professional heterogeneity.

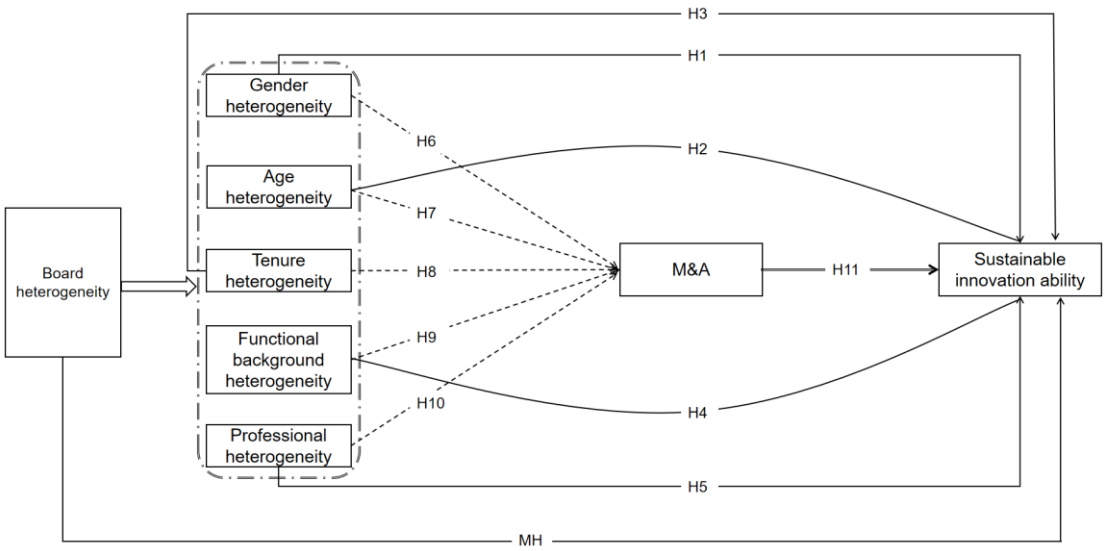

Figure 1. Research model.

The conceptual model only includes H1–H10, while H11 is too complex to be listed in the conceptual model. H11 relates to the mediating role of M&A behavior. **Table 2** further describes the research variables shown in the conceptual model.

Table 2. Study variables.

Types of variables	Variable name	Variable symbol	Variable definition
Explained variable	Enterprise sustainable innovation ability	Patent	The natural logarithm of the company's total number of patent applications for inventions is added to one
Explanatory variables	Board gender heterogeneity	Hgen	$H = 1 - \sum_{i=1}^{n} {p_i}^2$
	Board age heterogeneity	Hage	$H = 1 - \sum_{i=1}^{n} {p_i}^2$
	Heterogeneity of board tenure	Hten	Standard deviation/mean
	Heterogeneity of board functional background	Hfun	$H = 1 - \sum_{i=1}^{n} {p_i}^2$
	Board specialty heterogeneity	Hpro	$H = 1 - \sum_{i=1}^{n} {p_i}^2$
Mediating variables	M&A behavior	MAB	Whether the enterprise has a merger and acquisition, the value is 1 when the merger and acquisition behavior occur; If there is no M&A, the value is 0
Control variables	Company age	Age	Year of observation minus year of incorporation plus 1 Take the natural logarithm
	Company size	Size	Take the natural logarithm of total company assets
	Growth	Growth	Growth rate of main business income

On the measure of the heterogeneity of the board of directors: This paper adopts the Blau index, widely used in many kinds of literature, as the measure of the heterogeneity of the board of directors. The formula for calculating the Blau index is as follows:

$$H = 1 - \sum_{i=1}^{n} {p_i}^2$$

Where *pi* refers to the proportion of people of type I in the population, *n* is the number of all categories, and *H* values are between 0 and 1, with higher *H* values indicating more significant heterogeneity of the people on a particular feature. The respective variables are measured as follows: The board's gender is divided into two categories: male and female. On a 10-year scale, directors of all ages are divided into six groups: "1" for those under 30, "2" for those between 30 and 39, and so on, and "6" for those 70 and over. Tenure is measured using standard deviation/mean (Richard and Shelor, 2002; Tihanyi et al., 2000). Career background is divided into marketing/sales, law, technology, finance, production/operations, scholars, human resources/administration, management (including officials, military positions, party affairs, Communist Youth League, trade unions, etc.), others; Education professional background is divided into five categories: Class I (science, engineering, agriculture

and medicine), Class II (economics, management), Class III (philosophy, literature, history), Class IV (Law), Class V (other majors).

The Blau coefficient was used to calculate board gender heterogeneity (Hgen), board age heterogeneity (Hage), board tenure heterogeneity (Hten), board functional background heterogeneity (Hfun), and board specialty heterogeneity (Hpro) to make their scales comparable, and then assign equal weight to each factor. To construct the board heterogeneity index.

The research questions and assumptions are listed in **Table 3**.

Table 3. Research questions and hypotheses.

Research Questions		**Research hypotheses**
The effect of board heterogeneity on sustainable innovation ability of enterprises	MH	The heterogeneity of the board of directors has a significant positive impact on the sustainable innovation ability of enterprises
	H1	The gender heterogeneity of the board of directors has a significant positive impact on the sustainable innovation ability of enterprises
	H2	The age heterogeneity of the board of directors has a significant positive effect on the sustainable innovation ability of enterprises
	H3	The heterogeneity of board tenure has a significant positive effect on the sustainable innovation ability of enterprises
	H4	The functional background heterogeneity of the board of directors has a significant positive impact on the sustainable innovation ability of enterprises
	H5	The professional heterogeneity of the board of directors has a significant positive impact on the sustainable innovation ability of enterprises
The mediating role of M&A	H6	The heterogeneity of board gender is positively correlated with M&A
	H7	The heterogeneity of board age is positively correlated with M&A
	H8	The heterogeneity of board tenure is positively correlated with M&A
	H9	The functional background heterogeneity of the board of directors is positively correlated with M&A
	H10	The professional heterogeneity of the board of directors is positively correlated with M&A
	H11	M&a plays a significant mediating role in the relationship between the heterogeneity of the board of directors and the sustainable innovation capability of enterprises

3.2. Research design

The following models were established in this paper for regression analysis:

This paper constructs the following model to verify the impact of board heterogeneity on enterprises' sustainable innovation ability.

$$Patent = \beta_0 + \beta_1 Age + \beta_2 Size + \beta_3 Growth + \varepsilon \quad (1)$$

$$Patent = \beta_0 + \beta_1 Hgen + \beta_2 Hage + \beta_3 Hten + \beta_4 Hfun + \beta_5 Hpro + \beta_6 Age + \beta_7 Size + \beta_8 Growth + \varepsilon \quad (2)$$

$$Patent = \beta_0 + \beta_1 Hgen + \beta_2 Hage + \beta_3 Hten + \beta_4 Hfun + \beta_5 Hpro + \beta_6 Age + \beta_7 Size + \beta_8 Growth + \varepsilon \quad (3)$$

$$Patent = \beta_0 + \beta_1 Hgen + \beta_2 Hage + \beta_3 Hten + \beta_4 Hfun + \beta_5 Hpro + \beta_6 Age + \sum_{i=1}^{5} H \times MAB + \beta_7 Size + \beta_8 Growth + \beta_9 MAB + \varepsilon \quad (4)$$

In the above formula: β_0 represents the intercept, β_1–β_9 represents the coefficient of each variable, and ε is the residual.

4. Empirical analysis

4.1. Research sample and data source

The Science and Technology Board are dedicated to serving small and medium-sized enterprises of science and technology, focusing on small and medium-sized enterprises with normative, innovative, and technology-based characteristics, which have not yet entered the mature stage but have growth potential; Intermediaries and listed enterprises guarantee the integrity, accuracy, and authenticity of its information, and the threshold of financial assets is set up for individual investors. This study chooses the listed enterprises on the Science and Technology Board as the research object instead of the listed enterprises on the small and medium-sized boards, GEM board, and other boards, mainly for two reasons: On the one hand, most of the listed enterprises on the Science and Technology Board belong to the high-tech field, and the sustainable innovation ability is crucial to the development of the company; On the other hand, few scholars have studied the relationship between the heterogeneity of the board of directors of the listed enterprises on the Science and Technology Board and the sustainable innovation of the enterprises, so this is an innovative point of this study. A-board enterprises and science and technology board enterprises difference are shown in **Table 4**. Therefore, the selection of enterprises listed on the Science and Technology Board as the research object of this paper is representative, which is conducive to obtaining more detailed and targeted research results.

Table 4. A-board enterprises and science and technology board enterprises difference.

	A board	**Science and technology board**
Positioning and background	Mature enterprises, emphasizing profitability and stability	Scientific and technological innovation enterprises focus on technological innovation, high growth and high risk, and pay more attention to the future development prospects of enterprises
Regulatory standard	Audit system, regulatory standards are stricter	With the registration system, the supervision focuses on risk warning, information disclosure and investor protection, and also attaches importance to the innovation ability and market competitiveness of enterprises
Listing threshold	There are higher requirements for profitability and stability	Easier financial conditions, such as allowing unprofitable companies to go public
Market positioning	Large blue-chip enterprises, such as banks, liquor and other leading enterprises	A scientific and technological innovation enterprise that conforms to the national strategy, has core technologies and is highly recognized by the market
Number of listed enterprises	3294	424

The opening date of the Science and Technology Board is 22 July 2019. As of 31 December 2021, 424 enterprises are listed on the Science and Technology Board.

After identifying the research objectives, the author collects, collates, processes, and eliminates the enterprise data. The data of all enterprises is screened first, and then the enterprises with incomplete and abnormal data are deleted. Finally, 393 enterprises are obtained. All sample data sources are mainly based on the National Tai's database, and individual missing data are supplemented by a manual search of the annual reports of listed companies and the website of the State Intellectual Property Office.

4.2. Definition and measurement of variables

4.2.1. Explained variable: Enterprise sustainable innovation

In this paper, the number of patents granted is used to measure the sustainable innovation ability of enterprises. In order to solve the possible endogenous problem, the data of sustainable innovation and control variables of enterprises in this paper are used to lag one period. Based on the existing literature, this paper uses the number of invention patent applications to measure the sustainable innovation of enterprises for the following reasons: The existing literature mainly measures the innovation activities of enterprises from the perspective of R&D expenditure and the number of patents. The number of patents is considered to be a better measure because, as innovation output, it can more comprehensively reflect the transformation of firms' various observable and unobservable innovation inputs. On the contrary, R&D expenditure is only a particular, observable, and quantifiable part of the total innovation input. Human capital development, new technology introduction, elimination, and absorption of firms are not reflected.

Moreover, there may be a problem of distortion of financial statements in R&D expenditure. Second, the number of patent applications and grants recorded in the data of Guotai' an. This paper calculates the number of applications according to the number of applications. The reason is that the number of patent applications represents the technological innovation results of the enterprise's subjective self-evaluation.

In contrast, external sources review and recognize the number of authorized patents. However, patent authorization often has a time lag and is susceptible to government intervention and other factors. However, patent applications represent the knowledge output already formed by enterprises, so the number of patent applications is a more suitable indicator of sustainable innovation.

4.2.2. Explanatory variables

Measurement of board heterogeneity: This paper adopts the Blau index, widely used in literature, to measure board heterogeneity. The formula for calculating the Blau index is as follows:

$$H = 1 - \sum_{i=1}^{n} {p_i}^2$$

Where *pi* refers to the proportion of people of type I in the population, *n* is the number of all categories. *H* values are between 0 and 1, with higher *H* values indicating more significant population heterogeneity on a particular feature. The respective variables are measured as follows: The board's gender is divided into two categories: male and female. On a 10-year scale, directors of all ages are divided into six groups: "1" for those under 30, "2" for those between 30 and 39, and so on, and "6" for those 70 and

over. Tenure is measured using standard deviation/mean (Richard and Shelor, 2002; Tihanyi et al., 2000). Career background is divided into marketing/sales, law, technology, finance, production/operations, scholars, human resources/administration, management (including officials, military positions, party affairs, Communist Youth League, trade unions, etc.), others; Education professional background is divided into five categories: Class I (science, engineering, agriculture and medicine); Class II (economics, management); Class III (philosophy, literature, history); Class IV (Law); Class V (other majors).

The Blau coefficient was used to calculate board gender heterogeneity (Hgen), board age heterogeneity (Hage), board tenure heterogeneity (Hten), board functional background heterogeneity (Hfun), and board specialty heterogeneity (Hpro) to make their scales comparable, and then assign equal weight to each factor. To construct the board heterogeneity index.

4.2.3. Intermediary variable: M&A

In this paper, enterprise M&A behavior is regarded as the intermediary variable, and the measurement of enterprise M&A behavior mainly adopts the index of whether the enterprise succeeds in M&A. According to the classification guidelines of listed enterprises issued by the China Securities Regulatory Commission, a dummy variable is used for M&A behavior; that is, the value of successful M&A behavior is 1; The value of no successful merger and acquisition is 0.

4.2.4. Control variables

(1) Company Age (Age). Generally speaking, compared with mature enterprises, young enterprises are more likely to adopt new methods and technologies and carry out innovation. In this paper, age is measured using the year of observation minus the firm's establishment year plus the natural logarithm of 1.

(2) Company Size (Size). Company size is an essential factor affecting the sustainable innovation of enterprises. Generally speaking, the larger an enterprise is, the more obvious its essential conditions, scale effect, and reputation advantages, the more likely it is to obtain various resources required for innovation, and the more capable it is to deal with the risks brought by innovation. This paper uses the natural logarithm of a firm's total assets to measure firm size.

(3) Growth. The growth rate of the primary business income reflects the growth of an enterprise, and the growth of an enterprise is closely related to its sustainable innovation. In order to seek better development in the future, high-growth enterprises have the demand and motivation of continuous innovation. A higher primary business income growth rate can provide stable financial support for enterprise innovation. Therefore, this paper selects the growth rate of the enterprise's primary business income as the control variable.

4.3. Test model

In order to test the impact of board heterogeneity on enterprise sustainable innovation, the following regression model was constructed by using least square method:

$$Patent = \beta_0 + \beta_1 Age + \beta_2 Size + \beta_3 Growth + \varepsilon \quad (1)$$

$$Patent = \beta_0 + \beta_1 Hgen + \beta_2 Hage + \beta_3 Hten + \beta_4 Hfun + \beta_5 Hpro + \beta_6 Age + \beta_7 Size + \beta_8 Growth + \varepsilon \quad (2)$$

$$Patent = \beta_0 + \beta_1 Hgen + \beta_2 Hage + \beta_3 Hten + \beta_4 Hfun + \beta_5 Hpro + \beta_6 Age + \beta_7 Size + \beta_8 Growth + \varepsilon \quad (3)$$

$$Patent = \beta_0 + \beta_1 Hgen + \beta_2 Hage + \beta_3 Hten + \beta_4 Hfun + \beta_5 Hpro + \beta_6 Age + \sum_{i=1}^{5} H \times MAB + \beta_7 Size + \beta_8 Growth + \beta_9 MAB + \varepsilon \quad (4)$$

In the above formula: β_0 represents the intercept, β_1–β_9 represents the coefficient of each variable, and ε is the residual.

4.4. Descriptive statistics and correlation analysis

4.4.1. Descriptive statistics of main variables

In this paper, stata 15.0 is used to analyze the sample data. **Table 5** reports the results of the sample descriptive statistics analysis.

Table 5. Research variables.

Types of variables	Variable name	Variable symbol	Variable definition
Explained variable	Enterprise sustainable innovation ability	Patent	The natural logarithm of the company's total number of patent applications for inventions is added to one
Explanatory variables	Board gender heterogeneity	Hgen	$H = 1 - \sum_{i=1}^{n} p_i^2$
	Board age heterogeneity	Hage	$H = 1 - \sum_{i=1}^{n} p_i^2$
	Heterogeneity of board tenure	Hten	Standard deviation/mean
	Heterogeneity of board functional background	Hfun	$H = 1 - \sum_{i=1}^{n} p_i^2$
	Board specialty heterogeneity	Hpro	$H = 1 - \sum_{i=1}^{n} p_i^2$
Mediating variables	M&A behavior	MAB	Whether the enterprise has a merger and acquisition, the value is 1 when the merger and acquisition behavior occur; If there is no M&A, the value is 0.
Control variables	Company age	Age	Year of observation minus year of incorporation plus 1 Take the natural logarithm
	Company size	Size	Take the natural logarithm of total company assets
	Growth	Growth	Growth rate of main business income

Table 6 is descriptive statistics of the relevant variables in this paper. From the information in the table, it can be seen that the mean value of sustainable innovation of enterprises in the explained variable is 2.075, the minimum value is 0, and the

maximum value is 16.15, indicating that the innovation capability of enterprises varies significantly among the sample companies.

Among the explanatory variables, it can be seen that the mean age heterogeneity of the board of directors is only 0.035, which indicates that the age heterogeneity level of the sample enterprises as a whole is low, and the age difference among the board members of most enterprises is slight. The mean value of functional background heterogeneity is 0.581, which is more significant than 0.5, the maximum value is 0.75, and the minimum value is 0. The mean value of professional heterogeneity is 0.415, less than 0.5, the maximum value is 0.667, and the minimum value is 0, indicating that the board of directors has apparent differences in functional background heterogeneity and professional heterogeneity among the sample enterprises. The difference in the board of directors' functional background is more significant than that of professionals.

4.4.2. Correlation analysis

Table 7 shows the correlation analysis of the main variables in this paper. The results show that the correlation coefficient between professional heterogeneity and firm sustainable innovation is 0.232 ($p < 0.01$), that between functional background heterogeneity and firm sustainable innovation is 0.064 ($p < 0.05$), and that between tenure heterogeneity and firm sustainable innovation is 0.048. The correlation coefficient between gender heterogeneity and corporate sustainable innovation is 0.016, and the correlation coefficient between age heterogeneity and corporate sustainable innovation is 0.200, indicating that the heterogeneity of the board of directors is significantly positively correlated with corporate sustainable innovation. H1–5 is preliminarily verified. (1) There is a significant positive correlation between M&A behavior and sustainable innovation ($\beta = 0.310$, $p < 0.01$), indicating that M&A behavior can promote sustainable innovation; (2) there is a significant negative correlation between enterprise age and sustainable innovation ($p < 0.01$), which indicates that with the increase of enterprise age, enterprises are reluctant to invest more funds in R&D projects with long response period and high risk; (3) The correlation coefficients between the variables are all less than 0.5, indicating that the results of empirical analysis are not likely to be threatened by multicollinearity. In addition, this study further tested whether the empirical results were threatened by multicollinearity by calculating the VIF value of the variables. The results show that the maximum VIF value is 1.64, far less than 10, which further indicates that the empirical analysis results of this study are less threatened by multicollinearity.

Table 6. Descriptive statistics.

Variables	Sample size	Observations	Mean	Standard deviation	Minimum	Maximum
1. Patent	260	1543	2.075	1.942	0	16.150
2. Hpro	260	1545	0.415	0.152	0	0.667
3. Hfun	260	1538	0.581	0.109	0	0.75
4. Hten	260	1499	0.486	0.172	0.3	1
5. Hgen	260	1546	0.370	0.053	0	0.571
6. Hage	260	1546	0.035	0.051	0.458	0.221

Table 6. (*Continued*).

Variables	Sample size	Observations	Mean	Standard deviation	Minimum	Maximum
7. MAB	260	1546	0.379	0.141	0.091	0.755
8. Age	260	1546	2.216	0.189	1.609	2.708
9. Size	260	1546	2.942	0.264	1.946	3.556
10. Growth	260	1544	2.146	0.165	1.356	2.468

Table 7. Correlation analysis of variables.

Variables	1	2	3	4	5	6	7	8	9	10
1. Patent	1									
2. Hpro	0.232***	1								
3. Hfun	0.064**	0.033	1							
4. Hten	0.048*	0.080***	0.020	1						
5. Hgen	0.016	0.138***	0.026	0.042	1					
6. Hage	0.200***	0.014	0.025***	0.119***	0.033	1				
7. MAB	0.310***	0.008	0.102***	0.070***	0.091***	0.009	1			
8. Age	0.025	0.080***	0.009	0.062***	0.360***	0.016	0.111***	1		
9. Size	0.106***	0.141***	0.013	0.078***	0.066***	0.023	0.234***	0.107***	1	
10. Growth	0.032	0.024	0.020	0.039	0.078	0.006	0.156	0.068	0.102	1

Note: ***, ** and * represent significance levels of 1%, 5% and 10%, respectively.

4.5. Regression results and hypothesis testing

In this paper, hierarchical regression analysis is used to test the impact of board heterogeneity on corporate sustainable innovation and the mediating role of mergers and acquisitions between them. Specific results are shown in **Table 8** below.

A total of three empirical models were introduced in this study, among which:

In Model 1, only the dependent variable (enterprise sustainable innovation) and the control variable of this paper are introduced;

On the basis of Model 1, Model 2 introduces independent variables—board heterogeneity (gender heterogeneity, age heterogeneity, tenure heterogeneity, functional background heterogeneity, professional heterogeneity);

In Model 3, on the basis of Model 2, an intermediary variable was added: corporate mergers and acquisitions;

In Model 4, the interaction term between M&A and heterogeneity of board of directors is added on the basis of model 3.

Table 8. Regression model of board heterogeneity and corporate sustainable innovation.

Variables	Model (1)	Model (2)	Model (3)	Model (4)
Hgen		2.928***	1.577*	2.947***
Hage		1.461***	1.448***	4.001***
Hten		1.379***	3.182*	4.701*
Hfun		1.654***	2.397*	5.368**
Hpro		2.325***	3.271*	3.402*

Table 8. (*Continued*).

Variables	Model (1)	Model (2)	Model (3)	Model (4)
MAB			1.312	3.258**
$\sum_{i=1}^{5}$ H×MAB				3.229*
Age	0.649	0.369	0.498*	0.323
Size	7.631***	7.680***	7.632***	7.758***
Growth	1.977 ***	2.068***	2.126***	2.112***
_cons	6.648***	5.483***	5.996***	6.995***
R-suqared	0.072	0.128	0.127	0.129
Adj R2	0.069	0.124	0.122	0.123
F-number	23.85***	31.91***	24.05***	24.26***

Note: ***, ** and * represent significance levels of 1%, 5% and 10%, respectively.

Model 1 is the basic model of this paper. Only control and control variables are introduced to test the correlation between the control variables selected in this paper and the explained variables. As seen from **Table 8**, the explanatory power of control variables to the explained variable of enterprise sustainable innovation is 6.9% (*R2 F* value is 23.85 and significant, indicating that the control variable selected in this paper is influential. Among the control variables, company age, size, and growth significantly correlate with enterprise sustainable innovation. Among them, the correlation coefficient between firm age and firm innovation is −0.649, which is significant at a 1% confidence level, indicating that the level of firm sustainable innovation decreases with the growth of firm establishment time, which may be because enterprises need to rely on innovation to establish themselves in the market at the early stage of establishment, and they are full of innovation enthusiasm. With the growth of firm age, they will accumulate more resources. Innovation is one of many driving forces for the survival of enterprises, and the degree of emphasis on enterprise innovation decreases. The correlation coefficient between firm size and sustainable innovation is 7.631. It is significant at a 1% confidence level, indicating that sustainable innovation will improve with the expansion of firm size, and the larger the firm size, the stronger the sustainable innovation ability. There is a significant positive correlation between firm growth and firm sustainable innovation at a 1% confidence level, indicating that the stronger the firm growth, the more confident the firm is in its innovation and the more willing it is to invest in its innovation activities and the more potent its sustainable innovation ability.

In Model 2, the explanatory variable board heterogeneity is added based on Model 1 to empirically test the main effect of the independent variable board heterogeneity on the sustainable innovation of enterprises, that is, to test hypotheses 1–5. The adjusted *R* of Model 2 can be seen in **Table 8**. The increase from 0.069 in model 1 to 0.124 indicates that model 2 has a better fitting effect on the data. It is meaningful to introduce five explanatory variables, such as gender heterogeneity, age heterogeneity, tenure heterogeneity, functional background heterogeneity, and professional heterogeneity, into the model, which enhances the explanatory power of the model. The *F* statistic is 23.85, and Sig is less than 0.01, indicating that the model's overall significance is good. Regression results show that gender heterogeneity on the

board of directors significantly correlates positively with corporate sustainable innovation (β = 2.928, p < 0.01). Hypothesis 1 is verified.

The gender heterogeneity of the board of directors has a positive effect on the sustainable innovation of enterprises. The more significant the gender heterogeneity, the more the board of directors promotes the innovation of enterprises. Age heterogeneity of the board of directors was significantly positively correlated with sustainable innovation (β = 1.461, p < 0.01). Hypothesis 2 was verified. The age heterogeneity of the board of directors has a positive effect on the sustainable innovation of enterprises. The more significant the age heterogeneity, the more the board of directors promotes the innovation of enterprises. There is a significant positive correlation between board tenure heterogeneity and sustainable innovation (β = 1.379, p < 0.01). Hypothesis 3 verified that board tenure heterogeneity has a positive promoting effect on sustainable innovation. The functional background heterogeneity of the board of directors is significantly positively correlated with the sustainable innovation of enterprises (β = 1.654, p < 0.01), and hypothesis 4 is verified. The functional background heterogeneity of the board of directors positively affects sustainable innovation. There is a significant positive correlation between professional heterogeneity of the board of directors and sustainable innovation (β = 2.325, p < 0.01). Hypothesis 5 is verified. The professional heterogeneity of the board of directors has a positive effect on sustainable innovation.

Based on Model 2, Model 3 adds an intermediary variable, M&A, to test the impact of M&A on the heterogeneity of the board of directors. The adjusted R of Model 3 can be seen in **Table 8**, which is 0.122, the same as the adjusted R of Model 22. The size is the same, indicating that Model 3 has an excellent fitting effect on the data. Introducing the intermediary variables of enterprise M&A into the model is meaningful, and the model has a solid explanatory force. The *f* statistic is 24.05, and the Sig is less than 0.01. The overall significance of the model is good. The regression results show that the model passes the 10% significance test, and the coefficient is 3.182, indicating that M&A has a significant impact on the heterogeneity of the board of directors. H6–10 is valid.

Model 4 is based on model 3, adding the interaction term between M&A and board heterogeneity to empirically test the mediating effect of M&A on board heterogeneity and corporate sustainable innovation. As can be seen from **Table 8**, the adjusted *R2* of model 4 is 0.123, which is consistent with the adjusted *R2* of model 2, indicating that model 4 has an excellent fitting effect on the data, the introduction of interaction terms into the model is meaningful, and the model has a solid explanatory force. The statistic of *F* is 24.26, and Sig is less than 0.01, which indicates that the overall significance of the model is good. The intermediary effect of M&A passes the test at 5% significance, and the coefficient is 5.368, indicating that M&A enhances the influence of board heterogeneity on corporate sustainable innovation. Hypothesis 11 is verified.

Based on theoretical analysis, this paper puts forward H11 on the relationship between board heterogeneity and corporate sustainable innovation, in which H1–5 are the primary effect hypothesis and H6–11 are the intermediary effect hypothesis. The results of hypothesis testing are shown in **Table 9**.

Table 9. Results of hypothesis testing.

ID	Assumed contents	Test results
MH	The heterogeneity of the board of directors has a significant positive impact on the sustainable innovation ability of enterprises	Support
H1	The gender heterogeneity of the board of directors has a significant positive impact on the sustainable innovation ability of enterprises	Support
H2	The age heterogeneity of the board of directors has a significant positive effect on the sustainable innovation ability of enterprises	Support
H3	The heterogeneity of board tenure has a significant positive effect on the sustainable innovation ability of enterprises	Support
H4	The functional background heterogeneity of the board of directors has a significant positive impact on the sustainable innovation ability of enterprises	Support
H5	The professional heterogeneity of the board of directors has a significant positive impact on the sustainable innovation ability of enterprises	Support
H6	The gender heterogeneity of board is positively correlated with M&A	Support
H7	The heterogeneity of board age is positively correlated with M&A	Support
H8	The heterogeneity of board tenure is positively correlated with M&A	Support
H9	The functional background heterogeneity of the board of directors is positively correlated with M&A	Support
H10	The professional heterogeneity of the board of directors is positively correlated with M&A	Support
H11	M&A plays a significant mediating role in the relationship between the heterogeneity of the board of directors and the sustainable innovation capability of enterprises	Support

4.6. Robustness test

In order to check whether the research conclusions of this paper are robust, this paper uses the following two methods to carry out a robustness test.

4.6.1. Variable lag

The heterogeneity of the board of directors has a lag effect on the result of sustainable innovation, that is, the number of patent applications of enterprises. Meanwhile, to avoid the problem of time series autocorrelation, this paper delays the dependent variables in the model by one period to test the interaction of control, explanatory, and intermediary variables on enterprises' sustainable innovation. That is, the enterprise innovation data of the next period is used to test the hypothesis, and the test results are shown in **Tables 10** below.

4.6.2. Replace variables

In this paper, the explanatory variable, namely enterprise sustainable innovation, is replaced with R&D. These two indicators are firm innovation in a theoretical sense, so they will not affect the assumptions in this paper and meet the robustness requirements. This paper recalculates the relationship between various variables according to the model constructed above, and the test results are shown in **Table 11** below. Suppose the regression equation of the main variables is significant. In that case, the residual analysis has no autocorrelation, and the regression coefficient has no fundamental change, such as a positive number becoming negative, a negative number becoming positive, etc. The *P*-value is also significant, so the regression model meets the requirements, and the result is robust.

Table 10. Regression model (lag one stage).

Variables	Model (1)	Model (2)	Model (3)	Model (4)
Hgen		3.338***	2.012*	3.322***
Hage		1.774***	1.802***	5.971***
Hten		0.382	3.206 *	2.478
Hfun		7.861***	8.023***	8.640***
Hpro		8.023***	1.483	5.414***
MAB			0.510	0.214
$\sum_{i=1}^{5}$ H×MAB				8.050***
Age	2.254***	2.379***	2.447***	2.437***
Size	0.356	0.474	0.468	0.456
Growth	−1.183***	0.894***	0.877**	0.902***
_cons	7.147***	5.891***	6.545***	8.598***
R-suqared	0.082	0.151	0.151	0.156
Adj R2	0.079	0.145	0.145	0.149
F-number	22.94***	32.20***	24.37***	25.27***

Note: ***, ** and * represent significance levels of 1%, 5% and 10%, respectively.

As shown in **Table 10**, Model 1 is to test the correlation between control variables and explained variables. Empirical results show that most control variables and dependent variables are significantly correlated; Model 2 tests the correlation between explanatory variables and defined variables, and the empirical results show that gender heterogeneity of the board of directors has a significant positive impact on the sustainable innovation of enterprises (β = 3.338, p < 0.01), and age heterogeneity has a significant positive impact on the sustainable creation of enterprises (β = 1.774, p < 0.01). Tenure heterogeneity has a significant positive effect on sustainable innovation (β = 0.382, p < 0.01), functional background heterogeneity has a significant positive impact on sustainable innovation (β = 7.861, p < 0.01), professional heterogeneity has a significant positive effect on sustainable innovation (β = 8.023, p < 0.01). H1–5 was verified; Model 3 and Model 4 test the mediating effect of M&A, and the results show that M&A enhances the positive impact of board heterogeneity on sustainable innovation. H6–11 is verified; Model 4 is complete, and H1–5 is confirmed.

Table 11. Regression model (alternate variables).

Variables	Model (1)	Model (2)	Model (3)	Model (4)
Hgen		6.572***	5.149***	6.598***
Hage		3.184***	3.210***	8.808***
Hten		3.641***	5.332*	3.379***
Hfun		6.458	4.787***	11.778**
Hpro		5.568	5.465*	6.099**
MAB			1.188	1.527
$\sum_{i=1}^{5}$ H×MAB				8.720***
Age	5.377***	5.551***	5.562***	5.529***

Table 11. (*Continued*).

Variables	Model (1)	Model (2)	Model (3)	Model (4)
Size	1.109**	1.380**	1.496***	1.482***
Growth	2.488***	1.953***	1.825***	1.840***
_cons	16.473***	13.840***	14.075***	16.871***
R-suqared	0.065	0.131	0.132	0.134
Adj R2	0.062	0.127	0.127	0.129
F-number	21.28***	32.90***	25.08***	25.59***

Note: ***, ** and * represent significance levels of 1%, 5% and 10%, respectively.

As shown in **Table 11**, Model 1 tests the correlation between control variables and explained variables, and the empirical results show that most control variables and defined variables are significantly correlated; Model 2 tested the correlation between explanatory variables and explained variables, and the results showed that gender heterogeneity of the board of directors had a significant positive impact on the sustainable innovation of enterprises ($\beta = 6.572$, $p < 0.01$), and age heterogeneity had a significant positive impact on the sustainable creation of enterprises ($\beta = 3.184$, $p < 0.01$). Tenure heterogeneity has a significant positive effect on sustainable innovation ($\beta = 3.641$, $p < 0.01$), functional background heterogeneity has a significant positive impact on sustainable innovation ($\beta = 6.458$, $p < 0.01$), professional heterogeneity has a significant positive effect on sustainable innovation ($\beta = 5.568$, $p < 0.01$). H1–5 was verified; Model 3 and Model 4 test the mediating effect of M&A, and the results show that M&A enhances the positive impact of board heterogeneity on sustainable innovation. H6–11 is verified; Model 4 is complete, and H1–5 is confirmed.

After the variable lags one period and replaces the variable, no matter the explanatory variable or the interaction term, the coefficient sign of the explained variable is not affected, and the significance is not affected. Therefore, the model is established, and the result is robust and reliable.

5. Conclusions and policy implications

5.1. Research conclusions

With the deepening of the development of the knowledge economy and the increasingly fierce market competition, enterprises must carry out sustainable innovation to survive. The board of directors is an essential resource of the company and a source of strategic decision-making ability. How its heterogeneity affects the company's sustainable innovation has become an exciting research topic. Based on the practice of the heterogeneity of directors in China's Science and Technology Board, this paper explores the relationship between the heterogeneity of directors and the sustainable innovation of enterprises from the perspective of the mediating role of M&A behavior. Through the research, the following conclusions are drawn:

The Heterogeneity of directors has a significant impact on sustainable innovation. The board team with heterogeneous functional backgrounds has more vital sustainable innovation ability. Professional heterogeneity positively impacts corporate sustainability because professional heterogeneity cognition and knowledge are

reserved for the board of directors, which enriches and develops the team and thus improves the sustainable innovation ability of enterprises.

The heterogeneity of directors has a significant impact on M&A. When making decisions, the board of directors faces uncertainty from the external environment and the differences in trust and familiarity among the board members. When there are heterogeneous members in terms of age, gender, tenure, functional background, and profession, trust and communication among board members will increase, which can increase cohesion among board members and is conducive to the occurrence of corporate mergers and acquisitions. At the same time, when the information attributes of board members are heterogeneous in terms of educational background, career background, and so on, different plans may be provided for the team's decision-making, which will enhance the board's exploration of opportunities and also play an essential role in the flexibility of the team's strategic positioning, which can have a positive impact on the occurrence of corporate mergers and acquisitions.

M&A is an intermediary between the heterogeneity of directors and corporate sustainability. The reason why M&A can improve the sustainable innovation ability of enterprises is that M&A will produce a scale effect, which will promote the continuous innovation of enterprises while expanding the production scale and increasing output. At the same time, mergers and acquisitions bring talents and equipment elements to the leading mergers and acquisitions, which can improve the technical level of enterprises in production and sales. The innovation of management methods and production technology brought by M&A behavior can enhance the sustainable innovation ability of enterprises.

5.2. Countermeasures and suggestions

Using the data of small and medium-sized enterprises in China's Science and Technology Innovation Board, this paper explores the impact of five dimensions of board heterogeneity (gender heterogeneity, age heterogeneity, tenure heterogeneity, functional background heterogeneity, and professional heterogeneity. At the same time, it explores whether corporate mergers and acquisitions can play an intermediary role in the relationship between board heterogeneity and the sustainable innovation ability of enterprises. From the previous analysis, we believe that the heterogeneity of directors improves the innovation ability of enterprises. According to the content of this study, the following countermeasures and suggestions are put forward: (1) Rationally allocate Board members; (2) Standardize the M&A behavior of enterprises; (3) Implementation of M&A strategy.

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