HOW DO CORPORATE GOVERNANCE, ARTIFICIAL INTELLIGENCE, AND INNOVATION INTERACT? FINDINGS FROM DIFFERENT INDUSTRIES

Raef Gouiaa *, Run Huang **

* *Corresponding author,* University of Québec in Outaouais, Gatineau, Canada
Contact details: University of Québec in Outaouais, 283 Alexandre-Taché Blvd, CP1250, Succursale Hull, Gatineau, Québec J8X 3X7, Canada
** Huazhong Agricultural University, Wuhan, China

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Abstract

Research in the field of corporate governance has been exhaustive, and recently many scholars have focused on the relationship between corporate governance attributes and artificial intelligence (AI), corporate governance attributes, and corporate innovation (Asensio-López et al., 2019), however, there are few studies that combine corporate governance, AI, and corporate innovation. This article examines the relationships among corporate governance attributes, AI, and corporate innovation. Adopting a new perspective, we have tried to help resolve this issue using a content-analysis that integrates data from over 50 companies that trade on National Association of Securities Dealers Automated Quotations (NASDAQ) to analyze the relationship between board attributes, the practice of AI and firm innovation for the time 2018–2022. The results suggest that particular aspects of boards, such as board size, board diversity, and ownership concentration show significant correlations with firm AI development and innovation for overall industries, but the levels of associations also vary depending on different innovation measurements and samples considered in specific industries. Corporate governance has more significant variables in the manufacturing and information technology service industries. Moreover, the mediating effects of AI and innovation are examined, respectively. This research offers implications to corporate decision-makers as to how to proceed if the intent is to offer commercialized AI advancements and successful breakthrough innovations.

Keywords: Corporate Governance, Ownership Concentration, Artificial Intelligence, Innovation

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1. INTRODUCTION

While most previous research focused on the impact of internal governance on firm performance and value, in recent years, scholars have increasingly studied the influence of governance mechanisms on managerial innovation decisions. Scholars believe that innovation efforts and outcomes depend on factors influenced by corporate governance, such as ownership structure or board composition.

Ortega-Argils et al. (2005) found that highly concentrated ownership and reliance on debt financing hinder firms' investment in research and development (R&D) and do not yield favorable R&D outcomes. Asensio-López et al. (2019) argued that different internal corporate governance mechanisms may even be determining factors for firm innovation. In addition to ownership structure, the board structure also has a certain impact on firm innovation and its efficiency. Feng and Wen (2008) found a significant positive relationship between the proportion of independent directors on the board and innovation investment, the lower the proportion of independent directors, the relatively less innovation investment by the firm. It can be found that in recent years there has been a growing interest in the literature regarding the role played by boards and the characteristics of boards that are most conducive to promoting corporate innovation. However, the empirical evidence is not conclusive, and the results are sometimes contradictory. This is mainly because previous studies focused on a single variable related to the board, the variables were defined in different ways, or innovation was not considered from both input and output dimensions. Therefore, it is necessary to integrate all corporate governance elements that may have an impact on innovation activities.

Previous studies also proved that the effect of corporate governance on artificial intelligence (AI) existed, and there is an inherent connection mechanism between the two. However, the current research on this impact mechanism is still in the exploratory stage, few scholars have researched this aspect, and academics have not formed a unified view of the measurement of AI. Our study will also analyze the empirical mechanism of corporate governance affecting AI and test the impact in terms of specific governance elements.

Moreover, our findings also highlight the existence of the mediating effect of AI or innovation. Most of the previous literature analyzed AI and Innovation separately. By observing the variables measured by previous scholars, we found that the measurement indicators of AI and innovation are relatively fixed and have undetermined overlaps. Therefore, it can be inferred that due to the inefficiency in quantitatively distinguishing the two variables, scholars have not yet analyzed the two in a unified manner. Subsequently, we innovatively used the frequency of text words related to the two, extracted from financial reports as an indicator to measure the difference in the company's focus on AI development and innovation activities, which is also combined with traditional measurements (Coluccia et al., 2020), thereby confirming the effect and difference in the role of the two as mediating variables. To summarize, the main objective of this research is to unveil the inter-relationship among corporate governance, AI, and innovation, aiming to find the crucial impacts of characteristics of corporate governance on AI and innovation. Meanwhile, according to empirical results, we also explored the potential impacts of AI on changing corporate governance structures as our secondary objective.

The rest of this paper is structured as follows. Section 2 reviews the relevant literature. Section 3 demonstrates the methodology that has been used to conduct empirical research on revealing the inter-relationship among AI, corporate governance, and innovation. Section 4 analyses the results of empirical research. Section 5 discusses the findings of this research. Section 6 concludes the whole content and limitations of this research.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1. Corporate governance

Company governance is not a novel concept. Over the past two decades, corporate governance has become one of the most concentrated topics worldwide. The issues of company closures and development bottlenecks have put pressure on organizations across the globe, compelling them to implement sound governance practices effectively and successfully.

Regardless of the specific definitions used, researchers generally categorize corporate governance mechanisms into two types: internal and external governance. Building upon the perspectives of Shleifer and Vishny (1997), we consider internal governance to encompass the aspects of the board of directors, management, and supervisory board; while external governance includes creditors, managerial markets, product markets, legal protections, and others. Gillan and Starks (2003) adopt a macro perspective, defining corporate governance as the regulatory framework and factors that control a company's operations.

In the early stages of academic inquiry, research on corporate governance primarily focused on specific governance elements. For instance, Johnson et al. (1996) and Hermalin and Weisbach (2006) concentrated on board governance; Shleifer and Vishny (1997) reviewed the relevant literature from an investor protection perspective, with a specific focus on legal protections for investors and the concentration of corporate equity worldwide; and Holderness (2003) examined governance concerning large shareholders. Aguilera et al. (2006) provided a comprehensive exposition on ownership structures and types of controlling shareholders. Meanwhile, literature reviews also highlighted the overall progress in the field of corporate governance, such as those by Macey and O'hara (2003), Daily et al. (2003), and Morck et al. (2005).

Furthermore, certain studies placed particular emphasis on corporate governance issues in specific countries and regions. For example, Denis (2001) conducted a comprehensive review of corporate governance research over the past 25 years, primarily focusing on the United States; Claessens and Fan (2003) centered on corporate governance issues in Asia; Clarke (2003) highlighted corporate governance concerns in China; Fan et al. (2011) addressed corporate governance issues in emerging market countries. Denis and McConnell (2003) not only focused on research related to corporate governance in the United States but also examined governance in emerging market countries. Similarly, Ali et al. (2017) simultaneously explored research on social responsibility information disclosure in both developed and developing countries.

2.2. Innovation

Since Schumpeter and Swedberg (2021) first introduced the concept of "innovation" in his famous work "The Theory of Economic Development" in 1912, innovation has gradually gained attention from both the theoretical and practical spheres. Initially, scholars mainly conducted performance-based research on innovation, using innovation performance to reflect the results of firms' innovative behaviors, which are crucial for their survival and development. As business continues to evolve, organizations face increasing pressure to apply digital technology to update and transform their business models. Consequently, scholars have since conducted abundant exploratory research on the technological aspects of innovation within firms.

Yang and Liu (2020) defined enterprise technological innovation capability from a structural perspective, arguing that it is the integration of organizational adaptability, innovation capability, and the ability to acquire technology and information. Burgelman and Maidique (1988) viewed enterprise technological innovation capability as a series of comprehensive characteristics that support the firm's technology innovation strategy, including the allocation of available resources, understanding of industry and technological developments, and capabilities in structure and cultural conditions, as well as strategic management. This understanding linked the enterprise's technological innovation capability to its technology innovation strategy, emphasizing the supportive role of the former and the guiding role of the latter.

Leonard-Barton (1992) pointed out that the core of enterprise technological innovation capability lies in the capabilities of people with expertise, technological systems, management systems, and the company's values. His viewpoint highlighted the elements that permeate enterprise technological innovation capability. Neely and Hii (1998) reviewed research on innovation at the company, regional, and national levels, discussing the relationship between firm innovation capability and performance. Adams et al. (2006) established the fundamental framework for innovation management and included factors of significant importance in each category of the framework for measurement in the innovation process. Some researchers argue that the innovation process should be seen as a series of changes within a complete system, including hardware innovations as well as software-level innovations such as market environment, production facilities, and knowledge innovations (Kline & Rosenberg, 2009).

The advent of the digital age has led to a gradual increase in research on sustainable innovation, digital innovation, and AI-related innovation in the past decade. When discussing digital innovation, the term "digital transformation" is often mentioned. McKinsey defines it as not being about any single process but about how a company operates its business (Dörner & Edelman, 2016). Moreover, the technical aspect of digitization represents only a small part of a firm's comprehensive digital transformation. AI has long been regarded as a disruptive force capable of innovating various industries, and companies adopting AI applications are expected to increase revenue, reduce costs, and improve business efficiency (Alsheibani et al., 2020). Bican and Brem (2020) elucidated how different processes of digitalization are linked to sustainable innovation within companies under the context of digital transformation.

2.3. Artificial intelligence

Since the concept of AI was proposed in 1956, it has achieved significant progress in both theoretical research and application fields over more than six decades. AI has penetrated various domains of national life, including business, healthcare, and information security. Professor Nelson from the Artificial Intelligence Research Center at Stanford University defined AI as a discipline about knowledge, studying how to represent, acquire, and utilize knowledge (Jun Liu et al., 2022). Currently, AI is classified into strong AI and weak AI in academia. The development of AI technology itself can be considered as part of innovation, and AI can also promote other forms of innovation. Liu et al. (2020) empirically analyzed data from Chinese manufacturing firms and found that AI significantly promotes technological innovation through accelerated knowledge creation, technological spillovers, and enhanced learning under the control of R&D investment and ownership structure. Brem et al. (2021) believe that the generative and variable nature of AI enables entrepreneurs to rapidly identify potential technological applications, exploring AI as an initiator and facilitator of innovation. Reim et al. (2020) conducted in-depth research on the application of AI at the level of business model innovation and proposed four steps for implementing AI at the business level. Bahoo et al. (2023) emphasize that AI has reshaped the ways and content of corporate innovation, presenting a framework covering eight areas where AI intersects with business innovation (AI and business models, AI and product innovation, AI and open innovation, AI and innovation processes, AI and corporate innovation structure, AI and corporate knowledge innovation, AI and corporate market performance innovation, AI and supply chain management innovation), providing an overview of the role of AI in corporate innovation.

2.4. Artificial intelligence and innovation

AI is a discipline centered around knowledge, encompassing the representation, acquisition, and utilization of knowledge. The development of AI technology itself is considered a part of innovation. However, AI can also facilitate other forms of innovation within companies. By accelerating knowledge creation, technology spillover, enhancing learning and absorption capabilities, and increasing investment in research and talent, AI can promote various types of innovation, particularly technological innovation. The higher the level of AI development, the greater its influence on technological innovation. Brem et al. (2021) argued that the generative and variable nature of AI allows entrepreneurs to rapidly identify potential technological applications, framing AI as both an initiator and enabler of innovation.

2.5. Artificial intelligence and corporate governance

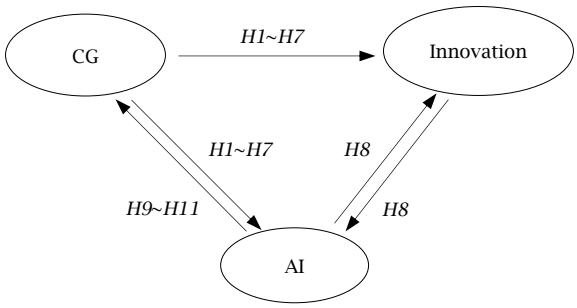
Previous research has found that AI has an impact on corporate governance, and there is an intrinsic link between the two. However, the impact of AI on

corporate governance has garnered significant attention in the academic community, but a consensus has not yet been reached.

Hilb (2020) proposed five scenarios of AI governance based on business, technological, and social perspectives: assistive AI, augmented AI, amplified AI, autonomous AI, and autopoietic AI. The study demonstrated the varying degrees of influence these scenarios have on board decisions. Verhoef et al. (2021) argue that AI can enhance corporate governance and better promote public interests, encompassing the obligations of companies to a wider range of stakeholders. Khan et al. (2022) (GLS analysis of firm revenue) revealed the mediating role of technological innovation in the relationship between board attributes and economic development. Cui et al. (2022) empirically analyzed the mechanisms and mediation effects of AI on corporate governance, suggesting that AI applications can enhance the information required for good governance and thus provide favorable conditions for improving corporate governance.

Based on previous research, the inherent differences in corporate governance among different companies have a significant impact on innovation and AI performance. Incentives from the board of directors and shareholders play an important role in corporate innovation. Since corporate governance affects the way companies integrate resources such as human and material resources, it subsequently affects investment decisions for innovation. Therefore, the corporate governance system can be regarded as the core for analyzing corporate innovation behavior (Belloc, 2012). The board of directors provides a formal link between owners and company operators and is described as the highest decision-making body in corporate governance (Fama & Jensen, 1983; Adams & Mehran, 2008). Although the literature indicates that the board of directors plays a crucial role in the relationship between corporate governance and strategy, there is limited evidence regarding the relationship between the board of directors and corporate innovation (Balsmeier et al., 2014).

Figure 1. Conceptual framework



Existing literature largely suggests that an excessively large board size has a negative impact on corporate innovation. On the one hand, as the board size expands, coordination inconsistencies in information exchange and communication among directors become more likely. On the other hand, with a larger board size, the individual contributions of directors to team outcomes are relatively smaller, potentially leading to a lack of individual motivation among directors (Latané et al., 1979). In contrast, a smaller board size leads to more corporate innovation, ultimately resulting in sustainable development (Chindasombatcharoen et al., 2022). Based on the above discussion, the present study proposes and tests the following hypothesis:

H1: There is a negative correlation between board size and AI practice or innovation efforts.

An independent board, primarily composed of external directors, is a crucial governance mechanism aimed at mitigating conflicts of interest between managers and shareholders. Some scholars argue that independent board members are essential for company development as they can provide resources for innovation activities (Mi Choi et al., 2012). Additionally, external directors act as proactive overseers, playing a role in restraining managerial opportunism and encouraging innovative efforts (Knyazeva et al., 2013). Studies have found that higher board independence positively influences an increase in patent numbers for companies, stimulating their innovative spirit (Coelho, 2015). Furthermore, independent boards positively influence the adjustment of risk preferences between managers and shareholders, thereby enhancing managerial investments in innovation. Considering the ownership structure of firms, board independence has a disproportionately greater impact on productive innovation at family firms (Bolton & Park, 2020). Overall, we believe there is a positive correlation between board independence and innovation, which promotes innovation.

H2: Board independence is positively related to corporate innovation decisions and AI-related activities.

Research by numerous scholars has shown that higher board diversity promotes corporate innovation. Diverse board compositions in terms of gender, age, etc., have a positive impact on various forms of innovation. Diverse boards provide a comprehensive understanding of the environment they face, enabling them to make more informed decisions. As the decision-making center of a company, diverse boards offer a broader range of viewpoints and perspectives, enhancing advisory capabilities and supporting exploratory innovation (Zhu et al., 2020). Thus, we posit that a diverse board, with members of varying ages, backgrounds, genders, and nationalities, contributes to the adoption of innovative decisions and actions.

H3: Board diversity is positively correlated with corporate innovation decisions and AI-related activities.

Ownership concentration and the identity of investors holding substantial ownership have an impact on innovation (Lee, 2005). The distribution of ownership in a company determines the control that decision-makers have over resource allocation and the incentives they have to invest in innovation (Miozzo & Dewick, 2002; Aghion et al., 2009). Different types of ownership identities, such as institutional investors, foreign investors, and family businesses, can have both positive and negative effects on innovation under different conditions (Asensio-López et al., 2018). Overall, we propose that concentrated ownership and certain types of ownership identities, such as institutional investors, foreign investors, or family investors, are likely to facilitate innovative decisions and activities.

H4: Concentrated ownership is negatively related to AI development and innovative activities.

Italian listed companies operating in the industries and the frequency of meetings held by the board assume a relevant role in supporting investments in innovation (Bianchi Martini et al., 2012). Board meeting frequency was put up to play

a significant impact on eco-innovation as one significant demographic factor (Zaman et al., 2023).

H5: Board meeting frequency is positively related to AI development and innovative progress.

Innovation performance could be promoted by corporate social responsibility via employee involvement and supplier collaboration (Zho et al., 2020).

H6: Corporate social responsibility has a positive correlation with AI and innovation within companies.

Chief executive officer (CEO) compensation has a significant regulating effect on the company's innovation capabilities, and the establishment of a compensation committee has a significant constraining effect on CEO compensation (Akram et al., 2022).

H7: The nomination committee and compensation committee are positively related to AI and innovation development within a company.

The application of AI in business model innovation has been increasing (Reim et al., 2020), reshaping the way companies innovate and the nature of their innovations. Eight intersecting domains were identified where AI and business innovation converge: AI and business models, AI and product innovation, AI and open innovation, AI and the innovation process, AI and corporate innovation structure, AI and corporate knowledge innovation, AI and innovation in market performance, and AI and supply chain management innovation (Bahoo et al., 2023). This study proposes that:

H8: AI has a positive impact on innovation within companies and plays a positive role in corporate governance and innovation efforts, so as for innovation.

It is widely acknowledged that AI systems will increasingly play a significant role in corporate governance, particularly within the board of directors. Once AI can replicate the advantages of human group decision-making and surpass human speed and quality of decisions, traditional board structures might become redundant. Multi-member boards might even disappear (Petrin, 2019). AI systems, capable of supporting, collaborating, and even replacing human decision-making in board settings (Hilb, 2020), have been coined "autonomous AI" or "self-generated AI". These AI types possess their decision mechanisms, potentially marginalizing human directors (Kaya, 2022). Lin (2018) argued that AI's neutral stance and algorithm-based objectivity make it more likely to provide impartial opinions devoid of personal interests, gradually diminishing the authority of human board members. Consequently, as AI evolves and integrates into corporate practices, board sizes are likely to decrease.

H9: The development of AI will have a reverse effect on the size of corporate boards.

AI can aid directors in fulfilling their duties, and as AI becomes more reliable, its usage can enhance board independence, thus reducing agency costs (Kamalnath, 2019). Mertens (2023) suggested that AI when used as a tool to support board decisions and managerial judgments, could rationalize board decision-making, challenge groupthink, and bolster board independence. As AI advances into the stage of autonomous AI, it could replace human directors, thereby increasing corporate independence (Cheng, 2022). In summary, we anticipate that AI will boost the independence of corporate boards.

H10: The development of AI within a company will have a positive effect on board independence.

Diversity in the backgrounds of board members has been integrated into supervisory standards in many countries worldwide. Diverse boards offer varied perspectives, aiding creative decision-making. However, if AI offers advisory opinions to the board or becomes a board member itself, thus reducing the need for human deliberation, the value of other factors crucial for diversity might diminish, potentially undermining board diversity policies (Eroğlu & Karatepe Kaya, 2022). Nevertheless, AI, due to inherent biases from its human designers, is likely to carry some degree of subjectivity. In the selection of board members, biases concerning diversity issues like female candidate quotas could lead to AI's awareness of these biases, resulting in more favorable selections for board diversity. Therefore, we posit that the impact of AI on board member diversity could be positive or negative.

H11: AI will have a positive effect on corporate board diversity.

3. RESEARCH METHODOLOGY

3.1. Sample description and data

To test our hypotheses, we analyze annual reports and other financial statements from 2018 to 2022 of over 60 American companies listed on the NASDAQ Composite index of our sample. These companies are from 5 different industries according to the classification of the North American Industry Classification System (NAICS). Companies with missing observations and outliers (based on 1st and 99th percentiles) were excluded. After matching and examining the data from the different sources the final sample consisted of 5400 observations corresponding to 60 companies.

Data for this study was collected from different databases. Firstly, accounting and financial data were manually extracted and collected from the EDGAR database. Secondly, data regarding board characteristics, ownership information, and environmental, social and governance performance (ESG) from 2018 to 2022 were collected from the Eikon database, with our definition of concentrated ownership structure when the top large 20 shareholders account for over 45% of shares. Lastly, annual reports were downloaded from the SEDAR online database, and analyzed by our Python code. This paper examines the relation between corporate governance systems and AI, innovation. More specifically, we analyze how corporate governance attributes, and particularly board characteristics, can affect AI, innovation efforts in the context of American-listed companies.

Furthermore, due to the widespread adoption of AI in recent years, with frequent mentions in annual reports, we calculated a company's AI application index through text analysis. To be more specific, we construct an AI-related vocabulary and use Python to automatically extract and count words that share similar attributes, with common characteristics of word expressions considered. This process involves the extraction of about 20 commonly used AI-related terms based on shared attributes, forming the sub-dictionary for this study. Included terms like big data, intelligence, authentication, automation, integration, digitization, virtual, algorithm, cloud computing, blockchain,

machine learning, integration, etc. Due to the broad and general nature of these terms, expressions not relevant to AI are manually excluded. Finally, the word frequencies of each phrase are summed to obtain the total word frequency, which is then considered to represent the AI application index for publicly listed companies. Moreover, the same procedures are also applied to innovation measurement as one main variable of the innovation index.

We utilize the content-analysis research method, using multiple regression analysis to examine our hypotheses. More specifically, we incorporate corporate governance variables, ESG score, and ownership structure characteristics into different regression models, to analyze the overall impact on AI practice and innovation. Additionally, based on existing studies, we control for other determining factors of innovation, including firm size and leverage. Apart from that, we establish another model to examine the mediation effect of AI and innovation indexes separately, aiming to prove the mediating effect played by one specific variable to another.

3.2. Corporate social responsibility index: ESG score

There are three categories of ESG indicators in the Thomson Reuters Eikon database: ESG score, ESG controversies, and ESG combined score. We chose the ESG score as our measurement, which is based on publicly available data in ten thematic areas. To make the ESG score easier to conduct analysis, we code it into 1–12 according to the ESG score from D- to A+ in the Eikon database.

3.3. Measures of explanatory variables

Table 1 below indicates a detailed definition and description of the variables used in this article.

Table 1. Measures of board characteristics and control variables

Variable	*Symbol*	*Description*
Board size	*BS*	Number of directors comprising the board of directors.
Board diversity	*BD*	Percentage of female directors on the board.
Board meeting	*BM*	Number of meetings held by the board of directors in a calendar year.
ESG scores	*ESG*	Comprehensive scores in environmental, social, and governance to evaluate social responsibility.
Board independence	*BI*	Percentage of independent directors on the board.
Ownership concentration	*OC*	Measured by dichotomous variable.
Nomination Committee	*C1*	Present whether the company has a nomination committee.
Compensation Committee	*C2*	Present whether the company has a compensation committee.
Mere AI	*MAI*	Number of words directly related to AI in an annual report.
Ratio 1	*R1*	Percentage of number of direct AI words to pages of an annual report.
Artificial intelligence	*AI*	Number of words broadly related to AI in an annual report.
Ratio 2	*R2*	Percentage of number of overall words to pages of annual report.
Innovation	*INN*	Number of words related to innovation in an annual report.
Ratio 3	*R3*	Percentage of number of innovation words to pages of an annual report.
R&D investment	*R&D*	Number of investments put into research and development.
Total assets	*TA*	Logarithm of the total assets.
Leverage	*Lev*	Total debts/total assets.
Industry	*IND*	Measured by five dichotomous variables for the 5 major industries under the classification of NAICS: IND1 (Manufacture), IND2 (Information), IND3 (Credit), IND4 (Insurance), IND5 (Professional service).

4. RESULTS

4.1. Descriptive results

The results presented in Table 2 reveal that the average board size is around 6 directors and ranges from 6 to 22 directors. An in-depth search into board diversity indicates that, among the 5 industries in our research, the mean proportion of women on board is 28%, with the lowest percentage of approximately 5% and the maximum could be found up to 58% of board directors are made up of women. These results also show that boards of United States companies meet at least 1 time during a year, up to 32 times a year, with an average of 10 meetings per year. The results reveal that the ESG scores vary from 2 to 12, in accordance with their D- to A+ level, with an average of 8 points. In terms of board independence, approximately 84% of directors are independent according to the requirements of the U.S. Securities and Exchange Act. Almost 70% of firms in this sample have a concentrated ownership structure. 77% of firms own nomination committees and 89% for compensation committees. In the detailed search into the industry by industry, we found the credit and insurance industries are the two which own the highest record of board size, with 13 and 14 directors on average respectively, and the credit industry also has the largest average number of women on board compared to other industries, around 33%. Through the correlation analysis, it can be seen in Table 3 that the correlation between corporate governance variables and board characteristics is relatively significant. Except for ownership concentration, board size, board diversity, board independence, board meeting, and social responsibility are positively related. Overall, there is a positive correlation between corporate governance elements and innovation data.

Table 2. Sample characteristics (in total)

Variable	*Mean*	*St. Dev.*	*Min*	*Max*
BS	11.850	2.673	6	22
BD	28.640%	10.110%	5.300%	58.300%
BM	9.960	4.897	1	32
ESG	8.220	2.227	2	12
BI	84.277%	11.537%	33.333%	93.000%
MAI	25.580	37.676	0	214
R1	0.170	0.249	0.000	1.561
AI	170.440	178.186	0	1049
R2	1.147	1.294	0.000	7.185
INN	13.270	12.758	0	99
R3	0.095	0.119	0.000	1.000
R&D	3050.669	3211.708	33.000	17528.000
TA	4.949	0.779	3.035	6.573
Lev	0.251	0.200	0.000	1.335

Table 3. Correlation results (in total)

	BS	*BD*	*BM*	*ESG*	*BI*	*OC*	*C1*	*C2*	*MAI*	*R1*	*AI*	*R2*	*INN*	*R3*	*RD*	*TA*	*Lev*	*IND1*	*IND2*	*IND3*	*IND4*	*IND5*
BS	1	0.018 (0.384)	0.192* (<0.001)	0.126* (0.023)	0.167** (0.004)	-0.232* (<0.001)	-0.044 (0.238)	0.021 (0.366)	-0.093 (0.067)	-0.121* (0.024)	-0.109* (0.038)	-0.120* (0.025)	-0.025 (0.343)	0.080 (0.096)	0.096 (0.184)	0.559* (<0.001)	0.240** (<0.001)	-0.319** (<0.001)	-0.122* (0.023)	0.194** (<0.001)	0.342** (<0.001)	0.087 (0.078)
BD	-0.018 (0.384)	1	0.196** (<0.001)	0.444** (<0.001)	0.255** (<0.001)	-0.038 (0.261)	-0.094 (0.058)	-0.041 (0.244)	-0.023 (0.349)	-0.005 (0.466)	-0.024 (0.343)	0.005 (0.464)	0.120* (0.022)	0.129* (0.015)	-0.015 (0.442)	0.177** (0.001)	-0.175** (0.002)	-0.140** (0.009)	-0.292** (<0.001)	0.180** (0.001)	-0.032 (0.298)	-0.054 (0.181)
BM	0.192* (<0.001)	0.196** (<0.001)	1	0.284** (<0.001)	0.235** (<0.001)	-0.130* (0.018)	-0.004 (0.472)	0.002 (0.485)	-0.116* (0.033)	-0.114* (0.034)	-0.022 (0.363)	-0.062 (0.161)	0.051 (0.207)	-0.033 (0.299)	0.181* (0.045)	0.375** (<0.001)	-0.113* (0.040)	-0.192** (<0.001)	-0.064 (0.153)	0.536** (<0.001)	-0.178** (0.002)	-0.076 (0.113)
ESG	0.126* (0.023)	0.444** (<0.001)	0.284** (<0.001)	1	0.494** (<0.001)	-0.423* (<0.001)	0.050 (0.212)	-0.212** (<0.001)	0.271** (<0.001)	0.269** (<0.001)	0.149** (0.008)	0.107* (0.043)	0.298** (<0.001)	0.182** (0.002)	0.510** (<0.001)	0.381** (<0.001)	-0.245** (<0.001)	0.113* (0.035)	-0.432** (<0.001)	0.309** (<0.001)	-0.072 (0.124)	0.017 (0.390)
BI	0.167** (0.004)	0.255** (<0.001)	0.235** (<0.001)	0.494** (<0.001)	1	-0.104* (0.047)	0.114* (0.034)	-0.002 (0.485)	0.034 (0.293)	0.087 (0.081)	-0.118* (0.030)	-0.079 (0.103)	0.109* (0.040)	0.131* (0.018)	0.062 (0.271)	0.126* (0.021)	-0.316** (<0.001)	0.008 (0.446)	-0.110* (0.039)	0.186** (0.001)	0.070 (0.131)	-0.149** (0.008)
OC	-0.232** (<0.001)	-0.038 (0.261)	-0.130* (0.018)	-0.423* (<0.001)	-0.104* (0.047)	1	0.011 (0.425)	0.276** (<0.001)	-0.225** (<0.001)	-0.234** (<0.001)	-0.128* (0.016)	-0.095 (0.056)	-0.164** (0.003)	-0.148** (0.006)	-0.607** (<0.001)	-0.248** (<0.001)	0.149** (0.008)	0.066 (0.134)	0.043 (0.237)	0.027 (0.323)	-0.134* (0.012)	-0.002 (0.488)
C1	-0.044 (0.238)	-0.094 (0.058)	-0.004 (0.472)	0.050 (0.212)	0.114* (0.034)	0.011 (0.425)	1	-0.050 (0.199)	0.031 (0.304)	0.045 (0.226)	-0.128* (0.016)	-0.150** (0.006)	0.022 (0.356)	0.036 (0.274)	-0.015 (0.442)	-0.078 (0.096)	-0.066 (0.142)	0.033 (0.292)	-0.021 (0.361)	0.160** (0.003)	-0.130* (0.014)	0.031 (0.302)
C2	0.021 (0.366)	-0.041 (0.244)	0.002 (0.485)	-0.212** (<0.001)	-0.002 (0.485)	0.276** (<0.001)	-0.050 (0.199)	1	0.123* (0.020)	0.126* (0.017)	0.131* (0.014)	0.143* (0.008)	0.055 (0.178)	0.085 (0.076)	-0.015 (0.443)	-0.223** (<0.001)	-0.217** (<0.001)	0.087 (0.071)	-0.191** (<0.001)	0.023 (0.350)	-0.103* (0.041)	0.158** (0.004)
MAI	-0.093* (0.067)	-0.023 (0.349)	-0.116* (0.033)	0.271** (<0.001)	0.034 (0.293)	-0.225** (<0.001)	0.031 (0.304)	0.123* (0.020)	1	0.970** (<0.001)	0.786** (<0.001)	0.711** (<0.001)	0.574** (<0.001)	0.410** (<0.001)	0.600** (<0.001)	-0.114* (0.028)	0.002 (0.485)	0.299** (<0.001)	-0.183** (0.001)	-0.194** (<0.001)	-0.296** (<0.001)	0.346** (<0.001)
R1	-0.121* (0.024)	-0.005 (.466)	-0.114* (0.034)	0.269** (<0.001)	0.087 (0.081)	-0.234** (<0.001)	0.045 (0.226)	0.126* (0.017)	0.970** (<0.001)	1	0.692** (<0.001)	0.670** (<0.001)	0.611** (<0.001)	0.501** (<0.001)	0.671** (<0.001)	-0.154* (0.005)	-0.024 (0.349)	0.321** (<0.001)	-0.169** (0.002)	-0.232** (<0.001)	-0.290** (<0.001)	0.324** (<0.001)
AI	-0.109* (0.038)	-0.024 (0.343)	-0.022 (0.363)	0.149** (0.008)	-0.118* (0.030)	-0.128* (0.016)	-0.128* (0.016)	0.131* (0.014)	0.786** (<0.001)	0.692** (<0.001)	1	0.951** (<0.001)	0.517** (<0.001)	0.353** (<0.001)	0.441** (<0.001)	-0.128* (0.016)	0.031 (0.311)	0.183** (<0.001)	-0.223** (0.001)	-0.183** (0.001)	-0.358** (<0.001)	0.559** (<0.001)
R2	-0.120* (0.025)	.005 (0.464)	-0.062 (0.161)	0.107* (0.043)	0.079 (0.103)	-0.095 (0.056)	-0.150** (0.006)	0.143** (0.008)	0.711** (<0.001)	0.670** (<0.001)	0.951** (<0.001)	1	0.504** (<0.001)	0.468** (<0.001)	0.450** (<0.001)	-0.189** (<0.001)	0.008 (0.450)	0.200** (<0.001)	-0.201** (<0.001)	-0.251** (<0.001)	-0.337** (<0.001)	0.567** (<0.001)
INN	-0.025 (0.343)	0.120 (0.022)	0.051 (0.207)	0.298** (<0.001)	0.109 (0.040)	-0.164** (0.003)	0.022 (0.356)	0.055 (0.178)	0.574** (<0.001)	0.611** (<0.001)	0.517** (<0.001)	0.504** (<0.001)	1	0.732** (<0.001)	0.712** (<0.001)	0.062 (0.148)	-0.045 (0.233)	0.148** (0.006)	-0.212** (<0.001)	-0.005 (0.464)	-0.169** (0.002)	0.204** (<0.001)
R3	0.080 (0.096)	0.129* (.015)	-0.033 (0.299)	0.182** (0.002)	0.131* (0.018)	-0.148** (0.006)	0.036 (0.274)	0.085 (0.076)	0.410** (<0.001)	0.501** (<0.001)	0.353** (<0.001)	0.468** (<0.001)	0.732** (<0.001)	1	0.640** (<0.001)	-0.015 (0.398)	-0.075 (0.111)	0.162** (0.003)	-0.168** (0.002)	-0.080 (0.088)	-0.095** (0.054)	0.147** (<0.001)
RD	0.096 (0.184)	-0.015 (0.442)	0.181* (0.045)	0.510** (<0.001)	0.062 (0.271)	-0.607** (<0.001)	-0.015 (0.442)	-0.015 (0.443)	0.600** (<0.001)	0.671** (<0.001)	0.441** (<0.001)	0.450** (<0.001)	0.712** (<0.001)	0.640** (<0.001)	1	0.543** (<0.001)	-0.033 (0.374)	-0.167* (0.048)	-	-	-	0.167* (0.048)
TA	0.559** (<0.001)	0.177** (.001)	0.375** (<0.001)	0.381** (<0.001)	0.126* (0.021)	-0.248** (<0.001)	-0.078 (0.096)	-0.223** (<0.001)	-0.114* (0.028)	-0.154** (0.005)	-0.128* (0.016)	-0.189** (<0.001)	0.062 (0.148)	-0.015 (0.398)	0.543** (<0.001)	1	-0.236** (<0.001)	-0.342** (<0.001)	-0.090 (0.064)	0.563** (<0.001)	0.147** (0.006)	-0.256** (<0.001)
Lev	-0.240** (<0.001)	-0.175** (0.002)	-0.113* (0.040)	-0.245** (<0.001)	-0.316** (<0.001)	0.149** (0.008)	-0.066 (0.142)	-0.217** (<0.001)	0.002 (0.485)	-0.024 (0.349)	0.031 (0.311)	0.008 (0.450)	-0.045 (0.233)	-0.075 (0.111)	-0.033 (0.374)	-0.236** (<0.001)	1	0.149** (0.008)	0.467** (<0.001)	-0.225** (<0.001)	-0.333** (<0.001)	-0.040 (0.260)
IND1	-0.319** (<0.001)	0.140** (0.009)	0.192** (<0.001)	0.113* (0.035)	0.008 (0.446)	0.066 (0.134)	-0.033 (0.292)	0.087 (0.071)	0.299** (0.028)	0.321** (<0.001)	0.183** (<0.001)	0.200** (<0.001)	0.148** (0.006)	0.162** (0.003)	-0.167* (0.048)	-0.342** (<0.001)	0.149** (0.008)	1	-0.252** (<0.001)	-0.305** (<0.001)	-0.323** (<0.001)	-0.288** (<0.001)
IND2	-0.122* (0.023)	-0.292** (<0.001)	-0.064 (0.153)	-0.432** (<0.001)	-0.110* (0.039)	0.043 (0.237)	-0.021 (0.361)	-0.191** (<0.001)	-0.183** (0.001)	-0.169** (0.002)	-0.223** (<0.001)	-0.201** (<0.001)	-0.212** (<0.001)	-0.168** (0.002)	-	-0.090 (0.064)	0.467** (<0.001)	0.252** (<0.001)	1	-0.198** (<0.001)	-0.209** (<0.001)	-0.186** (<0.001)
IND3	0.194** (<0.001)	0.180** (0.001)	0.536** (<0.001)	0.309** (<0.001)	0.186** (0.001)	0.027 (0.323)	0.160** (0.003)	0.023 (0.350)	-0.194** (<0.001)	-0.232** (<0.001)	-0.183** (0.001)	-0.251** (<0.001)	-0.005 (0.464)	-0.080 (0.088)	-	0.563** (<0.001)	-0.225** (<0.001)	-0.305** (<0.001)	-0.198** (<0.001)	1	-0.253** (<0.001)	-0.226** (<0.001)
IND4	0.342** (<0.001)	-0.032 (0.298)	-0.178** (0.002)	-0.072 (0.124)	0.070 (0.131)	-0.134* (0.012)	-0.130* (0.014)	-0.103* (0.041)	-0.296** (<0.001)	-0.290** (<0.001)	-0.358** (<0.001)	-0.337** (<0.001)	-0.169** (0.002)	-0.095 (0.054)	-	0.147** (0.006)	-0.333** (<0.001)	-0.323** (<0.001)	-0.209** (<0.001)	-0.253** (<0.001)	1	-0.238** (<0.001)
IND5	-0.087 (0.078)	-0.054 (0.181)	-0.076 (0.113)	0.017 (0.390)	0.149** (0.008)	-0.002 (0.488)	0.031 (0.302)	0.158** (0.004)	0.346** (<0.001)	0.324** (<0.001)	0.559** (<0.001)	0.567** (<0.001)	0.204** (<0.001)	0.147** (0.007)	-	0.167* (0.048)	-0.256** (<0.001)	-0.040 (0.260)	-0.288** (<0.001)	-0.226** (<0.001)	-0.238** (<0.001)	1

4.2. Regression results

4.2.1. Analysis of the effect of overall governance variables on artificial intelligence and innovation

In our first regression model, which examined the effect of board characteristics and composition on their emphasis on AI. The results show that ownership concentration could generate a negative impact on carrying out AI-related activities, and our control variables of IND2, IND3, and IND4 also reveal a negative influence. By contrast, IND5 defined as professional services shows a strong positive impact on referring AI.

In a more detailed analysis of individual industries, we found that there are significant differences in governance variables that play a significant role in implementing AI and innovation-related activities among the 5 separate industries. Specifically, board independence has a significant positive impact on AI and innovation in manufacturing companies; however, in the information industry, the proportion of independent directors has a significant negative impact on AI and innovation. Looking at the credit industry, board meeting has a significant positive effect on AI, and ESG score has a significant positive effect on innovation. Looking at the insurance industry, board size, and board diversity have a significant negative effect on AI. Finally, the service industry has the highest R-squared, 83.1%. Committee1 and ESG score have a significant negative impact on AI, and board meeting has a significant positive impact on AI.

In the second model, similar results could be found, ownership concentration is adversarial for companies to emphasize innovation, confirming our fourth hypothesis (*H4*). Meanwhile, the result of board size shows that the more directors on the board, the less likely for a company to implement innovative activities, which confirms our first hypothesis (*H1*).

The results of this regression model (shown in Table 4) analyzing the impact of board structure, board characteristics, and committee structure on the company's innovation level show satisfactory statistical results with significant statistical coefficients. This model shows that the size of the board of directors and the concentrated ownership structure have a significant negative impact on the innovation activities of enterprises. This suggests that boards with fewer directors will be more willing and able to engage in innovation-related activities. In addition, the concentrated ownership structure has a significant negative impact on the innovation index, which shows that the more concentrated the ownership, the more shareholders tend to be conservative and less willing to carry out innovative activities.

For a more detailed analysis of individual industries, we found that there are significant differences in the corporate governance variables that play a significant role in different industries. Specifically, board independence has a significant positive impact on innovation in manufacturing companies, a result that partly confirms our second hypothesis (*H2*); however, in the information industry, the proportion of independent directors has a significant negative impact on innovation. In both the credit and Insurance industries, ESG score has a significant positive impact on innovation. Finally, the professional service industry has the highest exoplanetary power, 83% of changes in artificial efforts could be recognized as being impacted by board characteristics. IND5 also observed that other significant variables — board size and board diversity have a significant positive effect on innovation, which is exactly the opposite of the insurance industry, also confirming our third hypothesis (*H3*).

Table 4. Regression results_AI (in total)

Variable	*AI*			*Innovation*		
	Standardized B	***t***	***Sig***	***Standardized B***	***t***	***Sig***
BS	-0.063	-0.819	0.414	-0.182	-1.826	0.069*
BD	-0.087	-1.520	0.130	0.002	0.020	0.984
BM	0.072	1.169	0.244	-0.027	-0.341	0.733
ESG	-0.154	-1.640	0.103	0.130	1.069	0.287
BI	0.047	0.688	0.492	0.107	1.206	0.229
OC	-0.277	-4.244	<0.001***	-0.216	-2.566	0.011**
C1	-0.121	-2.118	0.035	0.111	1.507	0.133
C2	0.050	0.836	0.404	0.109	1.403	0.162
TA	0.150	1.558	0.121	0.180	1.440	0.151
Lev	0.014	0.216	0.830	0.147	1.746	0.082*
IND2	-0.420	-5.494	<0.001***	-0.213	-2.151	0.033**
IND3	-0.301	-3.854	<0.001***	-0.185	-1.834	0.068*
IND4	-0.480	-6.040	<0.001***	-0.088	-0.854	0.394
IND5	0.351	6.185	<0.001***	0.131	1.783	0.076*
	R-squared = 0.535			R-squared = 0.222		
	N = 285			N = 285		

4.2.2. Analysis of the effect of governance variables on innovation in the manufacture and professional service industry

R&D investment, as the special observed variable of innovation of IND1 and IND5, also shows satisfactory statistical significance. In the IND1 manufacturing industry, board size, board independence, and concentrated ownership structure have a significant negative effect on R&D investment, while board diversity, committeee1, and Committee2 have a significant positive effect on R&D investment. IND5 service industry also shows that the concentrated ownership structure is not conducive to the growth of R&D investment and has a negative effect.

Table 5. Regression results_Innovation, R&D (IND1, IND5)

Variable	*Innovation*			*R&D investment*		
IND1	***Standardized B***	***t***	***Sig***	***Standardized B***	***t***	***Sig***
BS	-0.429	-2.625	0.011**	-0.190	-2.916	0.006***
BD	0.062	0.423	0.674	0.153	2.656	0.011**
BM	0.112	0.975	0.333	-0.005	-0.094	0.926
ESG	-0.056	-0.356	0.723	-0.004	-0.052	0.959
BI	0.529	3.218	0.002***	-0.231	-2.507	0.016**
OC	0-.320	-2.031	0.047**	-0.367	-5.596	<0.001***
C1	0.407	2.679	0.010**	0.321	4.983	<0.001***
C2	-0.178	-0.828	0.411	0.745	6.473	<0.001***
TA	0.451	2.433	0.018**	0.917	12.349	<0.001***
Lev	0.153	1.003	0.320	0.444	6.045	<0.001***
	R-squared = 0.401			R-squared = 0.910		
	N = 75			N = 75		
IND5						
BS	0.290	2.439	0.022**	-0.126	-0.544	0.593
BD	0.146	2.189	0.037**	0.137	1.033	0.315
BM	-0.065	-1.018	0.318	-0.012	-0.103	0.919
ESG	-0.053	-0.386	0.703	0.411	1.546	0.139
BI	0.146	1.270	0.215	-0.378	-1.599	0.127
OC	-0.142	-1.013	0.320	-0.899	-3.207	0.005***
C1	-0.385	-3.638	0.001***	-0.218	-1.068	0.300
C2	-	-	-	-	-	-
TA	0.267	2.091	0.046**	-0.189	-0.849	0.407
Lev	-0.062	-0.925	0.363	-0.110	-0.705	0.490
	R-squared = 0.916			R-squared = 0.864		
	N = 50			N = 50		

4.3. Mediation results

4.3.1. Analysis of the mediation effect of artificial intelligence or innovation on overall governance variables

The analysis of the results of the regression models presented in Table 6, examining the mediating effect of AI and innovation, respectively, show satisfactory explanatory powers, confirming the eighth hypothesis (*H8*). The adjusted R-squared values indicate that 37.5% of the change in innovation endeavor, and 62.7% of the change in AI efforts are explained by the characteristics of the board, the structure of the board, and ownership, in addition to variables whose effect has been controlled.

In our first mediation regression model, we test the mediation role of AI between corporate governance and innovation efforts. The results show that both ESG score and committee1 have a more satisfactory positive impact on Innovation under the mediation of AI practice, results that are consistent with our sixth and seventh hypotheses (*H6* and *H7*). This intermediary role still exists in the specific industry analysis; therefore, we infer that the importance of AI has a significantly enhanced intermediary role in the practice of corporate governance and innovation. The second regression model of intermediary function tests the intermediary effect of innovation, and the results show a higher explanatory degree than the former, and the negative effects of board diversity, ESG score, ownership structure, and committee1 are significantly enhanced. To conclude, the role of innovation efforts as an intermediary variable has also been confirmed. Therefore, *H8* is partly confirmed.

Table 6. Mediation results_CG – AI – Innovation (in total)

Variable	*CG – AI – Innovation*			*Variable*	*CG – Innovation – AI*		
Overall	***Standardized B***	***t***	***Sig***	*Overall*	***Standardized B***	***t***	***Sig***
BS	-0.146	-1.626	0.106	*BS*	-0.001	-0.009	0.993
BD	0.052	0.769	0.443	*BD*	-0.088	-1.702	0.090*
BM	-0.069	-0.954	0.341	*BM*	0.082	1.469	0.143
ESG	0.219	1.987	0.048**	*ESG*	-0.199	-2.348	0.020**
BI	0.080	1.001	0.318	*BI*	0.010	.170	0.865
OC	-0.057	-0.726	0.469	*OC*	-0.202	-3.401	<0.001***
C1	0.181	2.694	0.008***	*C1*	-0.159	-3.085	0.002***
C2	0.080	1.147	0.253	*C2*	0.013	.235	0.814
TA	0.180	1.440	0.151	*TA*	0.089	1.017	0.310
Lev	0.147	1.746	0.082*	*Lev*	-0.036	-.618	0.537
IND2	0.029	0.299	0.765	*IND2*	-0.347	-4.994	<0.001***
IND3	-0.012	-0.132	0.895	*IND3*	-0.237	-3.355	<0.001***
IND4	0.188	1.870	0.063*	*IND4*	-0.450	-6.290	<0.001***
IND5	-0.071	-0.982	0.327	*IND5*	0.306	5.956	<0.001***
AI	0.575	6.956	<0.001***	*Innovation*	0.343	6.956	<0.001***
R-squared = 0.222				R-squared = 0.535			
R*squared = 0.375				R*squared = 0.627			
N = 285				N = 285			

*Note: R-squared: the proportion of the variation in the dependent variable that is predictable from the independent variables without mediation effect. R*squared: the proportion of the variation in the dependent variable that is predictable from the independent variables with the mediation effect of AI or innovation.*

4.3.2. Analysis of the mediation effect of artificial intelligence in the manufacture and professional service industry

These two mediation models respectively test the impact of AI as an intermediary variable on the relationship between corporate governance and innovation in the manufacturing and service industries. The results show that under this model, the mediating effect of AI shows significant effects in the manufacturing industry. It is worth noting that in the discussion of the intermediary mechanism of these two industries, ownership concentration always has a significant negative impact; board diversity shows a significant positive correlation. Interestingly, in the manufacturing industry, board size has a significant negative effect on innovation activities, while in the service industry, it shows a significant positive effect on innovation. The statistical results of the Nomination committee are just the opposite: its establishment has a significant positive impact on the manufacturing industry, while it implements a negative impact on innovation in the service industry. These results reveal that there are different or even opposite outcomes when analyzing the mediation effect of AI in different industries, because of the intrinsic characteristics in various industries.

Table 7. Mediation results_CG – AI – Innovation/R&D (IND1, IND5)

Variable	***CG – AI – Innovation***			***Variable***	***CG – AI – R&D***		
IND1	***Standardized B***	***t***	***Sig***	*IND1*	***Standardized B***	**t**	**Sig**
BS	-0.383	-2.350	0.022**	*BS*	-0.200	-2.978	0.005***
BD	0.036	0.248	0.805	*BD*	0.156	2.678	0.010***
BM	0.105	0.930	0.356	*BM*	0.002	0.031	0.975
ESG	-0.019	-0.125	0.901	*ESG*	-0.012	-0.173	0.863
BI	0.450	2.677	0.010***	*BI*	-0.206	-2.076	0.044**
OC	-0.179	-1.013	0.315	*OC*	-0.393	-5.145	<0.001***
C1	0.406	2.714	0.009***	*C1*	0.324	4.986	<0.001***
C2	-0.136	-0.637	0.527	*C2*	0.731	6.212	<0.001***
TA	0.389	2.091	0.041**	*TA*	0.928	12.151	<0.001***
Lev	0.125	0.829	0.411	*Lev*	0.451	6.046	<0.001***
AI	0.214	1.690	0.096*	*AI*	-0.045	-0.686	0.496
R-squared = 0.401				R-squared = 0.910			
R*squared = 0.429				R*squared = 0.911			
N = 75				N = 75			
IND5				*IND5*			
BS	0.296	2.405	0.024**	*BS*	-0.124	-0.521	0.609
BD	0.148	2.167	0.040**	*BD*	0.139	1.017	0.324
BM	-0.054	-0.708	0.485	*BM*	-0.009	-0.078	0.939
ESG	-0.068	-0.449	0.657	*ESG*	0.394	1.389	0.183
BI	0.138	1.135	0.267	*BI*	-0.397	-1.544	0.141
OC	-0.158	-1.019	0.318	*OC*	-0.911	-3.108	0.006***
C1	-0.409	-2.889	0.008***	*C1*	-0.250	-0.978	0.342
C2	-	-	-	*C2*	-	-	-
TA	-0.036	-0.263	0.795	*TA*	-0.168	-0.685	0.503
Lev	-0.076	-0.876	0.389	*Lev*	-0.104	-0.638	0.532
AI	-0.036	-0.263	0.795	*AI*	-0.052	-0.222	0.827
R-squared = 0.916				R-squared = 0.864			
R*squared = 0.916				R*squared = 0.864			
N = 50				N = 50			

*Note: R-squared: the proportion of the variation in the dependent variable that is predictable from the independent variables without mediation effect. R*squared: the proportion of the variation in the dependent variable that is predictable from the independent variables with the mediation effect of AI.*

4.3.3. Analysis of the mediation effect of innovation in the manufacture and professional service industry

These two regression models test the mediating role of innovation in the manufacturing and information industries. The results show that concentrated ownership structure has a significant negative impact on the innovation development and AI development of both industries. This is consistent with the results of the above regression analysis and confirms *H4*. In addition, in the manufacturing industry, through the intermediary effect of R&D investment, the proportion of external independent directors has a significant positive correlation with AI research and development. In the information service industry, ESG score and Nomination committee have a significant negative impact on the development of AI through the intermediary effect; and the higher the frequency of board meetings, the more inclined the company is to conduct research and development of AI technology, which confirms *H5*.

Table 8. Mediation results_CG – Innovation/R&D – AI (IND1, IND5)

Variable	*CG – Innovation – AI*			*Variable*	*CG – R&D – AI*		
IND1	***Standardized B***	***t***	***Sig***	*IND1*	***Standardized B***	***t***	***Sig***
BS	-0.119	-0.691	0.493	*BS*	-0.270	-1.614	0.114
BD	0.107	0.738	0.463	*BD*	0.093	0.639	0.526
BM	0.007	0.060	0.953	*BM*	0.148	1.193	0.239
ESG	-0.158	-1.008	0.318	*ESG*	-0.193	-1.198	0.237
BI	0.250	1.408	0.164	*BI*	0.497	2.147	0.037**
OC	-0.591	-3.634	<0.001***	*OC*	-0.684	-3.398	0.001***
C1	-0.084	-0.525	0.601	*C1*	0.141	0.742	0.462
C2	-0.158	-0.733	0.466	*C2*	-0.139	-0.367	0.715
TA	0.190	0.979	0.331	*TA*	0.466	1.263	0.213
Lev	0.096	0.628	0.533	*Lev*	0.263	1.125	0.267
INN	0.219	1.690	0.096*	*INN*	-0.243	-0.686	0.496
R-squared = 0.387				R-squared = 0.510			
R*squared = 0.415				R*squared = 0.516			
N = 75				N = 75			
IND5				*IND5*			
BS	0.180	0.946	0.353	*BS*	0.032	0.127	0.901
BD	0.071	0.675	0.506	*BD*	0.042	0.291	0.775
BM	0.290	3.087	0.005***	*BM*	0.047	0.392	0.700
ESG	-0.400	-1.998	0.056*	*ESG*	-0.305	-1.012	0.326
BI	-0.220	-1.285	0.210	*BI*	-0.376	-1.396	0.181
OC	-0.451	-2.184	0.038**	*OC*	-0.283	-0.755	0.460
C1	-0.694	-3.722	<0.001***	*C1*	-0.643	-2.870	0.011**
C2	-	-	-	*C2*	-	-	-
TA	0.110	0.555	0.584	*TA*	0.380	1.574	0.134
Lev	-0.396	-4.023	<0.001***	*Lev*	0.114	0.679	0.506
INN	-0.073	-0.263	0.795	*INN*	-0.056	-0.222	0.827
R-squared = 0.831				R-squared = 0.853			
R*squared = 0.831				R*squared = 0.854			
N = 50				N = 50			

*Note: R-squared: the proportion of the variation in the dependent variable that is predictable from the independent variables without mediation effect. R*squared: the proportion of the variation in the dependent variable that is predictable from the independent variables with the mediation effect of innovation.*

4.3.4. Analysis of the mediation results from other industries

Our mediating effect regression model separately analyzed the banking and financial industries and found that the mediating effect of AI is significant. Sixty-two (62) percent and seventy-three point two (73.2) percent of the changes in AI and innovation development in the two industries can be explained by corporate governance factors, respectively. Under the mediating effect of AI, ESG score always plays a significant positive impact on innovation. In the model testing the mediating role of innovation, we found that in both industries, board diversity has a significant negative effect on AI development. This conclusion conflicts with the previous view that board diversity promotes AI development. Therefore, we infer that the inherent characteristics of an industry could influence its choice of board diversity and its impact on corporate governance.

4.4. Robustness of t-tests

Table 9 presents the results of the exploration of the effect of AI on corporate governance.

Table 9. Regression results_AI – CG (in total)

Variable	*Standardized B*	*t*	*Sig*	*R-squared*
BS	-0.241	-2.453	0.015**	0.031
BD	0.018	0.187	0.852	0.001
BI	-0.118	-1.896	0.059*	0.014
ESG	0.149	2.404	0.017**	0.022
	N = 285			

5. DISCUSSION

Corporate governance elements such as board characteristics and shareholder structure play a significant role. The results of this study verify the important impact of board characteristics and ownership structure, especially the importance of individual indicators such as board structure on the company's investment in AI development, innovation, and R&D investment. For different industry characteristics, the stronger the individual board characteristics, the more attention it will pay to the development of AI, and the stronger its promotion effect on innovative activities. Vice versa, the more investment in innovation, the stronger the joint effect on AI development.

This study shows that an overly concentrated ownership structure and a high number of directors have a negative impact on innovation progress and the development of AI in multiple industries. There are differences in the specific variables that affect AI and innovation activities in different industries. For the manufacturing industry, board independence has a significant positive impact on innovation, while there is the opposite impact in the information industry. In both the credit and insurance industries, the ESG score has a significant positive impact on innovation. In the professional service industry, board size and board diversity have a significant positive effect on innovation, Therefore, companies are encouraged to adapt to local conditions and choose corporate governance improvement methods suitable for their own industry characteristics to adapt to the trend in the context of big data and AI transformation and promote the company's progress in digitalization, intelligent upgradation, and innovative sustainable prosperity.

6. CONCLUSION

The research results help to enrich the literature in the field of corporate governance and demonstrate the importance of key features of corporate governance in promoting AI development and innovation in the digital era. This study determines a research structure method with text research as the core, supplemented by traditional variables, and the effectiveness is cross-checked through the successful extraction of word frequency from lots of annual reports and the results of different variables of the same indicator. Corporate governance has more significant variables in the manufacturing and information technology service industries. More attention is paid to AI development and more money is invested in research and development and innovation activities.

Our first contribution to industries is to provide statistical support to board directors, and shareholders to reconsider board activities and structure, which could provide insights to facilitate the improvement and enhance efficiency of corporate governance. Moreover, further analysis also presents the financial market and relative authorities with the potential impact of AI on governance characteristics, aiming to help modify or upgrade supervising policies according to the dynamic changing technology.

This study includes the main characteristics of the main corporate board and shareholder structures, but other characteristics were not considered. Therefore, further research in the future will incorporate other corporate governance elements such as major shareholder types, board tenure, etc. into combined discussions. We will also conduct country comparisons, such as comparing companies in the United States and Canada, to explore the similarities and differences in the impact of corporate governance factors on AI and innovation between countries.

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APPENDIX

Table A.1. Sample characteristics (by industries)

Manufacture	***Mean***	***St. Dev.***	***Min***	***Max***
Board size	10.44	2.282	6	15
Board diversity	30.881	10.308	14.3	54.5
Board meeting	8.44	3.379	4	24
ESG score	8.60	1.840	3	11
Board independence	84.424%	9.612%	57.14%	93.00%
AI	222.85	168.258	0	749
AI/pages	1.559	1.225	0.000	6.688
Innovation	16.29	16.951	0	99
Innovation/pages	0.126	0.143	0.000	0.750
R&D investment	2658.429	3706.298	33.0	17528.0
Total asset	4.524	0.558	3.534	6.417
Leverage	0.296	0.204	0.000	1.335
N = 15				
Information				
Board size	11.05	2.416	6	15
Board diversity	21.282	10.260	7.7	44.4
Board meeting	9.17	3.698	4	21
ESG score	5.80	2.576	2	10
Board independence	81.313%	18.762%	33.33%	92.86%
AI	72.50	27.888	8	151
AI/pages	0.506	0.238	0.059	1.218
Innovation	6.60	5.058	0	21
Innovation/pages	0.046	0.035	0.000	0.167
R&D investment	11.05	2.416	6	15
Total asset	4.775	0.787	3.035	5.742
Leverage	0.472	0.223	0.067	1.002
N = 10				
Credit				
Board size	12.90	2.065	10	17
Board diversity	33.184	8.121	16.7	58.3
Board meeting	16.04	5.756	8	32
ESG score	9.71	1.215	7	11
Board independence	88.940%	6.220%	58.33%	93.00%
AI	106.64	43.590	13	215
AI/pages	0.489	0.215	0.135	1.374
Innovation	13.14	8.949	3	35
Innovation/pages	0.076	0.139	0.013	1.000
Total asset	5.845	0.530	4.981	6.573
Leverage	0.164	0.061	0.055	0.326
N = 11				
Insurance				
Board size	13.59	3.026	9	22
Board diversity	28.010	10.072	5.3	50.0
Board meeting	8.29	3.143	1	15
ESG score	7.91	2.420	3	12
Board independence	85.922%	10.380%	53.33%	92.86%
AI	46.41	28.578	7	130
AI/pages	0.297	0.207	0.039	0.917
Innovation	9.07	9.165	0	38
Innovation/pages	0.073	0.109	0.000	0.500
Total asset	5.171	0.645	3.865	5.982
Leverage	0.114	0.113	0.000	0.381
N = 11				
Professional service				
Board size	11.35	1.973	8	15
Board diversity	27.456	8.312	10.0	41.7
Board meeting	9.19	4.170	4	22
ESG score	8.30	1.489	6	11
Board independence	80.755%	9.754%	60.00%	92.31%
AI	385.20	226.573	5	1049
AI/pages	2.731	1.603	0.046	7.185
Innovation	18.88	13.110	0	54
Innovation/pages	0.133	0.090	0.000	0.356
R&D investment	3779.114	1826.875	1553.0	6774.0
Total asset	4.517	0.492	3.488	5.193
Leverage	0.232	0.158	0.033	0.563
N = 10				

Table A.2. Regression results_AI (by industries)

Variable	*Standardized B*	*t*	*Sig*
Manufacture			
Total asset	0.289	1.539	0.129
Leverage	0.129	0.841	0.404
Board size	-0.213	-1.288	0.203
Board diversity	0.121	0.820	0.416
Board meeting	0.031	0.270	0.788
ESG score	-0.170	-1.071	0.289
Board independence	0.366	2.201	0.032**
Ownership concentration	-0.661	-4.142	<0.001***
Committee1	0.005	0.033	0.974
Committee2	-0.197	-0.905	0.369
	R-squared = 0.387		
Information			
Total asset	-0.453	-0.575	0.571
Leverage	0.410	1.258	0.222
Board size	0.250	0.407	0.688
Board diversity	-0.091	-0.265	0.793
Board meeting	0.198	0.947	0.354
ESG score	0.126	0.279	0.783
Board independence	-0.671	-1.816	0.083*
Ownership concentration	-	-	-
Committee1	0.295	0.768	0.451
Committee2	-0.766	-1.620	0.120
	R-squared = 0.387		
Credit			
Total asset	-0.504	-0.692	0.495
Leverage	-0.189	-0.677	0.505
Board size	0.066	0.381	0.706
Board diversity	-0.422	-1.701	0.102
Board meeting	0.909	3.587	0.001***
ESG score	0.235	0.805	0.429
Board independence	-0.124	-0.628	0.536
Ownership concentration	-0.015	-0.023	0.982
Committee1	-	-	-
Committee2	0.040	0.094	0.926
	R-squared = 0.531		
Insurance			
Total asset	-0.032	-0.065	0.949
Leverage	0.621	1.311	0.200
Board size	-0.528	-1.714	0.097*
Board diversity	-0.436	-3.265	0.003***
Board meeting	0.106	0.613	0.545
ESG score	0.353	1.264	0.216
Board independence	-0.038	-0.111	0.913
Ownership concentration	0.065	0.295	0.770
Committee1	0.310	1.053	0.301
Committee2	0.512	1.320	0.197
	R-squared = 0.659		
Professional service			
Total asset	0.091	0.501	0.620
Leverage	-0.392	-4.111	<0.001***
Board size	0.159	0.938	0.357
Board diversity	0.060	0.632	0.533
Board meeting	0.295	3.254	0.003***
ESG score	-0.397	-2.019	0.053*
Board independence	-0.230	-1.412	0.169
Ownership concentration	-0.440	-2.212	0.036**
Committee1	-0.666	-4.437	<0.001***
Committee2	-	-	-
	R-squared = 0.831		

Table A.3. Regression results_Innovation (by industries)

Variable	*Standardized B*	*t*	*Sig*
Information			
Total asset	0.540	0.747	0.463
Leverage	-0.593	-1.982	0.060*
Board size	-0.570	-1.013	0.322
Board diversity	0.082	0.259	0.798
Board meeting	-0.147	-0.770	0.449
ESG Score	0.279	0.674	0.508
Board independence	-0.780	-2.300	0.031**
Ownership concentration	-	-	-
Committee1	0.310	0.881	0.388
Committee2	0.062	0.143	0.888
	R-squared = 0.484		
Credit			
Total asset	-1.473	-1.757	0.092*
Leverage	-0.268	-0.834	0.412
Board size	0.286	1.439	0.163
Board diversity	0.127	0.445	0.660
Board meeting	0.120	0.411	0.685
ESG Score	0.863	2.573	0.017**
Board independence	0.183	0.808	0.427
Ownership concentration	-0.263	-0.362	0.721
Committee1	-	-	-
Committee2	-0.535	-1.093	0.285
	R-squared = 0.379		
Insurance			
Total asset	0.205	0.360	0.721
Leverage	0.693	1.290	0.207
Board size	-0.381	-1.092	0.284
Board diversity	-0.237	-1.568	0.128
Board meeting	-0.111	-0.571	0.572
ESG Score	0.704	2.229	0.034**
Board independence	0.226	0.575	0.570
Ownership concentration	-0.067	-0.271	0.789
Committee1	0.787	2.364	0.025**
Committee2	0.866	1.973	0.058*
	R-squared = 0.563		

Table A.4. Mediation results_CG – Innovation – AI/CG – AI – Innovation (by industries) (Part 1)

Variable	*CG – AI – Innovation*			*CG – Innovation – AI*		
	Standardized B	*t*	*Sig*	*Standardized B*	*t*	*Sig*
Information						
Total asset	0.677	0.963	0.346	-0.647	-0.841	0.410
Leverage	-0.718	-2.398	0.026**	0.624	1.825	0.082*
Board size	-0.645	-1.183	0.250	0.455	0.751	0.461
Board diversity	0.109	0.359	0.723	-0.121	-0.363	0.720
Board meeting	-0.208	-1.100	0.284	0.251	1.228	0.233
ESG score	0.241	0.601	0.554	0.025	0.057	0.955
Board independence	-0.576	-1.640	0.116	-0.390	-0.981	0.338
Ownership concentration	-	-	-	-	-	-
Committee1	0.221	0.640	0.529	0.183	0.484	0.633
Committee2	0.295	0.665	0.514	-0.788	-1.725	0.099*
AI	0.304	1.607	0.123	0.361	1.607	0.123
	R-squared = 0.484			R-squared = 0.387		
	R*squared = 0.540			R*squared = 0.454		
Credit						
Total asset	-1.033	-1.829	0.080*	0.464	0.899	0.378
Leverage	-0.103	-0.477	0.638	-0.013	-0.068	0.946
Board size	0.228	1.718	0.099*	-0.122	-1.017	0.320
Board diversity	0.494	2.452	0.022**	-0.505	-3.040	0.006***
Board meeting	-0.672	-2.786	0.011**	0.830	4.891	<0.001***
ESG score	0.659	2.903	0.008***	-0.333	-1.516	0.143
Board independence	0.291	1.907	0.069*	-0.244	-1.832	0.080*
Ownership concentration	-0.251	-0.516	0.611	0.159	0.374	0.711
Committee1	-0.570	-1.744	0.095*	-	-	-
Committee2	-	-	-	0.392	1.347	0.191
AI	0.871	5.555	<0.001***	0.658	5.555	<0.001***
	R-squared = 0.146			R-squared = 0.531		
	R*squared = 0.620			R*squared = 0.800		

Table A.4. Mediation results_CG – Innovation – AI/CG – AI – Innovation (by industries) (Part 2)

Variable	*CG – AI – Innovation*			*CG – Innovation – AI*		
	Standardized B	***t***	***Sig***	***Standardized B***	***t***	***Sig***
Insurance						
Total asset	0.227	0.503	0.619	-0.145	-0.362	0.720
Leverage	0.254	0.578	0.568	0.241	0.619	0.541
Board size	-0.008	-0.029	0.977	-0.318	-1.273	0.214
Board diversity	0.070	0.499	0.621	-0.305	-2.759	0.010***
Board meeting	-0.186	-1.189	0.244	0.167	1.210	0.236
ESG score	0.455	1.762	0.089*	-0.035	-0.144	0.887
Board independence	0.253	0.808	0.426	-0.162	-0.585	0.563
Ownership concentration	-0.113	-0.569	0.574	0.101	0.581	0.566
Committee1	0.569	2.106	0.044**	-0.123	-0.482	0.633
Committee2	0.505	1.404	0.171	0.035	0.108	0.915
AI	0.705	4.212	<0.001***	0.550	4.212	<0.001***
	R-squared = 0.563			R-squared = 0.659		
	R*squared = 0.732			R*squared = 0.791		

*Note: R-square: the proportion of the variation in the dependent variable that is predictable from the independent variables without mediation effect. R*square: the proportion of the variation in the dependent variable that is predictable from the independent variables with the mediation effect of innovation or artificial intelligence.*

Figure A.1. Distribution of companies in the sample