STEM expertise in Australian boardrooms: trends and impact on firm outcomes

Natalie Elms
School of Accountancy, Queensland University of Technology, Brisbane, Australia
John Nowland
Department of Accounting, Illinois State University, Normal, Illinois, USA, and
Ashesha Paveena Weerasinghe
School of Accountancy, Queensland University of Technology, Brisbane, Australia

Received 23 July 2025
Revised 6 November 2025
3 February 2026
Accepted 3 February 2026

Abstract

Purpose – Australia's innovation performance lags other advanced economies, highlighting the need to understand how boards can better support innovation. This study aims to examine the evolving representation of directors with science, technology, engineering and mathematics (STEM) expertise on Australian corporate boards and the extent to which this representation impacts innovation investment and firm value.

Design/methodology/approach – Hand-collected data on director backgrounds from the top 500 Australian Stock Exchange (ASX)-listed firms are used to assess changes in board STEM representation between 2007 and 2022. Regression analysis is then employed to examine the relationship between STEM director representation, innovation investment and firm value.

Findings – Despite a modest increase between 2007 and 2022, the representation of STEM directors on Australian corporate boards remains low. However, firms with greater STEM board expertise are associated with higher levels of innovation investment and firm value. These effects are strongest in firms without STEM CEOs and in industries with lower STEM representation.

Practical implications – As firms face increasing technological complexity and opportunities, appointing directors with STEM backgrounds may offer a competitive advantage. Policies and initiatives aimed at expanding the supply of STEM directors are therefore recommended.

Originality/value – While director expertise is known to influence firm outcomes, limited evidence exists on how STEM expertise at the board level shapes innovation and firm value, particularly in the Australian context. This study provides new evidence on how board STEM expertise contributes to both outcomes.

Keywords Corporate governance, Board composition, STEM expertise, Innovation, Upper echelons theory, Resource dependency theory

Paper type Research article

1. Introduction

"An analysis of the history of technology shows that technological change is exponential . . . so, we won't experience 100 years of progress in the 21st century – it will be more like 20,000 years of progress" - *Ray* Kurzweil, 2005.

Just as Kurzweil (2005) predicted, the 21st century has produced the most profound rate of technological change in history, creating both incredible opportunities and significant challenges for organizations. Capital investment in technology is becoming increasingly critical, as evidenced by the cautionary tales of former industry giants such as Kodak, Blockbuster, and Nokia, highlighting the repercussions of failing to innovate (Bereznoy, 2019; Hill and Rothaermel, 2003).

Journal of Accounting Literature
Vol. 48 No. 5, 2026
pp. 302-326
Emerald Publishing Limited
e-ISSN: 2452-1469
p-ISSN: 0737-4607
DOI 10.1108/JAL-07-2025-0373

Investment in corporate innovation is essential for survival and a key driver of firm growth and value (Kurzhals *et al.*, 2020; Zhu *et al.*, 2024). Board of directors play a pivotal role in determining firm strategy and outcomes (Finkelstein *et al.*, 2009). In Australia, the need for boards to leverage digital technologies and oversee technological risks has become a pressing issue. A national survey of corporate directors shows that 21% of organizations have no digital transformation strategy, while 41% report that fewer than one-quarter of their board members possess technology skills, and 13% of have no technology skills (Governance Institute of Australia, 2022). At the same time, directors identify cybersecurity, cyber-attacks, data governance, and staff technology capability as among the most critical risks facing organizations. Professional services firms, including PwC and EY, have similarly highlighted the importance of technological competencies at board level in addressing contemporary governance challenges (Cerny and Di Pietro, 2025; Boiciuc *et al.*, 2025). These risks are not only speculative: recent legal action by the market regulator, the Australian Securities and Investments Commission, against directors for failing to prepare and respond to cyber-attacks highlights growing regulatory expectations for technological expertise in the boardroom (Bloch *et al.*, 2025). These developments highlight the strategic value of technological expertise on boards.

Building on these concerns, this study argues that the board's competencies and priorities influence a firm's engagement in innovative activities. We propose that directors with expertise in science, technology, engineering, and mathematics (henceforth, STEM) are particularly well positioned to influence technology-driven innovation and, consequently, firm value. Examining Australian listed firms, we find only a modest increase in STEM directors between 2007 and 2022, and that the representation remains low. However, firms with greater STEM representation are more likely to invest in innovations and exhibit stronger firm value. These findings support the view that board-level technological expertise is a critical governance resource.

We draw on two prominent theories in the corporate governance literature to predict the board's influence on corporate innovation investment. Upper echelons theory (UET) posits that organizations are reflections of their leaders (Hambrick and Mason, 1984). From this perspective, critical organizational decisions such as resource allocation and strategic direction are shaped by the cognitive frameworks and values of managers and directors, making it reasonable to expect that directors' appetite for innovation and technological investment will be mirrored in firm outcomes (Carpenter *et al.*, 2004; Hambrick and Mason, 1984). Complementing this view, resource dependency theory (RDT), emphasizes the board's role in supporting strategic decision-making by providing access to human and relational capital (Pfeffer and Salancik, 1978). In this capacity, directors serve as critical conduits for accessing resources and mitigating risks associated with innovation (Chen *et al.*, 2018; Haque and Jones, 2020; Kor, 2006; Ting *et al.*, 2021). Taken together, UET and RDT suggest that directors with expertise in STEM-related fields bring a cognitive orientation and appetite for innovation as well as the technical knowledge, experience, and networks to identify and capitalize on technological opportunities. Given the likely impact of the board on corporate innovation, it is surprising that few studies have considered the impact of director expertise on corporate innovation.

The purpose of this study is twofold. First, motivated by the profound technological advancements of the last two decades, our initial aim is to examine how the representation of STEM expertise on Australian listed boards has changed over the past 15 years (2007–2022). We define STEM expertise as experience gained from STEM-related roles, encompassing both educational and work experiences. Second, we investigate the impact of STEM directors on corporate outcomes by testing two hypotheses: (1) the proportion of directors with STEM expertise on the board is positively associated with corporate innovation investment, and (2) the proportion of directors with STEM expertise on the board is positively associated with firm value.

This study focuses on Australian listed boards for several reasons. First, most research investigating the impact of firm leadership on innovation has been conducted using data from the world's two leading economies: the USA and China (Kurzhals *et al.*, 2020). Studying corporate governance in alternative contexts such as Australia provides new perspectives to advance knowledge (Kumar and Zattoni, 2019). Second, as a nation, Australia's innovation capabilities lag those of other developed countries. In the 2024 Global Innovation Index [1] Australia ranks 30th in innovation outputs, compared to the 5th and 7th global rankings for the USA and China. This indicates that Australia, like many other countries, has room for improvement in leveraging technology. Understanding whether and how board composition impacts corporate innovation can help firms and governments with less developed innovation capabilities compete more robustly globally.

Our initial descriptive analysis shows that the representation of directors with STEM expertise in Australian listed firms in 2022 is 12.9%, compared to 8.4% in 2007. While this indicates a positive increase, STEM directors remain significantly underrepresented on boards. By comparison, directors with expertise in the finance-related fields of accounting and banking composed 36% of Australia's top 500 listed boards in 2022 (33% in 2007) and more than a quarter of board composition across all industry sectors. STEM directors have the highest representation in the Materials sector (27%), the Information Technology (IT) sector (27%) and the Healthcare sector (24%). This is as expected, given the high level of technical and innovative activities in these industries. Yet, even in these sectors, STEM directors are outnumbered by directors with financial and executive expertise.

The second phase of our analysis involves testing our hypotheses. We report a positive and significant relationship between the proportion of STEM directors and corporate innovation investment. This suggests that, although STEM directors comprise only a small percentage of the total director pool, their influence on innovation is significant. Support is also provided for our second hypothesis, which reports a positive association between STEM directors and firm value. Given the earlier finding that STEM directors increase corporate innovation investment, this result aligns with a larger body of work demonstrating that corporate innovation is associated with higher firm value (Rubera and Kirca, 2012). These results are robust to sensitivity and endogeneity testing. Additional analysis shows that our results are strongest in firms where chief executive officers (CEOs) lack expertise and in industries with fewer STEM directors.

This study makes several contributions to the literature, policy, and practice. First, we contribute to the corporate governance literature by comprehensively examining director expertise in Australian-listed firms. Building on Gray and Nowland (2017), we show the extent to which director expertise and board diversity of expertise have evolved since 2007. Second, we provide support for both UET and RDT and argue that directors with STEM expertise are likely to promote innovation and extract value from technological investments. Consequently, firms focused on innovation may benefit from appointing more directors with STEM expertise.

Third, this study provides timely and relevant insights for policymakers and practitioners. Despite our results showing compelling evidence that directors with STEM expertise contribute to investment in innovation and firm value, we find that the proportion of STEM directors on boards remains low in Australia. We encourage boards and nomination committees to consider the value of STEM expertise in appointment decisions, especially for firms outside of the technology and healthcare industries, where STEM representation is lowest and our results are strongest. Finally, one possible reason for the low representation of STEM expertise on boards may be related to the supply shortage of such expertise. Therefore, we encourage policies and practices that can increase the supply of STEM directors.

The remainder of this paper proceeds as follows. Section two summarizes the relevant literature leading to our hypotheses. Section three outlines our research design. Section four presents our descriptive analyses of director expertise and its evolution in Australian listed firms. This is followed by the results of our hypothesis testing and additional robustness tests. Section five summarizes and concludes the paper.

2. Literature review

2.1 Board characteristics and corporate innovation

Prior studies examining the impact of board composition on firm innovation have primarily focused on group-level board characteristics. Among these, board gender diversity has received the most attention, with findings generally suggesting a positive influence on innovation (Griffin *et al*., 2021; Kurzhals *et al*., 2020; Makkonen, 2022). These studies argue that gender diversity on boards enhances the boards' monitoring function, alleviating agency problems and supporting innovation activities (Chen *et al*., 2018; Sierra-Morán *et al*., 2024). From a resource and human capital perspective, gender diverse boards are also thought to strengthen the board's advisory role by contributing unique expertise that brings diverse perspectives to strategic decision-making, facilitating greater creativity and innovation (Griffin *et al*., 2021; Vafaei *et al*., 2021).

While board diversity has generally been shown to enhance innovation, the effects of board independence and board size remain less conclusive. Some studies find that board independence positively influences innovation, attributing this to stronger governance, while outside directors offer valuable knowledge and connections (Berezinets *et al*., 2019; Lu and Wang, 2018). However, others argue that independent directors often lack sufficient firm knowledge to promote innovation effectively, and that their heightened oversight can foster mistrust within management, ultimately stifling innovation (Bobillo *et al*., 2018; Buchwald and Thorwarth, 2018; Tribbitt and Yang, 2017). Supporting this viewpoint, studies have found a positive relationship between inside directors and firm innovation (Chouaibi and Jarboui, 2012; Hoskisson *et al*., 2002).

The optimal board size for firm innovation also remains unclear. Some studies suggest that larger boards lead to greater innovation as they provide greater access to resources, knowledge and information, contributing to diverse viewpoints and promoting a culture of innovation (Chatjuthamard and Jiraporn, 2023; Chen *et al*., 2015). In contrast, others argue that larger boards can experience communication and coordination issues that hinder decision-making and stifle innovation (Cheng, 2008; Rossi and Cebula, 2015; Yermack, 1996). Meanwhile, other studies find no significant relation between board size and innovation, suggesting that the quality of the board is more important than its size (Asensio-López *et al*., 2019; Chouaibi and Jarboui, 2012; Liu *et al*., 2025).

The knowledge and expertise of directors are also likely to be key determinants of firm innovation. Prior research has shown that directors with scientific and industry expertise can enhance innovation by improving the quality and efficiency of R&D activities (Faleye *et al*., 2018; Sundaramurthy *et al*., 2014; Valenti and Horner, 2020). Technical knowledge, more broadly, has also been shown to drive innovation. For example, Zhang *et al*. (2025) find that CEOs with an IT background are associated with greater investment in green technology. Similarly, directors with digital literacy have been found to improve the internal allocation of resources, particularly in high-tech start-ups where human, financial, and technological resources are often constrained (Knockaert and Ucbasaran, 2013; Oliveira *et al*., 2022). Cross-firm experience can also play a role in driving innovation, with one study finding that directors who simultaneously serve on the boards of high-tech and low-tech firms can transfer innovation-related knowledge, benefiting low-tech firms (Reguera-Alvarado and Bravo, 2018). Likewise, directors with prior experience in innovative firms or technical roles have been shown to have a positive influence on firm innovation outcomes (Balsmeier *et al*., 2014; Dalziel *et al*., 2011).

Despite growing evidence that directors' knowledge and skills positively influence firm outcomes, limited attention has been given to how directors with STEM expertise contribute to firm innovation. One notable exception is a recent study that investigated STEM-related education and innovation in Chinese firms (Hsieh *et al*., 2022). While formal education provides the foundation for expertise, practical experience in STEM roles is arguably more valuable for advising and overseeing innovation-related decisions (Rousseau and Stouten, 2024). Directors with STEM expertise bring cognitive capabilities, technical knowledge, and problem-solving skills developed through both specialized training and hands-on experience. Attributes such as complex problem-solving, risk management, and an innovation-oriented mindset are particularly relevant for guiding strategic innovation (Jiang *et al*., 2024; Zeb *et al*., 2024). Building on this literature, we argue that examining directors' STEM expertise offers a meaningful extension of prior research on how boards influence corporate innovation.

2.2 Theoretical background and hypothesis development

We draw on two prominent theories in the corporate governance literature to establish a theoretical connection between board STEM expertise and corporate innovation. UET posits that firm outcomes reflect the preferences and characteristics of top executives (Hambrick and Mason, 1984). From this viewpoint, attributes such as education, professional background, and experience influence how managers perceive problems and make strategic decisions. Hambrick (2007) argues that upper echelons interpret situations through cognitive lenses shaped by their personal attributes, which in turn inform corporate decision-making and firm outcomes. UET has been used to explain the positive influence of diversity on firm outcomes, including enhanced corporate social and environmental responsibility (Chapple *et al*., 2025; Cosma *et al*., 2021; Liu, 2018) and reduced fraud (Capezio and Mavisakalyan, 2016). Empirical research in the Australian context supports this logic, with Shen *et al.* (2026) finding that CEOs with higher educational qualifications are associated with greater R&D investment, highlighting how education and experience can shape a firm's strategic priorities.

More directly related to innovation outcomes, Jiang *et al*. (2024) draw on UET to show that CEOs with a technology background foster innovation by promoting digital transformation, strengthening internal controls, and cultivating an innovative culture. Similarly, Dissanayake *et al*. (2025) argue that CEOs with an engineering background possess unique technical skills and networks that enable them to take greater risks. Building on this logic, we argue that directors with STEM expertise possess cognitive capacities and behavioural tendencies shaped by their engagement in technical work and innovation. These attributes are likely to influence their strategic orientation, making them more inclined to support innovation-related decisions, particularly in areas such as R&D investment and technology adoption. Through their specialized knowledge, STEM-expert directors are also better equipped to evaluate and engage with technically complex matters, thereby shaping the firm's innovation agenda.

Second, Resource Dependence Theory (RDT) posits that a firm's strategic orientation is closely tied to the opportunities to access essential resources necessary for survival (Pfeffer and Salancik, 1978). The board of directors plays a central role in corporate governance by bringing external expertise to the board and facilitating access to external resources associated with strategic initiatives and decision-making (Farooq *et al*., 2023; Gray and Nowland, 2017; Pfeffer and Salancik, 1978). RDT has been applied to directors' contributions and firms' strategic choices. For example, studies on board gender diversity suggest that women directors enhance board effectiveness by bringing diverse knowledge and valuable external connections (Liao *et al*., 2018), as well as providing channels of communication and legitimacy (Hillman and Dalziel, 2003). The underlying premise in these studies is that directors contribute unique resources to firms that would otherwise be difficult to obtain internally. A similar argument applies to directors with STEM expertise, who can provide technological insight and specialized human capital gained through prior experience, while also improving access to external information networks and innovation-relevant resources.

Drawing on insights from both UET and RDT, we hypothesize that STEM expertise on corporate boards will positively influence investment in corporate innovation. Innovation is widely recognized as a critical driver of growth and firm value. STEM directors are well-positioned to shape strategic direction by identifying, evaluating, and guiding innovation initiatives (Aghion *et al*., 2013; Kang *et al*., 2018). An essential role of the board in the innovation process is to advise and support management in exploring new ideas (Manso, 2011). The quality of this advice depends on the knowledge and skills of the directors and their willingness to engage with new ideas. From both UET and RDT perspectives, the appetite for innovation and the capacity to support it are heightened when the board includes directors with STEM expertise. Thus, we argue that increasing the representation of STEM directors on boards will enhance the likelihood that management will receive informed and relevant advisory support, which in turn promotes innovation and drives firm value, leading to the following hypotheses:

H1. The proportion of directors with STEM expertise on boards is positively associated with corporate innovation investment.

H2. The proportion of directors with STEM expertise on boards is positively associated with firm value.

3. Research design

3.1 Sample selection and data

Data relating to director expertise was manually collected from the top 500 fims listed on the Australian Stock Exchange (ASX) for 2022. This involved reviewing directors' biographies in annual reports and categorizing directors' expertise into 11 categories, based on the prior work of Gray and Nowland (2017), who examined director expertise in Australian listed firms in 2007. A list of these 11 categories is provided in Table 1. This process yielded a dataset of 3,465 directors from the sample firms, including managing directors/CEOs. The breakdown of all director expertise is detailed in Table 2, which includes percentages of total directors in each category. The analysis reveals that the most significant percentage of expertise is executive (35%), followed by banking (19%) and accounting (17%). The lowest representation of expertise is found in academics, doctors, and politicians (each at 1%). The nature and extent of director expertise compared to 2007 (e.g. Gray and Nowland, 2017) and in terms of industry sectors and market capitalization of firms are explored in greater detail using descriptive statistics, tables, and figures in our results (see section 4.2).

Table 1. Director expertise categories

Code	Expertise	Definition and classification
EXEC	Executives	General executive/businessperson and not classified in one of the other occupational groups, including prior CEO roles and professional NEDs
ACCT	Accountants	Experience as a Certtified Practicing Accountant (CPA) or Chartered Accountant (CA), partner (including retired) of an accounting firm, or chief financial officer (CFO) of a company
BANK	Bankers	Experience in banking and finance industries, wealth management, corporate finance, and equity markets. Includes actuary and financial planning
LAW	Lawyers	Experience as a practicing lawyer, barrister, or judge; partner in a law firm. Includes company secretaries
SCIEN	Scientists	Experience as a scientist, includes geologist & IT/Tech
ENG	Engineers	Engineering experience, including IT
DOC	Doctors	A medical doctor, including medical experts
CNSLT	Consultants	Management, marketing, IT or industry-specific consultants
POLI	Politicians	Previously held political office, also used for roles within the Australian Defence Force
CEO	Other CEOs	Is currently the CEO/Managing Director of another company
ACDM	Academics	Has prior or current university appointments, or other educator

Note(s): This table is re-produced from Gray and Nowland (2017), STEM directors are those with expertise as scientists, engineers and doctors

Table 2. Summary of director expertise 2022 – ASX 500

Category	EXEC	ACCT	BANK	LAW	SCIEN	ENG	DOC	CONSL	POLI	CEO	ACDM	Total
Panel A: Director expertise by categories – ASX 500 firms												
# Directors	1,199	579	664	223	263	155	31	208	30	66	47	3,465
% Directors	35%	17%	19%	6%	8%	4%	1%	6%	1%	2%	1%	100%

STEM director percentage range (%)	The number of firms in the sample within the range
Panel B: STEM boards by percentage of STEM directors – ASX 500 firms	
0	270
1–20	108
21–40	74
41–60	35
61–80	13
81–100	0

Note(s): STEM directors are those with expertise as scientists, engineers and doctors

3.2 Variable measurement

Prior studies have generally used R&D expense as a proxy for investment in corporate innovation (e.g. Shen *et al.*, 2026). This makes sense in the US context, as all R&D costs are typically expensed periodically. However, the Australian accounting standard for intangible assets (AASB 138) provide different accounting treatments for research costs and development costs. Research costs are expensed each period, whereas development costs can be capitalized. Thus, focusing solely on R&D expenses each period is likely to underestimate innovation activities in Australian firms. We overcome this issue by including both R&D expense and capital expenditure in our measure of corporate innovation investment (Innovation = (R&D expense + Capex)/Total assets). Capital expenditure comprises software development costs, net intangible assets, exploration and development activities, and fixed asset purchases, as collected from the Morningstar database. R&D expense is obtained from Refinitiv DataStream.

To examine whether STEM directors influence firm value (H2), we use TobinsQ as our outcome variable. TobinsQ is commonly used to measure firm value and to explore the association between firm value and governance structures (e.g. Luo and Salterio, 2014; Renders and Gaeremynck, 2012). TobinsQ is the ratio of market value to book value of assets (Singh *et al.*, 2018). Our independent variable STEM Board (STEM%) is the proportion of directors on a board that have expertise in a STEM field – science, technology, engineering or mathematics.

Firm-level control variables include firm size (FSIZE), measured using total assets; financial performance, measured using return on assets (ROA); leverage (LEV); and cash holdings (CASH). Prior research indicates that innovation is shaped through firms' resources and performance (Chen *et al.*, 2023; Balsmeier *et al.*, 2017). Leverage and CASH represent firms' financial constraints that influence innovation activities (Chen *et al.*, 2023; Balsmeier *et al.*, 2017). In addition, several board characteristics have been found to influence innovations (e.g. Griffin *et al.*, 2021; Kang *et al.*, 2018; Balsmeier *et al.*, 2017). We therefore include board size (BDSIZE, number of directors on the board), independence (BDIND, the percentage of independent directors on the board), and gender diversity (BDGEND, the percentage of women directors on the board). Research indicates that women CEOs contribute to increased corporate innovation (Javed *et al.*, 2023). We therefore include the CEO's gender (CEOG, a dummy variable equal to one if the CEO is a woman and zero otherwise). Prior research also indicates that CEOs can influence corporate policies and outcomes. From the RDT perspective, the STEM expertise of CEOs is also a resource to firms. Thus, we include CEOs' STEM expertise as a control variable (STEMCEO, a dummy variable equal to one if the CEO has a STEM background and zero otherwise). These data were obtained from Refinitiv/DataStream, Connect4, and Morningstar databases. All variable definitions are provided in Table 3.

Table 3. List of variables

Variable	Definition
Innovation	(Capital expenditure + R&D expense)/total assets
TobinsQ	Ratio of market value to book value of assets
Stem Board (STEM%)	Proportion of STEM directors on the board (expertise in a field of Science, Technology, Engineering or Math)
Return on assets (ROA)	Total profit/total assets
Firm size (FSIZE)	Book value of the firm's total assets at balance date
Leverage (LEV)	Long + short term debt/(total capital + short term debt) * 100
Cash holdings (CASH)	Cash/total assets
Board size (BSIZE)	Number of directors on the board
Board independence (BDIND)	Proportion of independent directors on the board
Board diversity (BDGEND)	Proportion of female directors on the board
STEM CEO	Dummy variable equal to 1 if the CEO has a STEM background and 0 otherwise
CEO Gender (CEOGEN)	Dummy variable equal to 1 if the CEO is female and 0 otherwise

3.3 Model specification

Robust regressions (iteratively weighted least squares) are used in our analysis. This method is an alternative to ordinary least squares regressions and performs well for data with outliers or influential observations (Ramdani and Witteloostuijn, 2010; Rousseeuw and Leroy, 2005). All independent variables are lagged by one year to address concerns about reverse causality. This ensures that STEM directors were in firms one year before the outcome. Our econometric equations for H1 and H2 are as follows, respectively:

$$\begin{aligned} INNOVATION_{i,t} = \alpha &+ \beta_1\, STEM\%_{i,t-1} + \beta_2\, ROA_{i,t-1} + \beta_3\, FSIZE_{i,t-1} + \beta_4\, LEVERAGE_{i,t-1} \\ &+ \beta_5\, CASH_{i,t-1} + \beta_6\, BDSIZE_{i,t-1} + \beta_7\, BDIND_{i,t-1} + \beta_8\, BDDIV_{i,t-1} \\ &+ \beta_9\, STEMCEO_{i,t-1} + \beta_{10}\, CEOG_{i,t-1} + Industry\ Fixed\ Effects + \varepsilon_{it} \end{aligned}$$

$$\begin{aligned} FIRMVALUE_{i,t} = \alpha &+ \beta_1\, STEM\%_{i,t-1} + \beta_2\, ROA_{i,t-1} + \beta_3\, FSIZE_{i,t-1} + \beta_4\, LEVERAGE_{i,t-1} \\ &+ \beta_5\, CASH_{i,t-1} + \beta_6\, BDSIZE_{i,t-1} + \beta_7\, BDIND_{i,t-1} + \beta_8\, BDDIV_{i,t-1} \\ &+ \beta_9\, STEMCEO_{i,t-1} + \beta_{10}\, CEOG_{i,t-1} + Industry\ Fixed\ Effects + \varepsilon_{it} \end{aligned}$$

4. Empirical results

4.1 Descriptive analysis

4.1.1 STEM directors by industry sectors, firm size, and board size. The first stage of our analysis involves examining the nature and extent of STEM director representation in our sample and comparing it with the work of Gray and Nowland (2017), who investigated director expertise in Australian listed firms in 2007. Table 4 presents the number and proportion of directors in each category of expertise for both 2007 and 2022, along with the changes in proportions within each category of expertise over this period. As reported, the proportion of directors in each category has changed marginally over the past 15 years. The results show that although the proportion of executives has reduced from 47% to 35%, this category of expertise still represents the highest proportion of directors in the top 500 listed firms [2]. Additionally, the long-standing dominance of corporate leadership by directors with expertise in accounting, finance, and law persists after 15 years. In 2007, approximately 40% of directors had backgrounds in accounting, banking, and law (15.75%, 17.06%, and 6.93%, respectively). By 2022, these three areas of expertise collectively account for 42% (16.71%, 19.16% and 6.44%), indicating the predominant expertise of directors in the top 500 firms. Meanwhile, the proportion of directors with a STEM background (including doctors, engineers, and scientists) has increased from 8.36% to 12.96%, suggesting that firms are diversifying their board structures to include more STEM expertise. However, the overall comparison reveals that the expertise of boards in Australia's top 500 listed firms has not significantly shifted in the past 15 years. Furthermore, considering the growing importance of technical and technological capital in firms, the 4% increase in directors from a STEM background from 2007 to 2022 may be inadequate.

Next, we analysed the data by industry sector and firm size. Figure 1 illustrates the directors' expertise by industry sector. Directors with expertise in accounting and banking are represented in all industries at a rate above 25%, with significant representation in specific sectors, such as Financials and Real Estate, which is expected given the nature of their operations. The highest representation of STEM directors is seen in the IT (27%), Materials (27%), Healthcare (24%) and Energy (16%) sectors. This is anticipated, given the nature of scientific operations in these fields compared to those in other fields. However, even in these sectors, boards are still dominated by directors with expertise as executives, accountants and bankers. For instance, while engineering directors account for 15% of the Materials sector,

Table 4. Director expertise comparison between 2022 and 2007

Category	EXEC	ACCT	BANK	LAW	SCIEN	ENG	DOC	CONSL	POLI	CEO	ACDM	Total
2022 – ASX 500												
# Directors	1,199	579	664	223	263	155	31	208	30	66	47	3,465
% Directors	34.60%	16.71%	19.16%	6.44%	7.59%	4.47%	0.89%	6.00%	0.87%	1.90%	1.36%	100%
2007 – ASX 500												
# Directors	1,639	552	598	243	144	137	12	59	39	51	31	3,505
% Directors	46.76%	15.75%	17.06%	6.93%	4.11%	3.91%	0.34%	1.68%	1.11%	1.46%	0.88%	100%
Change												
2022–2007	−12.16%	0.96%	2.10%	−0.50%	3.48%	0.56%	0.55%	4.32%	−0.25%	0.45%	0.47%	

Note(s): STEM directors are those with expertise as scientists, engineers and doctors

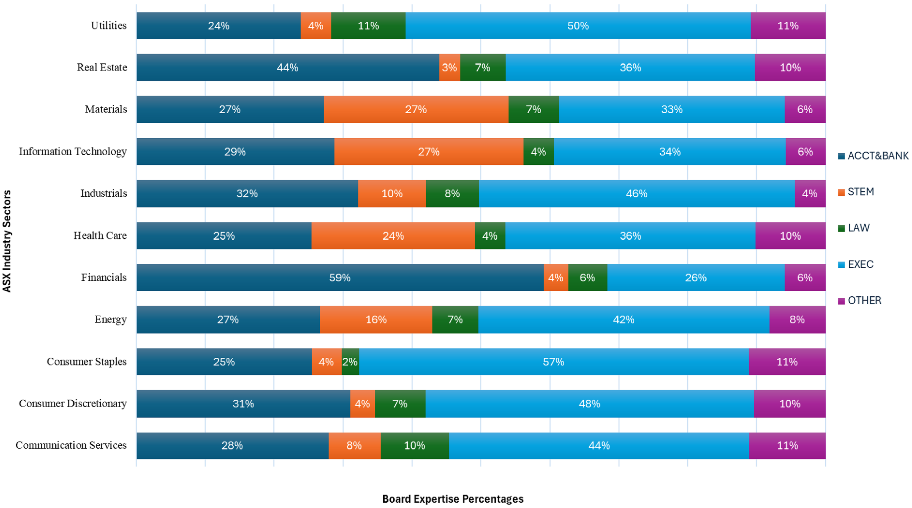

Figure 1. Board expertise across top 500 firms based on ASX industry sectors

those with accounting and banking skills represent 28%. This raises the question of whether the expertise of directors is adequate to meet the demanding technical requirements in these sectors.

Figure 2 illustrates the director's expertise based on market capitalization and divides the sample into five groups of firms, each containing 100 firms to represent their size. The figure details the breakdown of the proportion of each area of expertise within each group. Directors from a STEM background are represented across all categories with similar proportions, except in the top 100 to 200 range, where their representation is lower. Engineers, doctors and scientists dominate the top 200 to 300 firms, with each expertise accounting for 25%, 32% and 20% of the total in this category, respectively. A significant proportion of academic and political/defence directors are found in the top 100 firms, with 54% and 50% representing their total directors within the same area of expertise. Accountants, bankers, lawyers and executives again feature prominently among the top 200 firms.

4.1.2 STEM boards and corporate innovation investment. As an initial examination of our hypothesized relationship between STEM expertise on boards and corporate innovation investment (H1), we analyse the average level of innovation investment of different firms. Table 5 reports the innovation investment of firms in industry sectors relative to the industry

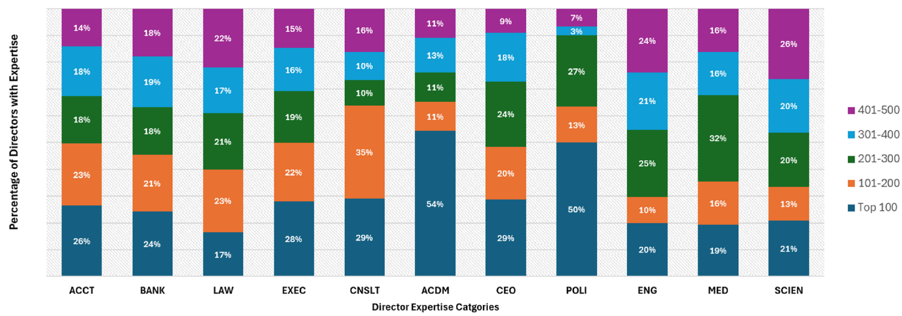

Figure 2. Board expertise across top 500 firms based on market capitalization

Table 5. Corporate innovation investment at different levels of STEM expertise

Industry sectors	Industry average	% of STEM directors on boards Less/ Equal 25%	26–50%	Above 50%
Communication services	5%	5%	8%	10%
Consumer discretionary	5%	5%	5%	
Consumer staples	9%	9%		
Energy	10%	9%	11%	
Financials	2%	2%	0%	
Health care	20%	12%	33%	18%
Industrials	6%	6%	7%	2%
Information technology	12%	9%	15%	9%
Materials	17%	15%	19%	23%
Real estate	3%	3%	0%	
Utilities	5%	5%		
All sectors	9%	6%	18%	20%

Note(s): This table shows the average corporate innovation investment in each cell

average at varying levels of STEM expertise on boards (less than/equal to 25%, 26%–50% and more than 50%). This indicates that when STEM expertise is below 25% the innovation investment by firms in all industries is equal to or below the industry average. In contrast, firms in the IT, healthcare, materials, energy, and communications services sectors in the sample invest significantly more than the industry average when STEM representation exceeds 26%. This analysis supports our hypothesis that investment in corporate innovation increases with greater STEM expertise on boards, laying the groundwork for our multivariate analysis.

4.2 Multivariate analysis

4.2.1 Summary statistics of variables. Our original sample of 500 firm observations (from the prior section) is reduced to 404 observations in our multivariate analysis. This is due to missing data in the control variables. Summary statistics of the variables used in our multivariate analysis are detailed in Table 6. The average values for innovation and firm value (TobinsQ) are 0.10 and 2.19, respectively. The average percentage of STEM board members is 13%. In the sample, on average, ROA is 0.06, firm size is 21 (natural log of total assets), leverage is 2.25 and CASH is 0.16. The average board size is 7, board independence is 47% and gender diversity 28%. Pearson correlations are presented in Table 6, Panel B. As expected, most correlations between variables are low to moderate, with the highest being that between firm size and board size ($r = 0.57$). These values do not indicate a risk of multicollinearity. In initial support for our hypotheses, we find significant positive correlations between STEM boards and innovation ($r = 0.39$) and between STEM boards and firm value ($r = 0.20$).

4.2.2 Hypothesis testing. Table 7 presents the regression results examining the relationships between STEM boards and investment in corporate innovation (H1) and between STEM boards and firm value (H2). The results of the first model indicate that the proportion of STEM directors on boards is positively related to corporate innovation investment (0.100, $p < 0.01$), supporting our first hypothesis (H1). The results of the second model indicate a positive relationship between STEM boards and firm value (0.643, $p < 0.05$), supporting our second hypothesis (H2). Thus, we find that boards with greater STEM expertise are associated with more corporate innovation investment and higher firm value.

The results support the theoretical expectations derived from UET and RDT regarding the positive impact of STEM expertise on innovation and firm value. The influence of STEM directors on innovation and subsequent value creation may be driven by several underlying

Table 6. Summary statistics and Pearson correlations

Variable	Mean	Std Dev	Min	Max
Panel A: Summary statistics				
TobinsQ	2.19	2.83	0.57	21.09
Innovation	0.10	0.199	0.00	0.48
STEM%	0.13	0.18	0.00	0.80
ROA	0.06	0.60	−1.76	4.65
FSIZE	21.01	1.80	17.25	26.71
LEV	2.25	2.12	1.00	16.07
CASH	0.16	0.20	0.00	0.91
BDSIZE	7.00	2.22	4.00	14.00
BDIND	47.13	37.03	0.00	100.00
BDGEND	28.10	0.14	0.00	75.00
STEMCEO	0.17	0.38	0.00	1.00
CEOG	0.07	0.25	0.00	1.00

Variable	TobinsQ	Innovation	STEM BOARD %	ROA	FSIZE	LEV	CASH	BD SIZE	BD IND	BD GEN	STEM CEO
Panel B: Pearson correlations											
TobinsQ											
Innovation	*0.16*										
STEM%	*0.20*	*0.39*									
ROA	*−0.11*	*−0.10*	*−0.15*								
FSIZE	*−0.39*	*−0.23*	*−0.30*	*0.16*							
LEV	0.00	*−0.12*	*−0.15*	0.00	*0.27*						
CASH	*0.46*	*0.23*	*0.34*	*−0.21*	*−0.51*	*−0.16*					
BDSIZE	*−0.13*	*−0.11*	−0.08	0.04	*0.57*	*0.13*	*−0.19*				
BDIND	−0.04	0.00	−0.01	*0.13*	*0.34*	*0.12*	−0.08	*0.30*			
BDGEND	−0.09	*−0.24*	−0.22	*0.21*	*0.39*	*0.17*	*−0.21*	*0.26*	*0.34*		
STEMCEO	*0.17*	*0.28*	*0.59*	*−0.12*	*−0.21*	−0.08	*0.22*	*−0.14*	*−0.16*	*−0.16*	
CEOG	−0.07	*−0.09*	−0.02	−0.03	0.09	0.15	−0.02	0.02	0.02	*0.27*	−0.02

Note(s): Statistically significant correlations at 5% are in Italic

Table 7. STEM boards, corporate innovation and firm value

	Innovation	Firm value
Intercept	−0.011 [0.21]	1.431* [1.86]
STEM%	0.100*** [5.78]	0.643** [2.45]
ROA	0.014 [1.36]	0.818*** [5.42]
FSIZE	0.003 [1.48]	−0.029 [0.91]
LEV	−0.001 [1.00]	0.006 [0.33]
CASH	1.012 [0.90]	2.026*** [9.88]
BDSIZE	−0.003*** [2.15]	0.024 [1.20]
BDIND	0.001*** [2.00]	0.001 [1.00]
BDGEND	−0.056*** [2.77]	0.090 [0.29]
STEM CEO	−0.016** [2.26]	−0.153 [1.42]
CEOG	0.004 [0.45]	−0.054 [0.36]
Industry Fixed Effects	Yes	Yes
R-square	0.162	0.155
# Observations	404	404

Note(s): Statistical significance levels of 0.01, 0.05, 0.1 are denoted by ***, ** and * respectively and *t*-values are reported in parentheses

mechanisms, including specialized technical skills, willingness to innovate, access to networks of technological experts, and confidence in managing uncertainty and risk. From the UET perspective, prior literature shows that CEOs with technical or engineering backgrounds possess specialized skills that encourage calculated risk-taking and promote an innovative culture within organizations (Dissanayake *et al*., 2025; Jiang *et al*., 2024). STEM directors' cognitive capacities and behavioural tendencies, shaped through careers in technical fields, equip them to engage effectively with the complexities of innovation investments, including risk appraisal, technology requirements, governance, and balancing costs with benefits (Dissanayake *et al*., 2025; Jiang *et al*., 2024; Ting *et al*., 2021). From the RDT perspective, STEM directors bring access to external knowledge capital from their connections to professional and technology networks (Jiang *et al*., 2024; Ting *et al*., 2021; Weerasinghe and Dissanayake, 2025). Combined, these skills and external resources strengthen board decision making on innovation investments and enhance the firm's capacity to realize value from technology.

For the control variables, we find that board independence is positively associated with innovation. This finding is consistent with prior literature and the argument that strengthened governance and scrutiny by directors help to align management's interests with shareholders by encouraging long-term innovative investment (Griffin *et al*., 2021; Kang *et al*., 2018; Balsmeier *et al*., 2017). Our finding that board size is negatively associated with innovation is consistent with prior studies that argue smaller boards benefit from greater coordination and communication, which enhance decision-making and innovation (Cheng, 2008; Yermack, 1996). However, our results for board gender diversity reveal a negative association with innovation, which contradicts prior research (e.g. Griffin *et al*., 2021; Vafaei *et al*., 2021). This could be because the increased push for female directors on boards in recent years has crowded out the hiring of STEM directors, resulting in less investment in innovation.

We also report a negative association between STEM CEOs and corporate innovation investment. This is an unexpected result and suggests that STEM CEOs are associated with less innovation investment (while STEM boards are associated with more innovation investment). While this result is surprising, prior research suggests that similarities between CEO characteristics and board characteristics can produce nuanced outcomes. For example, Liu (2018) shows that female CEOs are negatively associated with corporate lawsuits, but only in firms with low levels of female directors on their boards. Thus, our unexpected result for

STEM CEOs could be driven by the dynamics between STEM CEOs and STEM directors on boards. For example, it is possible that the presence of STEM expertise on boards may reduce the prominence of STEM CEOs' influence. Further, Table 6 indicates that STEM CEOs and STEM boards are significantly positively correlated ($r = 0.60$), implying that firms managed by STEM CEOs are also more likely to have STEM expertise on their boards. Given this result, we examine the interaction between STEM CEOs and STEM boards in more detail in Section 4.3.2.

4.2.3 Potential non-linear relationship. While the above analysis suggests a significant positive relationship between STEM boards and corporate innovation investment, as well as firm value, the regression analysis assumes a linear relationship between these variables. Given that STEM expertise on boards ranges from 0 to 80% (Table 6) and prior literature on board characteristics reveals nuanced non-linear effects in corporate outcomes, we investigate whether the results are robust to potential non-linear relationships. First, we include squared values of the STEM board variable (STEM%_SQ) in the model and reperformed the analysis. The results in Table 8 indicate that the squared term is significantly positive; however, the standard variable (STEM%) is non-significant. This does not imply a non-linear relationship.

We then examine whether a critical mass of STEM expertise has an influence on innovation. To test whether STEM boards' influence on innovation persists after a certain percentage of expertise on boards (e.g. at 25%, a critical mass), we create three dummy variables for STEM boards: STEM1, STEM2, and STEM3. These represent 1, 2, and 3 STEM directors on boards and are included separately in the three regression models to test the influence of each. The results are reported in Table 8. All regression results indicate a very similar significant positive relationship between STEM directors and innovation, suggesting that there is no threshold point of influence (i.e. no critical mass).

4.3 Robustness tests and additional analysis

4.3.1 Endogeneity. Empirical tests of associations are susceptible to concerns about endogeneity. One potential issue is the risk of reverse causality. Innovative firms may attract STEM directors, and the higher innovation may be a result of firm characteristics rather than the influence of appointed directors. We lagged the independent variables to address this concern, ensuring that the STEM board percentage is employed one year before the dependent variable, innovation.

Another endogeneity concern arises from the difference in firm and governance characteristics of the sample. In our context, this means that the differences in firm and governance characteristics between firms with a low percentage of STEM directors and those with a high percentage of STEM directors drive the results, rather than unique variations in STEM board variables. This is commonly addressed in prior literature using matched samples generated through propensity score matching (PSM) (e.g. Fan *et al.*, 2021). While PSM is widely used, one limitation of this approach is the reduction of the sample size. Entropy balancing (EB) offers a robust alternative to the PSM approach, addressing this limitation. Besides robustness, EB generates matched samples using observation weights; thus, the original sample size is retained (Zhao and Percival, 2017). Given the limited observations in our sample, we adopt the EB method to generate our matched sample. We create a binary variable of STEM boards, equal to 1 if the percentage of STEM directors is above 10% (STEMHigh – treated) and 0 otherwise (STEMLow – control). Then, we employ the EB method to generate weights that match all other covariates between these two STEM board groups. The process results in entropy weights that were applied to observations in minimizing the statistical mean differences of covariates between STEMHigh and STEMLow groups of firms. This essentially means that the weighted sample shows no significant differences between the STEM high and low groups, thereby isolating the unique influence of STEM boards in the regressions. The regression results using the EB sample are reported in the first two models in Table 9. The percentage of STEM directors on boards is positively associated

Table 8. STEM boards and corporate innovation – non-linear effects

	STEMBOARD% Squared		1 STEM director		2 STEM directors		3 STEM directors	
Variables	Estimate	*t*-statistics	Estimate	*t*-statistics	Estimate	*t*-statistics	Estimate	*t*-statistics
Intercept	−0.003	[0.062]	0.013	[0.313]	0.006	[0.132]	0.007	[0.170]
STEM%	0.019	[0.499]						
STEM%_SQ	0.204***	[3.432]						
STEM1			0.013***	[2.681]				
STEM2					0.011***	[2.595]		
STEM3							0.012***	[2.773]
ROA	0.007	[0.733]	0.015*	[1.770]	0.017**	[1.943]	0.016*	[1.809]
FSIZE	0.003	[1.400]	0.003*	[1.667]	0.003*	[1.722]	0.003*	[1.722]
LEV	−0.001	[1.000]	−0.001	[1.100]	−0.001	[1.100]	−0.001	[1.000]
CASH	0.013	[1.000]	0.020*	[1.707]	0.021*	[1.769]	0.018	[1.534]
BDSIZE	−0.003**	[1.923]	−0.002**	[1.909]	−0.002**	[2.000]	−0.002**	[2.091]
BDIND	0.000***	[2.000]	0.000***	[2.000]	0.000***	[2.000]	0.000***	[2.000]
BDGEND	−0.055***	[2.756]	−0.053***	[3.087]	−0.052***	[2.943]	−0.052	[2.949]
STEMCEO	−0.015**	[2.143]	−0.002	[0.377]	−0.003	[0.500]	−0.005	[0.891]
CEOG	0.005	[0.533]	0.007	[0.899]	0.005	[0.575]	0.004	[0.519]
Industry Fixed Effects	Yes		Yes		Yes		Yes	
R-square	0.18		0.18		0.18		0.18	
# Observations	404		404		404		404	

Note(s): *, ** and *** indicate statistical significance at 10, 5, and 1% levels, respectively

Table 9. Robustness tests

	Entropy-balanced sample		Residual inclusion model	
	Innovation	Firm value	Innovation	Firm value
Intercept	−0.007 [0.49]	2.172 [2.61]	0.001 [0.02]	2.036 [2.81]
STEM%	0.140*** [7.94]	0.826*** [3.33]		
STEMRES%			0.050*** [3.98]	0.506* [1.99]
ROA	0.022*** [2.07]	1.64*** [7.77]	0.008 [1.04]	0.746*** [5.09]
FSIZE	0.003 [1.26]	−0.058* [1.81]	0.002 [1.40]	−0.046 [1.53]
LEV	−0.000 [0.11]	0.009 [0.37]	−0.001 [0.75]	0.008 [0.47]
CASH	0.002 [0.12]	1.475*** [8.24]	−0.023** [2.38]	1.887*** [9.53]
BDSIZE	−0.005*** [3.71]	0.030 [1.58]	−0.002** [2.22]	0.036* [1.93]
BDIND	0.000** [2.00]	0.002 [1.25]	0.000*** [1.00]	0.001 [1.18]
BDGEND	−0.045** [2.16]	0.227 [0.76]	−0.016 [1.09]	−0.082 [0.27]
STEMCEO	−0.025*** [3.27]	0.095 [0.88]	0.004 [0.91]	−0.033 [0.37]
CEOG	−0.001 [0.13]	−0.165 [1.13]	0.003 [0.50]	−0.090 [0.66]
Industry Fixed Effects	Yes	Yes	Yes	Yes
R-square	0.135	0.129	0.163	0.151
# Observations	404	404	404	404

Note(s): Statistical significance levels of 0.01, 0.05, 0.1 are denoted by ***, ** and * respectively and *t*-values are reported in parentheses

with corporate innovation investment (H1, 0.046, $p < 0.01$) and firm value (H2, 0.691, $p < 0.01$). This approach confirms that our results are valid after minimizing sample biases related to firm and governance characteristics.

To further address endogeneity concerns, we employ another robust technique, the residual inclusion approach. Firm and governance characteristics may account for most of the variation in innovation and firm value, while the STEM board percentage serves as a mere aggregated proxy for these covariates. Although the EB approach enhances the validity of our results by minimizing sample biases, the residual inclusion method is beneficial for isolating the unique influence of the STEM board percentage on innovation and firm value. We initially predicted the STEM board percentage, controlling for all other covariates in the model, and obtained the residuals (STEMRES%). With an *R*-squared of 53%, the model suggests that 47% of the variance in the STEM board percentage remains unexplained by these covariates. This 47% (or the residuals) represents the unexplained proportion of variance in the STEM board percentage due to covariates (i.e. the unique proportion). The residuals are then used to replace the original STEM board percentage in the model, with findings reported in Table 9. The results remain consistent with previous analyses, indicating a positive association between the residuals of the STEM board percentage and innovation investment as well as firm value. Thus, the STEM board percentage signifies a unique influence on innovation investment (H1) and value (H2) that cannot be attributed to other firm and governance characteristics.

4.3.2 Additional analysis. We also conduct additional analysis of our sample firms to determine if our results are consistent across different sub-samples. In Section 4.1, we highlight that directors with STEM expertise are clustered in specific industries, including IT, Materials, Health Care, and Energy. Thus, it is essential to determine whether STEM boards are associated with greater innovation in these industries and/or in other industries where there are fewer STEM directors. Table 10 presents this analysis relating STEM boards to innovation investment. We find that the relationship between STEM boards and innovation is insignificant in the IT, materials, health care and energy industries. However, the relationship between STEM boards and innovation is positive in other industries (0.042, $p < 0.01$). This suggests that directors with STEM expertise have a more significant effect on innovation investment in these different industries, where there is a relative scarcity of directors with STEM expertise.

Due to the potential interaction effect between STEM boards and STEM CEOs, we also undertake analysis on sub-samples of firms with and without STEM CEOs. Table 10 shows that the positive relationship between STEM boards and innovation is only significant (0.085, $p < 0.01$) in firms without STEM CEOs. This suggests that directors with STEM expertise have a greater impact on innovation investment in firms where the CEO lacks STEM expertise. But the effect of STEM boards is reduced when firms have STEM CEOs. This supports our conjecture of a nuanced interaction between STEM boards and STEM CEOs, as discussed in Section 4.2.2.

Finally, our primary analysis focuses on innovation investment, a critical precursor to innovation. Other studies have measured corporate innovation by considering outputs in the form of patents and patent citations (Kurzhals *et al.*, 2020). While patent data is not widely available in commercial databases in Australia, we sourced as much relevant data as possible by extracting data on patent activity for ASX 500 firms in 2022 from the Intellectual Property Government Open Dataset [3]. We found that 13 of our sample firms had applied for a patent. For each of these firms, we then considered the proportion of their board composed of directors with STEM expertise and compared it to the average in the firm's industry. Table 11 shows that of the 13 sample firms that applied for a patent, 10 (77%) had a percentage of STEM directors above the industry average. This provides further support to our theory and hypothesis that an increased representation of STEM expertise on boards will both enhance investment in innovation and innovation outcomes.

Table 10. Additional analysis

	IT, materials healthcare, energy Innovation	Other industries Innovation	STEMCEO = 1 Innovation	STEMCEO = 0 Innovation
Intercept	0.267* [3.20]	0.016 [0.51]	0.333 [0.98]	−0.041 [1.36]
STEM%	0.023 [0.19]	0.042*** [8.55]	0.013 [0.02]	0.085*** [25.09]
ROA	−0.166*** [29.08]	0.003 [0.08]	−0.258*** [24.43]	0.003 [0.07]
FSIZE	−0.009 [1.06]	0.001 [0.01]	−0.013 [0.73]	0.004** [4.42]
LEV	−0.006 [0.88]	0.001 [0.01]	−0.004 [0.21]	−0.001 [1.94]
CASH	0.136*** [8.60]	0.01 [0.01]	0.070 [0.63]	0.026** [4.43]
BDSIZE	−0.005 [0.71]	−0.001 [0.04]	−0.005 [0.26]	−0.002* [3.35]
BDIND	0.001*** [4.59]	0.001* [3.37]	0.001 [0.87]	0.001*** [7.94]
BDGEND	−0.069 [0.70]	−0.022** [3.81]	−0.074 [0.31]	−0.053*** [8.09]
STEM CEO	0.006 [0.09]	−0.005 [0.85]		
CEOG	0.021 [0.26]	−0.003 [0.35]	0.019 [0.06]	0.008 [0.88]
Industry Fixed Effects	Yes	Yes	Yes	Yes
R-square	0.197	0.259	0.278	0.189
# Observations	175	229	74	330

Note(s): Statistical significance levels of 0.01, 0.05, 0.1 are denoted by ***, ** and * respectively and *t*-values are reported in parentheses

Table 11. ASX500 Firms that applied for a Patent in 2022

Firm ASX code	Industry	STEM board %	Industry Ave	Above or below industry average
ARB	Consumer Discretionary	17%	4%	Above
BLK	Consumer Staples	17%	4%	Above
CBA	Financials	9%	4%	Above
CSL	Health Care	33%	24%	Above
FMG	Materials	13%	27%	Below
NAN	Health Care	25%	24%	Above
RAC	Health Care	25%	24%	Above
WBC	Financials	0%	4%	Below
CUV	Health Care	43%	24%	Above
CXL	Materials	33%	27%	Above
TLG	Materials	20%	27%	Below
CAT	Information Technology	67%	27%	Above
FZO	Information Technology	43%	27%	Above

Note(s): This table shows the ASX500 firms that applied for a patent in 2022 and the firm's proportion of directors with STEM expertise compared to the average proportion of STEM board expertise in the firm's industry

5. Conclusion

In this paper, we examined the evolving representation of directors with STEM expertise on Australian corporate boards over the past 15 years and their influence on corporate innovation investment and firm value. Despite the growing importance of technology over this period, the representation of STEM directors has only marginally increased and remains low, particularly when compared to directors from traditional fields such as accounting, banking, and law. Yet our findings also show that STEM directors contribute significant value to firms. We argue that their cognitive capacities and technical expertise enable STEM directors to identify, assess, and respond to technological opportunities and risks, thereby enhancing their advisory and monitoring roles in relation to innovation and technology strategies. This is supported by our results, which show a positive and significant association between STEM director representation and both corporate innovation investment and firm value. Notably, these effects are strongest in firms without STEM CEOs and in industries with lower overall STEM representation, suggesting that STEM directors help fill a critical gap in firms' innovation strategy and capabilities.

Our findings provide meaningful contributions to the literature with implications for both policy and practice. First, our results are grounded in two well-established theories: UET and RDT. From a UET perspective, we argue that directors with STEM expertise are better positioned in their advisory role to promote greater investment in innovation. Their willingness and ability to engage in technical matters inform strategic decisions, leading to both increased technical investments and improved value capture from those investments (Hambrick and Mason, 1984). From an RDT perspective, STEM directors enhance firms' technical and technological capital by contributing human and social capital, including enhanced access to external information networks and innovation-related opportunities. Prior research has used UET and RDT to explain how board diversity fosters innovation by bringing diverse cognitive perspectives and external resources to boardroom discussions (Kurzhals *et al.*, 2020; Zhu *et al.*, 2024). In line with this work, we demonstrate that STEM expertise has a positive impact on corporate innovation investment and firm value. In doing so, we extend the literature by offering new empirical support for the application of UET and RDT to the impact of STEM directors on corporate boards.

Given the critical role of innovation in driving organizational growth and firm value, a substantial body of research has examined how board characteristics influence firm innovation. However, much of this literature has focused on group-level attributes such as board diversity, independence and board size (Sierra-Morán *et al.*, 2024). While there is considerable evidence that directors' knowledge and skills influence firm outcomes (Hillman and Dalziel, 2003), limited attention has been paid to how specific expertise – such as STEM expertise – influences investment in innovation. Our second contribution, therefore, lies in extending the corporate governance literature by providing novel evidence on the impact of director STEM expertise in innovation investment decisions. We define and measure STEM expertise as practical experience acquired through working in science, technology, engineering and mathematics-related roles. This approach provides a more nuanced and relevant measure of director expertise than prior studies that rely solely on formal qualifications.

Third, our finding that boards with higher STEM representation are associated with greater firm value contributes to the growing body of research examining the link between corporate innovation and firm performance. While numerous studies have established a positive relation between innovation and firm value, the governance mechanisms through which innovation translates into improved value remain less well understood. Innovation is widely recognized as critical for growth, adaptability, and competitive positioning (Kurzhals *et al.*, 2020; Zhu *et al.*, 2024), but it is also characterized by high costs, long time horizons, and uncertain outcomes (Thraya *et al.*, 2019). As a result, not all innovation investments yield positive returns. Our research contributes to this debate by highlighting the role of board expertise in shaping positive outcomes from innovation activities. Specifically, we argue that the presence of STEM directors enables firms to more effectively evaluate, guide and extract value from innovation investments, thereby enhancing firm value.

Our findings have important practical implications for boards and policymakers. By examining the Australian context, where innovation capabilities are less developed than in major economies such as China and the USA, we provide an alternative perspective and insights relevant to other small and mid-sized economies. Our results suggest that boards and nomination committees should consider the value of STEM expertise in director appointments, especially in firms outside the technology and healthcare industries where STEM representation is lowest and our results are strongest. Recent national data indicate that construction, agriculture, transport and real estate are amongst the least innovation active industries in Australia (Australian Bureau of Statistics, 2023). Greater board level STEM expertise in these industries may help foster a more innovation orientated culture and embrace technology driven strategic opportunities.

The low representation of STEM expertise on boards may reflect a limited availability of talent. Insights from board gender diversity studies suggest that an effective way to overcome this constraint is to develop a pipeline of executives equipped for board roles (Klettner *et al.*, 2016). Collaborations with industry organizations such as the Tech Council of Australia can play an important role in this capacity building by providing resources and advocacy to improve technology capability in corporate leadership (Tech Council of Australia, 2022). These initiatives can help cultivate a larger pool of STEM leaders with the skills required for effective board oversight in an increasingly technology driven environment.

More broadly, these findings highlight the importance of aligning board expertise with increasing technological complexity in organizational decision making. Emerging governance challenges, such as climate transition and cyber risk, require technological solutions, placing greater demands on boards' capacity to oversee technology related strategy and risk. Our results indicate that firms with greater STEM expertise at board level are better positioned to evaluate and govern these technological solutions. In this way, strengthening STEM representation on boards supports both firm competitiveness and the effectiveness of board oversight in contemporary governance contexts.

Our study has several limitations that also present opportunities for future research. First, our measure of corporate innovation investment relies on R&D expenditure and capital expenditure. While imperfect, it provides a more comprehensive measure of investment, a critical input for innovation activity. Future studies could build on our findings by using a measure of innovation output, such as patents and/or citations. Second, to expand the generalizability of our findings, future research could replicate this study in other countries and across different regulatory environments. Third, while the scope of this study was to examine STEM director representation, future research could explore how other structural governance mechanisms, such as board technology subcommittees or the use of external technology advisers, contribute to board decision making related to innovation. Finally, future research could also examine the processes through which STEM directors influence board discussion and decision making using qualitative and survey based methods.

Overall, this study demonstrates that STEM expertise is an important yet under-represented dimension of board capital. As organizations face increasing technological complexity and innovation-driven opportunities, our findings suggest that appointing directors with STEM backgrounds can enhance firm innovation and value.

Acknowledgments

The authors would like to thank and acknowledge the Colin Brain foundation for supporting this research and the participants at the 2025 AFAANZ conference along with anonymous reviewers for their helpful comments.

Notes

1. Australia Ranking in the Global Innovation Index 2024 compiled by the World Intellectual Property Organization (WIPO).
2. The reduction of the executive expertise category is likely to be driven by higher disclosure over time. Compared to 2007, 2022 biographies disclose more information about director expertise leading to categorize them under the relevant expertise.
3. IPGOD 2022 | Resources | data.gov.au – beta

References

Aghion, P., Van Reenen, J. and Zingales, L. (2013), "Innovation and institutional ownership", *The American Economic Review*, Vol. 103 No. 1, pp. 277-304, doi: 10.1257/aer.103.1.277.

Asensio-López, D., Cabeza-García, L. and González-Álvarez, N. (2019), "Corporate governance and innovation: a theoretical review", *European Journal of Management and Business Economics*, Vol. 28 No. 3, pp. 266-284, doi: 10.1108/ejmbe-05-2018-0056.

Australian Bureau of Statistics (2023), "Innovation in Australian Business 2022-23 financial year", available at: https://www.abs.gov.au/statistics/industry/technology-and-innovation/innovation-australian-business/2022-23

Balsmeier, B., Buchwald, A. and Stiebale, J. (2014), "Outside directors on the board and innovative firm performance", *Research Policy*, Vol. 43 No. 10, pp. 1800-1815.

Balsmeier, B., Fleming, L. and Manso, G. (2017), "Independent boards and innovation", *Journal of Financial Economics*, Vol. 123 No. 3, pp. 536-557, doi: 10.1016/j.jfineco.2016.12.005.

Bereznoy, A. (2019), "Changing competitive landscape through business model innovation: the new imperative for corporate market strategy", *Journal of the Knowledge Economy*, Vol. 10 No. 4, pp. 1362-1383, doi: 10.1007/s13132-015-0324-x.

Berezinets, I., Berezkin, K., Ilina, Y. and Naoumova, I. (2019), "Board of directors as a factor of firm performance in innovative companies", *International Journal of Innovation Management*, Vol. 23 No. 6, 1950060, doi: 10.1142/s1363919619500609.

Bloch, V., Kerrigan, C. and Payten, J. (2025), "Cyber enforcement in the spotlight again as ASIC pursues Fortnum Private Wealth", available at: https://www.allens.com.au/insights-news/insights/2025/07/cyber-enforcement-in-the-spotlight-again-as-asic-pursues-fortnum-private-wealth/

Bobillo, A.M., Rodríguez-Sanz, J.A. and Tejerina-Gaite, F. (2018), "Corporate governance drivers of firm innovation capacity", *Review of International Economics*, Vol. 26 No. 3, pp. 721-741, doi: 10.1111/roie.12321.

Boiciuc, K., Watson, R. and Ey, G. (2025), "Technology moves fast. Governance is slow", *How Can Boards Keep Up?*, available at: https://www.ey.com/en_au/insights/technology/how-can-boards-keep-up-with-technology

Buchwald, A. and Thorwarth, S. (2018), "Outside directors on the board, competition and innovation", *International Journal of Economics and Business Research*, Vol. 16 No. 2, pp. 210-231, doi: 10.1504/ijebr.2018.094014.

Capezio, A. and Mavisakalyan, A. (2016), "Women in the boardroom and fraud: evidence from Australia", *Australian Journal of Management*, Vol. 41 No. 4, pp. 719-734, doi: 10.1177/0312896215579463.

Carpenter, M.A., Geletkanycz, M.A. and Sanders, W.G. (2004), "Upper echelons research revisited: antecedents, elements, and consequences of top management team composition", *Journal of Management*, Vol. 30 No. 6, pp. 749-778.

Cerny, M. and Di Pietro, R. (2025), "Cyber readiness for boards and executives", available at: https://www.pwc.com.au/cyber-security-digital-trust/cyber-readiness.html

Chapple, L., Weerasinghe, A.P., Williamson, A.K. and Nowland, J. (2025), "Are benevolent directors more environmentally responsible?", *Journal of Accounting Literature*, Vol. 47 No. 5, pp. 517-539, doi: 10.1108/JAL-12-2024-0362.

Chatjuthamard, P. and Jiraporn, P. (2023), "Corporate culture, innovation and board size: recent evidence from machine learning and earnings conference calls", *Corporate Governance: The International Journal of Business in Society*, Vol. 23 No. 6, pp. 1361-1378, doi: 10.1108/cg-09-2022-0371.

Chen, S., Bu, M., Wu, S. and Liang, X. (2015), "How does TMT attention to innovation of Chinese firms influence firm innovation activities? A study on the moderating role of corporate governance", *Journal of Business Research*, Vol. 68 No. 5, pp. 1127-1135, doi: 10.1016/j.jbusres.2014.11.002.

Chen, J., Leung, W.S. and Evans, K.P. (2018), "Female board representation, corporate innovation, and firm performance", *Journal of Empirical Finance*, Vol. 48, pp. 236-254, doi: 10.1016/j.jempfin.2018.07.003.

Chen, I.J., Lin, W.C., Lo, H.C. and Chen, S.S. (2023), "Board diversity and corporate innovation", *Review of Quantitative Finance and Accounting*, Vol. 61 No. 1, pp. 63-123, doi: 10.1007/s11156-023-01145-4.

Cheng, S. (2008), "Board size and the variability of corporate performance", *Journal of Financial Economics*, Vol. 87 No. 1, pp. 157-176, doi: 10.1016/j.jfineco.2006.10.006.

Chouaibi, J. and Jarboui, A. (2012), "Investigating the effect of the directors' board characteristics on financial performance through innovation activities", *International Journal of Behavioural Accounting and Finance*, Vol. 3 Nos 1-2, pp. 65-87, doi: 10.1504/ijbaf.2012.047360.

Cosma, S., Schwizer, P., Nobile, L. and Leopizzi, R. (2021), "'Environmental attitude in the board', Who are the 'green directors'? Evidences from Italy", *Business Strategy and the Environment*, Vol. 30 No. 7, pp. 3360-3375, doi: 10.1002/bse.2807.

Dalziel, T., Gentry, R.J. and Bowerman, M. (2011), "An integrated agency–resource dependence view of the influence of directors' human and relational capital on firms' R&D spending", *Journal of Management Studies*, Vol. 48 No. 6, pp. 1217-1242.

Dissanayake, S., Weerasinghe, A. and Dissanayake, D. (2025), "Engineer CEOs and corporate risk taking", *Journal of Accounting Literature*, Vol. 47 No. 5, pp. 249-269, doi: 10.1108/jal-06-2024-0132.

Faleye, O., Hoitash, R. and Hoitash, U. (2018), "Industry expertise on corporate boards", *Review of Quantitative Finance and Accounting*, Vol. 50 No. 2, pp. 441-479, doi: 10.1007/s11156-017-0635-z.

Fan, X., Li, S. and Villatoro, N. (2021), "CEO gender and corporate labor cost", *Review of Financial Economics*, Vol. 39 No. 3, pp. 360-380, doi: 10.1002/rfe.1141.

Farooq, S., Gan, C. and Nadeem, M. (2023), "Boardroom gender diversity and investment inefficiency: new evidence from the United Kingdom", *Corporate Governance: An International Review*, Vol. 31 No. 1, pp. 2-32, doi: 10.1111/corg.12443.

Finkelstein, S., Hambrick, D.C. and Cannella, A.A. (2009), *Strategic Leadership: Theory and Research on Executives, Top Management Teams, and Boards*, Oxford University Press, Oxford.

Governance Institute of Australia (2022), "Driving the digital revolution: a guide for boards", available at: https://governanceinstitute.com.au/app/uploads/2023/11/driving-digital-revolution.pdf?

Gray, S. and Nowland, J. (2017), "The diversity of expertise on corporate boards in Australia", *Accounting and Finance*, Vol. 57 No. 2, pp. 429-463, doi: 10.1111/acfi.12146.

Griffin, D., Li, K. and Xu, T. (2021), "Board gender diversity and corporate innovation: international evidence", *Journal of Financial and Quantitative Analysis*, Vol. 56 No. 1, pp. 123-154, doi: 10.1017/s002210901900098x.

Hambrick, D.C. (2007), "Upper echelons theory: an update", *Academy of Management Review*, Vol. 32 No. 2, pp. 334-343.

Hambrick, D.C. and Mason, P.A. (1984), "Upper echelons: the organization as a reflection of its top managers", *Academy of Management Review*, Vol. 9 No. 2, pp. 193-206, doi: 10.2307/258434.

Haque, F. and Jones, M.J. (2020), "European firms' corporate biodiversity disclosures and board gender diversity from 2002 to 2016", *The British Accounting Review*, Vol. 52 No. 2, 100893, doi: 10.1016/j.bar.2020.100893.

Hill, C.W. and Rothaermel, F.T. (2003), "The performance of incumbent firms in the face of radical technological innovation", *Academy of Management Review*, Vol. 28 No. 2, pp. 257-274, doi: 10.2307/30040712.

Hillman, A.J. and Dalziel, T. (2003), "Boards of directors and firm performance: integrating agency and resource dependence perspectives", *Academy of Management Review*, Vol. 28 No. 3, pp. 383-396, doi: 10.2307/30040728.

Hoskisson, R.E., Hitt, M.A., Johnson, R.A. and Grossman, W. (2002), "Conflicting voices: the effects of institutional ownership heterogeneity and internal governance on corporate innovation strategies", *Academy of Management Journal*, Vol. 45 No. 4, pp. 697-716, doi: 10.2307/3069305.

Hsieh, T.S., Kim, J.B., Wang, R.R. and Wang, Z. (2022), "Educate to innovate: STEM directors and corporate innovation", *Journal of Business Research*, Vol. 138, pp. 229-238, doi: 10.1016/j.jbusres.2021.09.022.

Javed, M., Wang, F., Usman, M., Gull, A.A. and Zaman, Q.U. (2023), "Female CEOs and green innovation", *Journal of Business Research*, Vol. 157, 113525, doi: 10.1016/j.jbusres.2022.113515.

Jiang, A., Ma, J., Wang, Z. and Zhou, M. (2024), "Does knowledge of digital technology affect corporate innovation? Evidence from CEOs with digital technology backgrounds in China", *Applied Economics*, Vol. 56 No. 49, pp. 5939-5956, doi: 10.1080/00036846.2023.2266605.

Kang, J.-K., Liu, W.-L., Low, A. and Zhang, L. (2018), "Friendly boards and innovation", *Journal of Empirical Finance*, Vol. 45, pp. 1-25, doi: 10.1016/j.jempfin.2017.09.007.

Klettner, A., Clarke, T. and Boersma, M. (2016), "Strategic and regulatory approaches to increasing women in leadership: multilevel targets and mandatory quotas as levers for cultural change", *Journal of Business Ethics*, Vol. 133 No. 3, pp. 395-419, doi: 10.1007/s10551-014-2069-z.

Knockaert, M. and Ucbasaran, D. (2013), "The service role of outside boards in high tech start-ups: a resource dependency perspective", *British Journal of Management*, Vol. 24 No. 1, pp. 69-84, doi: 10.1111/j.1467-8551.2011.00787.x.

Kor, Y.Y. (2006), "Direct and interaction effects of top management team and board compositions on R&D investment strategy", *Strategic Management Journal*, Vol. 27 No. 11, pp. 1081-1099.

Kumar, P. and Zattoni, A. (2019), "Farewell editorial: exiting editors' perspective on current and future challenges in corporate governance research", *Corporate Governance: An International Review*, Vol. 27 No. 1, pp. 2-11, doi: 10.1111/corg.12268.

Kurzhals, C., Graf-Vlachy, L. and König, A. (2020), "Strategic leadership and technological innovation: a comprehensive review and research agenda", *Corporate Governance: An International Review*, Vol. 28 No. 6, pp. 437-464, doi: 10.1111/corg.12351.

Kurzweil, R. (2005), *The Singularity Is Near*, Viking Books, New York.

Liao, L., Lin, T. and Zhang, Y. (2018), "Corporate board and corporate social responsibility assurance: evidence from China", *Journal of Business Ethics*, Vol. 150 No. 1, pp. 211-225, doi: 10.1007/s10551-016-3176-9.

Liu, C. (2018), "Are women greener? Corporate gender diversity and environmental violations", *Journal of Corporate Finance*, Vol. 52, pp. 118-142, doi: 10.1016/j.jcorpfin.

Liu, Y., Zhou, Z. and Wu, W. (2025), "Board characteristics and firm innovation: a qualitative comparative analysis", *Management Decision*, Vol. 63 No. 3, pp. 1037-1056, doi: 10.1108/md-06-2023-1067.

Lu, J. and Wang, W. (2018), "Managerial conservatism, board independence and corporate innovation", *Journal of Corporate Finance*, Vol. 48, pp. 1-16, doi: 10.1016/j.jcorpfin.2017.10.016.

Luo, Y. and Salterio, S.E. (2014), "Governance quality in a 'comply or explain' governance disclosure regime", *Corporate Governance: An International Review*, Vol. 22 No. 6, pp. 460-481, doi: 10.1111/corg.12072.

Makkonen, T. (2022), "Board diversity and firm innovation: a meta-analysis", *European Journal of Innovation Management*, Vol. 25 No. 6, pp. 941-960.

Manso, G. (2011), "Motivating innovation", *The Journal of Finance*, Vol. 66 No. 5, pp. 1823-1860, doi: 10.1111/j.1540-6261.2011.01688.x.

Oliveira, F., Kakabadse, N. and Khan, N. (2022), "Board engagement with digital technologies: a resource dependence framework", *Journal of Business Research*, Vol. 139, pp. 804-818, doi: 10.1016/j.jbusres.2021.10.010.

Pfeffer, J. and Salancik, G.R. (1978), *The External Control of Organizations: A Resource-Dependency Perspective*, Harper & Row, New York.

Ramdani, D. and Witteloostuijn, A.v. (2010), "The impact of board independence and CEO duality on firm performance: a quantile regression analysis for Indonesia, Malaysia, South Korea and Thailand", *British Journal of Management*, Vol. 21 No. 3, pp. 607-627, doi: 10.1111/j.1467-8551.2010.00708.x.

Reguera-Alvarado, N. and Bravo, F. (2018), "The impact of directors' high-tech experience on innovation in low-tech firms", *Innovation*, Vol. 20 No. 3, pp. 223-239, doi: 10.1080/14479338.2017.1407220.

Renders, A. and Gaeremynck, A. (2012), "Corporate governance, principal-principal agency conflicts, and firm value in European listed companies", *Corporate Governance: An International Review*, Vol. 20 No. 2, pp. 125-143, doi: 10.1111/j.1467-8683.2011.00900.x.

Rossi, F. and Cebula, R.J. (2015), "Does the board of directors affect the extent of corporate R&D? Evidence from Italian listed companies", *Economics Bulletin*, Vol. 35 No. 4, pp. 2567-2580.

Rousseau, D.M. and Stouten, J. (2024), "Experts and expertise in organizations: an integrative review on individual expertise", *Annual Review of Organizational Psychology and Organizational Behavior*, Vol. 12 No. 1, pp. 159-184, doi: 10.1146/annurev-orgpsych-020323-012717.

Rousseeuw, P.J. and Leroy, A.M. (2005), *Robust Regression and Outlier Detection*, John Wiley & Sons, New York.

Rubera, G. and Kirca, A.H. (2012), "Firm innovativeness and its performance outcomes: a meta-analytic review and theoretical integration", *Journal of Marketing*, Vol. 76 No. 3, pp. 130-147, doi: 10.1509/jm.10.0494.

Shen, Y., Wallace, D., Ramiah, V. and Reddy, K. (2026), "Innovating with impact: CEO attributes and their influence on firm innovation in Australia", *Journal of Accounting Literature*, Vol. 48 No. 1, doi: 10.1108/JAL-09-2024-0234.

Sierra-Morán, J., Cabeza-García, L., González-Álvarez, N. and Botella, J. (2024), "The board of directors and firm innovation: a meta-analytical review", *BRQ Business Research Quarterly*, Vol. 27 No. 2, pp. 182-207, doi: 10.1177/23409444211039856.

Singh, S., Tabassum, N., Darwish, T.K. and Batsakis, G. (2018), "Corporate governance and Tobin's Q as a measure of organizational performance", *British Journal of Management*, Vol. 29 No. 1, pp. 171-190, doi: 10.1111/1467-8551.12237.

Sundaramurthy, C., Pukthuanthong, K. and Kor, Y. (2014), "Positive and negative synergies between the CEO's and the corporate board's human and social capital: a study of biotechnology firms", *Strategic Management Journal*, Vol. 35 No. 6, pp. 845-868, doi: 10.1002/smj.2137.

Tech Council of Australia (2022), "Turning Australia into a global technology powerhouse", available at: https://techcouncil.com.au/wp-content/uploads/2022/02/TCA-2030

Thraya, M.F., Lichy, J., Louizi, A. and Rzem, M. (2019), "High-tech acquirers and the moderating role of corporate governance", *The Journal of High Technology Management Research*, Vol. 30 No. 2, 100354, doi: 10.1016/j.hitech.2019.100354.

Ting, H.-I., Wang, M.-C., Yang, J.J. and Tuan, K.-W. (2021), "Technical expert CEOs and corporate innovation", *Pacific-Basin Finance Journal*, Vol. 68, 101603, doi: 10.1016/j.pacfin.2021.101603.

Tribbitt, M.A. and Yang, Y. (2017), "An agency perspective on the board of directors and corporate entrepreneurship", *Management Research Review*, Vol. 40 No. 11, pp. 1201-1215, doi: 10.1108/mrr-09-2016-0217.

Vafaei, A., Henry, D., Ahmed, K. and Alipour, M. (2021), "Board diversity: female director participation and corporate innovation", *International Journal of Accounting and Information Management*, Vol. 29 No. 2, pp. 247-279, doi: 10.1108/ijaim-06-2020-0080.

Valenti, A. and Horner, S. (2020), "The human capital of boards of directors and innovation: an empirical examination of the pharmaceutical industry", *International Journal of Innovation Management*, Vol. 24 No. 6, 2050056, doi: 10.1142/S1363919620500565.

Weerasinghe, A.P. and Dissanayake, S. (2025), "Engineer CEOs and corporate investment efficiency", *Pacific Accounting Review*, Vol. 37 No. 1, pp. 69-88, doi: 10.1108/PAR-06-2024-0124.

Yermack, D. (1996), "Higher market valuation of companies with a small board of directors", *Journal of Financial Economics*, Vol. 40 No. 2, pp. 185-211, doi: 10.1016/0304-405x(95)00844-5.

Zeb, A., Ullah, I., Iqbal, A., Rahman, M.U. and Aziz, S. (2024), "CEO's science and engineering background and green innovation: evidence from China", *Sage Open*, Vol. 14 No. 1, 21582440241232767, doi: 10.1177/21582440241232767.

Zhang, X., Zhang, W., Wang, J. and Chen, B. (2025), "Impact of CEO's IT background on green technology innovation: evidence from China", *Corporate Governance: An International Review*, Vol. 33 No. 5, pp. 1203-1222, doi: 10.1111/corg.12644.

Zhao, Q. and Percival, D. (2017), "Entropy balancing is doubly robust", *Journal of Causal Inference*, Vol. 5 No. 1, 20160010, doi: 10.1515/jci-2016-0010.

Zhu, D.H., Zhao, Z. and Semadeni, M. (2024), "How and why top executives influence innovation: a review of mechanisms and a research agenda", *Journal of Management*, Vol. 51 No. 6, doi: 10.1177/01492063241284962.

Corresponding author
Natalie Elms can be contacted at: natalie.elms@qut.edu.au