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# Women Directors and R&D Investments Relationship: Does Their Intellectual Capital Matter?

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## ABSTRACT

Recent corporate governance literature highlights the crucial role of women directors in shaping firms' strategic investments, particularly in research and development (R&D). Although existing studies often measure gender diversity by the percentage of women on boards, they overlook women directors' specific roles and characteristics. This study addresses this gap by exploring the conditions necessary to comprehend how and whether women directors influence R&D investments. Drawing on the intellectual capital-based view theory, we examine the moderating effect of women directors' intellectual capital on the relationship between board gender diversity and corporate R&D investments. A Tobit model is applied to a unique hand-collected dataset of Italian-listed industrial companies. Our findings confirm the hypotheses, revealing that foreign (human capital), interlocked (relational capital) and tenured (structural capital) women directors positively moderate the relationship between the proportion of women on the board and the firms' R&D expenditures.

## 1 | Introduction

Women directors are increasingly recognised as crucial contributors to firms' R&D investments (Almor et al. 2022; Chen et al. 2016). They bring fresh perspectives, foster the exchange of ideas, and enhance creativity and innovation (Miller and Del Carmen Triana 2009; Torchia et al. 2011). However, their presence can also lead to communication and coordination challenges, potentially causing conflicts among board members and delaying decision-making processes. Empirical research reflects mixed results, highlighting positive (Midavaine et al. 2016; Saggese et al. 2021) and negative (Almor et al. 2022; Chu and Oldford 2023) impacts of women directors on R&D investment decisions.

The mixed and conflicting findings regarding the effects of women directors on R&D investments may be influenced by various factors, such as different contexts, sampling periods, industries investigated and the measures utilised to proxy gender diversity and R&D investments (Almor et al. 2022). Relying solely on the percentage of women on board as a measure of gender diversity overlooks the unique characteristics of woman directors, which have been shown to significantly influence firm policies and corporate strategies (Cambrea et al. 2020; Veltri et al. 2021). These inconsistencies in empirical findings have prompted scholars to advocate for more complex models that account for direct and indirect associations simultaneously (Kanadli et al. 2018; Sarto and Saggese 2022). This approach aligns with broader calls to examine how board diversity

enhances managerial decision-making (Baghdadi et al. 2023) and fosters innovative capabilities (Van Doorn et al. 2022).

In line with this approach, we suggest investigating the relationship between women directors and R&D investment decisions by examining the conditions that influence the strength or direction of this association (Jollineau and Bowen 2023). Building on these insights, we argue that examining the specific attributes of women directors is vital to deepening our understanding of this relationship (Rahman et al. 2024); it is not merely the presence of women directors that matters for R&D strategic investment decisions.

Drawing on the intellectual capital-based view (ICBV) theory (Reed et al. 2006), we focused on the attributes that reflect women directors' intellectual capital (IC), categorised into human capital (HC), relational capital (RC) and structural capital (SC). Specifically, we developed hypotheses to examine the impact of women directors on R&D investments at two levels. At the first level, we investigated demographic diversity, measured by the ratio of women directors on the board, and predicted that increasing the proportion of women directors would negatively influence corporate R&D investments. At the second level, we explored the IC of women directors, hypothesising that their influence on R&D investments is moderated by the following variables: international experience, other directorships on the board of directors and years of professional experience (tenure).

Our research focuses on the IC attributes of women directors and their impact on the relationship between women directors and R&D investment decisions. Although some studies have explored aspects of information-related diversity among women directors, such as the number of educated women directors (Midavaine et al. 2016) and the expert influence of women directors (Saggese et al. 2021), they have found positive implications for R&D spending. However, no prior research has comprehensively examined all dimensions of IC among women directors or how IC-skilled women directors affect corporate innovation.

We addressed our research hypotheses using a comprehensive sample of Italian industrial listed companies from 2003 to 2017. The analysis was based on a unique, hand-collected dataset containing detailed information on the demographic and personal characteristics of women directors. These data were manually compiled from annual corporate governance reports available on the firms' official websites and the Italian Stock Exchange website.

Our findings revealed a negative relationship between the proportion of women directors and R&D investments. However, when considering the moderating role of the IC attributes of women directors, the results indicate a positive association. Specifically, larger R&D investments are observed in companies with a higher percentage of women directors who possess international experience, hold additional board positions and have significant professional experience.

This study offers several theoretical contributions. It extends the existing theoretical framework, which typically proxies gender diversity by the percentage of women on boards, overlooking attributes that may influence R&D investment decisions. Our study is grounded in the ICBV, responding to calls in the literature to expand theoretical perspectives beyond agency theory and upper echelons theory (UET) (Kurzhals et al. 2020). This is important because dominant frameworks, such as agency theory and UET, often focus narrowly on the structural or demographic characteristics of boards, potentially overlooking the cognitive and knowledge-based resources that directors bring. Our research contributes to this broader theoretical development by introducing ICBV among women directors as a critical element for understanding how board gender diversity influences R&D investment. This allows us to move beyond viewing women's presence on boards as a simple demographic ratio and instead consider the diversity in their human and relational capital as a meaningful factor in strategic decision-making. Our findings advance the understanding beyond agency theory and UET as they argue that the mixed results of previous studies investigating women directors and R&D investment decisions could be due to the missed consideration of IC women directors' attributes, which can positively contribute to R&D investment decisions.

Furthermore, our research advances the understanding of board gender diversity by introducing IC diversity among women directors as a critical theoretical element for examining their impact on R&D investments (Almor et al. 2022; Chu and Oldford 2023; Midavaine et al. 2016).

## 2 | The Intellectual Capital-Based View Framework

The ICBV (Reed et al. 2006) is an evolution of the resource-based view (Barney 1991; Wernerfelt 1984) and the knowledge-based view of the firm (Grant 1996). According to the ICBV, intellectual assets are strategic resources that drive a firm's competitive advantage and innovation (Scaringella 2024; Strazzullo et al. 2024; Wu et al. 2008). In the IC literature, IC is commonly divided into three categories: human capital (HC), relational capital (RC) and structural capital (SC).

This tripartition originates from the work of Edvinsson and Malone (1997), who conceptualised IC as a two-level construct: HC (knowledge created by and stored within a firm's employees) and SC (the embodiment, empowerment and supportive infrastructure of HC). SC was further divided into organisational capital (knowledge embedded in a firm's information technology systems and processes) and customer capital (relationships between a firm and its customers). Bontis (1998) expanded this framework by incorporating customer capital within the broader category of RC, which encompasses all external relationships.

Although these IC categories have been widely applied at the firm level (Mouritsen et al. 2001) and the economy level to represent groups of companies (Bontis 2002), limited research has focused on the IC of corporate boards. Berezinets et al. (2016) are the first to introduce the concept of IC within the board of directors. To operationalise IC, the authors adopted the framework articulated by Hillman and Dalziel (2003), which has been applied by several authors (Chen et al. 2013; Haynes and Hillman 2010; Wincent et al. 2010).

This framework divides IC into two components: HC and social capital. HC refers to the knowledge and expertise embedded in board members, reflected in their educational background and skill sets. Conversely, social capital encompasses board members' relationships with internal and external stakeholders and inter-firm connections.

## 3 | Literature Review and Hypotheses Development

### 3.1 | The Relationship Between Women Directors and R&D Investments

The literature widely discusses women directors' influence on board decisions (Kanadli et al. 2018). This relationship is even more complex regarding R&D investment decisions owing to the inherent uncertainty of innovation investments and their long-term impact. The literature presents several perspectives on how women directors affect R&D investment decisions.

One perspective suggests that gender-diverse boards benefit from a broader range of task-related information, knowledge and skills. This diversity generates varied opinions and perspectives, providing the board with more resources to navigate strategic decisions such as R&D investments (Adams and Funk 2012; Miller and Del Carmen Triana 2009). Conversely, another perspective argues that gender-diverse boards negatively affect R&D investments compared with boards composed solely of male directors (Almor et al. 2022).

A third position highlights the importance of achieving a critical mass of women on the board. Researchers suggest that when boards include only one or two women (tokens), their influence on firm innovation is minimal. However, when at least three women are present (consistent minority), they can significantly affect firm innovation (Torchia et al. 2011).

Empirical studies on the relationship between women directors and R&D investments produced mixed results. For example, Midavaine et al. (2016) examined a sample of US companies and found a positive relationship between the number of women directors and R&D investments. Similarly, Saggese et al. (2021), focusing on a sample of Italian high-tech firms, demonstrated that women directors positively influence R&D investments—but only when at least three women are present on the board, achieving a 'critical mass'.

In contrast, other studies report a negative association. Using a cross-country sample, Almor et al. (2022) suggest that a higher percentage of women directors leads to reduced R&D investments. Chu and Oldford (2023) found similar results in Chinese companies, where higher women's board representation was associated with lower R&D activities.

A nuanced perspective is provided by Asad et al. (2023), who examined US companies and found a positive relationship between board diversity (measured as an aggregate index) and R&D spending. However, when disaggregating the index, they observed a negative relationship between gender diversity and R&D investments. To explain these conflicting results, Asad et al. (2023) referred to Bernile et al. (2018), who emphasised the importance of board characteristics in producing quality decisions.

The recent study by Smulowitz et al. (2025) argues that the women's effect on R&D outputs (patents) is conditional on the firms' performance relative to aspirations, meaning that when performance is poor relative to aspirations and when the firm is close to failure, boards with more women directors will reduce innovation output. In contrast, when performance is high relative to aspirations, boards with a higher proportion of women will increase innovation outputs.

Our research idea posits that the mere presence of women directors on boards is insufficient to capture their influence on strategic investment decisions fully. Instead, their attributes and the intellectual capital they bring to the boardroom are critical. Given that relying solely on the percentage of women directors overlooks their diversity of perspectives and viewpoints, which are known to enhance strategic decision-making (Ben-Amar et al. 2013), we propose the following hypothesis:

**H1.** *The ratio of women on boards of directors negatively affects R&D investments.*

### 3.2 | The IC Attributes of Women Directors

Research on the effects of women directors on R&D investments has produced mixed and conflicting findings, which may be influenced by various factors, including differing contexts, sampling periods, industries studied, and the measures used to proxy gender diversity and R&D investments (Almor et al. 2022). These inconsistencies have led scholars to suggest that future research should investigate the conditions under which this relationship exists or varies in strength or direction (Jollineau and Bowen 2023).

Consistent with the ICBV, we propose that each woman director contributes unique resources to the board, enhancing the overall IC of the company through her experiences, expertise and external connections. Accordingly, we tested whether the association between women directors and R&D investment decisions exists or varies in strength or direction when IC-skilled women are on boards. Differing from Berezinets et al. (2016), we decompose women directors' IC into three components: HC, SC and RC—to provide a more nuanced and detailed definition of IC.

HC refers to the intrinsic qualities and skills associated with gender, which the literature suggests can influence innovation. Women directors are hypothesised to reduce narrow-mindedness, stimulate debate and foster a problem-solving culture on boards (Huse and Solberg 2006). These qualities encourage the identification of innovative opportunities, leading to increased investments in R&D (Díaz-García et al. 2013; Finkelstein and Mooney 2003). In this context, Volonté and Gantenbein (2016) emphasise the importance of directors' HC, demonstrating its influence on a company's acquisition strategy. Their study reveals that higher board HC is positively associated with international acquisitions (Volonté and Gantenbein 2016) as companies benefit from directors with international experience. Such directors, familiar with the complexities

of global markets, possess the skills and abilities required to navigate international challenges. Additionally, the knowledge and diverse perspectives gained abroad by directors provide crucial resources that shape a firm's strategic decisions (Dobija et al. 2022).

Directors with higher levels of education and international experience are expected to possess exceptional communication skills, oral and written, which are adequate across different cultural contexts (Martínez-García et al. 2022). Women are reported to have higher education levels than men (European Commission 2018) and are increasingly pursuing international careers (Singh et al. 2008). Higher levels of HC on the board are associated with superior advice to management, enabling better decision-making (Khanna et al. 2014). Similarly, Chen (2014) demonstrates that enhanced HC on the board, through developing valuable strategies, supports R&D investments and strengthens innovative capabilities.

Based on this literature, we propose the following research hypothesis:

**H2.** *Women directors' HC influences the direction of the relationship between the ratio of women directors and R&D investments, such that the relationship will become positive when the women directors' HC on the board increases.*

RC refers to the ability of women directors to leverage knowledge gained from their networks, internally among board members and externally through connections with stakeholders outside the company (Bravo and Reguera-Alvarado 2017). These external relationships enable women directors to expand their knowledge, acquire new experiences and competencies and access critical resources—most notably information—that support effective R&D investment decisions. Furthermore, external connections enhance women directors' prestige power, which stems from their reputation and influence (Terjesen et al. 2009).

RC encompasses the ties women directors establish with the external environment, providing access to information, influence, legitimacy and other essential resources (Pérez-Calero et al. 2016). By leveraging these ties, women directors can help male executives supplement their knowledge and market insights, facilitating better innovation decisions (Fu et al. 2021). Furthermore, RC, which arises from exchanging knowledge among individuals (Arena et al. 2022), can be a critical driver for increasing R&D investments.

Based on these considerations, we propose the following research hypothesis:

**H3.** *Women directors' RC influences the direction of the relationship between the ratio of women directors and R&D investments, such that the relationship will become positive when the women directors' RC on the board increases.*

SC refers to the implicit attributes 'determined mostly by people, their experience, their values, beliefs and perspectives' (Beltramino et al. 2020, 916). In this context, SC encompasses all the characteristics of women directors that result from training activities (Beltramino et al. 2020). Trained women directors can exert expert power, which is defined as the influence directors exercise on the decision-making process through their professional skills and knowledge (Daily and Johnson 1997; Van Der Vegt and Bunderson 2005).

Women directors with expert power are more likely to share and uphold their perspectives, offering critical contributions to strategic board tasks (Westphal and Khanna 2003). Their presence enhances board decision-making by providing new and diverse perspectives and alternatives, which can foster innovative decisions and investments (Bennouri et al. 2018), leading to effective R&D investment.

Based on this literature, we propose the following research hypothesis:

**H4.** *Women directors' SC influences the direction of the relationship between the ratio of women directors and R&D investments, such that the relationship will become positive when the women directors' SC on the board increases.*

## 4 | The Italian Context

Italy follows a civil law tradition (La Porta et al. 1998), and its corporate governance system is characterised by large block holders, typically represented by families, multinational companies or the state (Minichilli et al. 2009). This system has a limited role in capital markets (De Jong 1997) and an absence of a robust market for corporate control (Melis 2000). As a result, Italian corporate governance is characterised by strong block holders, unprotected minority shareholders and weak managerial power (Melis 2000).

Over time, reforms in commercial law have sought to improve corporate governance by modifying board structures and compositions. These changes include introducing alternative board models alongside the traditional one, which remains the most common, and efforts to enhance board governance practices (Zona and Zattoni 2007). Specifically, new regulations have encouraged the appointment of a higher proportion of independent directors—board members without direct or indirect ties to the company that could compromise their judgement. Additionally, the Golfo-Mosca Act 120/2011 introduced mandatory gender quotas for all listed firms, requiring a minimum representation of women directors on boards (Cambrea et al. 2020).

Conducting our research in Italy allowed us to address a gap highlighted by a recent review, which called for studies focusing on contexts outside of the USA (Kurzhals et al. 2020). Italy was particularly suitable for our research question because of its evolving gender representation on boards. Although progress has been made, women remain significantly under-represented in executive roles. Until 2012, Italy had the lowest percentage of women on boards among the most prominent European firms. However, the implementation of Law 120/2011 (Golfo-Mosca Law) led to a significant increase in the presence of women directors.

The Golfo-Mosca Law mandates that the under-represented gender account for at least one-third of board members for three board nominations after August 2012, with an initial quota of one-fifth for the first term. As a result, by the end of the period

under investigation (2003–2017), Italy has achieved the second-highest percentage of women directors in Europe (33.6% at the end of 2017), trailing only France.

Nevertheless, a disparity remains between executive and non-executive women on boards. In 2017, women accounted for only 3% of executive positions versus 38% of non-executive roles. This disparity highlights that the percentage of women holding structural power derived from formal positions and hierarchical authority remains one of the lowest among the boards of major European firms (Linciano et al. 2017).[1]

## 5 | Research Methodology

### 5.1 | Sample Selection and Data Source

The research hypotheses were tested on a sample of Italian industrial companies listed on Euronext Milan between 2003 and 2017. The initial sample consisted of 2258 total observations. According to the previous literature, we excluded companies with missing data on R&D expenses (Dimitropoulos 2020), reducing the sample to 473 observations.

We constructed a unique hand-collected dataset containing information on women directors' demographic characteristics to investigate our research hypothesis. These data were manually gathered from individual firms' annual corporate governance reports, available on their official websites and the Italian Stock Exchange website. After excluding observations with missing women directors' data, the sample was reduced to 433 firm-year observations.

Next, we merged the R&D data and governance dataset with financial control variables obtained from Datastream, yielding 422 observations. All firm-level controls were lagged by 1 year to address potential simultaneity and mitigate endogeneity issues. As a result, the final sample comprised 388 firm-year observations from 63 unique firms.

The restricted number of observations is primarily because of the limited quantity of Italian-listed companies that invest in R&D (Miroshnychenko et al. 2020; Saggese et al. 2021).

### 5.2 | Variable Measurement

Our research framework hypothesised that the relationship between women's representation on boards and R&D investments exists or differs in strength or direction is conditional on women directors' HC, RC and SC attributes (Figure 1).

The dependent variable, *R&D investments*, was measured as the ratio of R&D expenditures to total assets (Bauweraerts et al. 2022). Following Miroshnychenko et al. (2020), given the low propensity of our sample companies to invest in R&D, the R&D investments variable was left censored at zero.

The presence of women directors on the board was captured using *women ratio*, calculated as the proportion of women directors to the total number of board members. As our sample did not include cases of boards with more women directors than male directors, this variable appeared to be an appropriate proxy to capture the level of the boards' gender diversity (Torchia et al. 2018).

To proxy women directors' HC, we employed the *foreign women* ratio, measured as the proportion of women directors with foreign nationality on the board (Nekhili and Gatfaoui 2013). In the literature, international experience was recognised as a key component of HC (Volonté and Gantenbein 2016). Board members with international experience possess valuable skills that enable companies to compete in new business areas or foreign markets (Martínez-García et al. 2022), providing boards with additional resources and diverse perspectives (Dobija et al. 2022).

To proxy women directors' (external) RC, we used the interlocked women ratio, calculated as the proportion of women directors on two or more boards (Wincent et al. 2010). This proxy aligned with the theoretical perspective that interlocked directors gain new knowledge, competencies and information through their roles on multiple boards, which can support a company in achieving its strategic goals (Fich and Shivdasani 2006).

To proxy women directors' (implicit) SC, we used the tenure women director's ratio, calculated as the average tenure of women directors. A longer tenure captured the director's experience and knowledge of the firm, improving their advisory capabilities and contributions to board capital (Bravo and Reguera-Alvarado 2017). In line with the literature on gender diversity and the board–innovation relationship (Almor et al. 2022; Bauweraerts et al. 2022; Saggese et al. 2021), we included several financial and governance proxies as control variables. ROA is a measure of profitability calculated as the ratio of operating income to total assets (Li et al. 2022). Firm size is measured as the natural logarithm of total assets (Miroshnychenko et al. 2020). Debt is calculated as the ratio of long-term debt to total assets (Sciascia et al. 2015). Cash holdings are the cash and cash equivalents to net assets (Cambrea et al. 2020). Sales growth was a proxy to identify the firm's growth opportunities, measured as the sales of the company in year $t$ minus sales in year $t-1$, divided by sales in year $t-1$

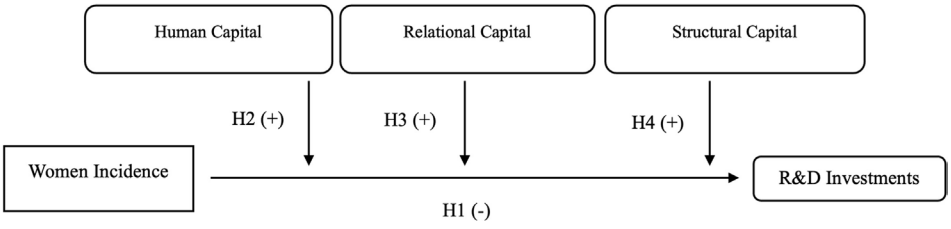


**FIGURE 1** | Graphically illustrates the research framework.

(Sarto et al. 2019). Cash flow is defined as cash flow divided by total assets (Miroshnychenko et al. 2020). Tangibility is computed by the ratio of fixed assets in year *t* to total assets in year *t*. Firm age is the number of firm years (Bauweraerts et al. 2022), which has been computed as the difference between the year of the observation and the company's founding year. We employed some board of directors' proxies as control variables, namely CEO duality, board size and independent directors. CEO duality is calculated as a dummy variable coded as 1 if the CEO also covers the position of the board chair and 0 otherwise (Dalziel et al. 2011). Board size is computed as the number of board members (Almor et al. 2022). Independent directors are the percentage of independent directors on the board (Almor et al. 2022). Finally, as previous literature has highlighted the primary importance of considering board human capital heterogeneity in the high-tech industry (Sarto et al. 2019), we computed a dummy variable equal to 1 if the company operates in a high-tech sector and 0 otherwise. High-tech firms were identified using the classification by Messeni Petruzzelli et al. (2022), which aligns with the Eurostat indicators on high-tech industry and knowledge.

### 5.3 | The Empirical Model

To empirically test our research hypotheses and examine the impact of women directors on R&D investments, we analysed the nature of our dependent variable and confirmed that the zeros represent true values. These zeros reflect the firm's deliberate choice not to engage in R&D activities, rather than being imputed for missing data. Therefore, the dependent variable (R&D investments) was left censored at zero, meaning it did not take negative values and included numerous observations with a value of 0.

Consistent with prior literature (Miroshnychenko et al. 2020), we adopted the Tobit estimator, the most suitable econometric approach for handling censored data (Amore and Murtinu 2021). We included industry dummy variables and year dummies in all regressions to account for heterogeneity across industrial sectors and time periods.

To test hypotheses H2–H4, which examine the relationship between women directors and R&D investment decisions as conditional on women directors' IC attributes, we introduced three different interacted terms in the regression analysis (Jollineau and Bowen 2023): women ratio × foreign women (HC), women ratio × interlocked women (RC) and women ratio × tenure women (SC).

## 6 | Results

### 6.1 | Descriptive Statistics

Table 1 presents the descriptive statistics for the key variables in our final sample and the correlation among the variables used in the econometric analysis.

On average, firms in our sample invested 2.5% of total assets in R&D, aligning closely with prior studies analysing R&D investments in Europe (Bauweraerts et al. 2022). Women directors constituted 11.4% of all board members, whereas foreign women directors accounted for < 1.0%. 3.9% of women directors held more than two board seats, and the average tenure for women was 5.28 years. The average board size in our sample ranged between 9 and 10 members.

The correlation analysis indicates no significant relationship between R&D investments and women directors. Additionally, inter-correlations among the independent variables are low, reducing the risk of collinearity and ensuring stable coefficients in the regression models.

### 6.2 | Key Results From Multiple Regression Analyses

Table 2 shows the main findings. Model 1 included only control variables and the women ratio proxy; Models 2–4 introduced interaction terms between the women ratio variable and the three women IC attributes: HC, RC and SC.

Model 1 estimated the impact of the percentage of women directors on R&D investments. The results revealed a negative and significant relationship between women directors and R&D investments ($\beta = -0.058$, $p < 0.01$). This finding suggested that a higher proportion of women directors on the board was associated with reduced R&D investments. This result aligned with Almor et al. (2022), who found that more gender-diverse boards were associated with lower investment in R&D projects.

Models 2–4 incorporated interaction terms between women ratio and the three dimensions of women directors' IC: foreign women (HC), interlocked women (RC) and tenure women (SC). All interaction term coefficients were positive and statistically significant, confirming the presence of a moderation effect. The positive coefficients, which contrasted with the negative direct relationship in Model 1, indicated that the relationship between women directors and R&D investments was conditional on the presence of IC-skilled women directors. This finding supported the hypothesis that IC attributes modified the strength and direction of the association (Jollineau and Bowen 2023).

Model 2 examined the moderating effect of foreign women directors, a proxy for HC. The interaction variable between the women ratio and foreign women directors was positive and statistically significant ($\beta = 1.303$, $p < 0.10$), supporting H2. The results indicated that the HC of women directors positively moderated the relationship between women directors and R&D investments, leading to an overall increase in R&D investments. Model 3 explored the role of interlocked women directors, a proxy for RC. The interaction term between the women ratio and interlocked women directors was positive and statistically significant ($\beta = 0.488$, $p < 0.05$), confirming H3. This finding suggested that women directors serving on multiple corporate boards enhanced corporate R&D investments. Model 4 focused on the role of tenured women directors, a proxy for SC. The interaction term between the women ratio and tenured women directors was positive and

**TABLE 1** | Correlation matrix and descriptive statistics.

| | Variable | Mean | SD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | R&D investments | 0.025 | 0.032 | 1 | | | | | | | |
| 2 | Women ratio | 0.114 | 0.119 | 0.0759 | 1 | | | | | | |
| 3 | Foreign women | 0.006 | 0.028 | 0.0193 | 0.291*** | 1 | | | | | |
| 4 | Interlocked women | 0.039 | 0.073 | −0.0838 | 0.636*** | 0.0159 | 1 | | | | |
| 5 | Tenure women | 5.281 | 7.065 | 0.126* | 0.459*** | 0.0613 | 0.238*** | 1 | | | |
| 6 | ROA | 0.031 | 0.095 | −0.221*** | −0.0860 | −0.0431 | 0.0389 | −0.114* | 1 | | |
| 7 | Firm size | 13.958 | 2.160 | −0.284*** | −0.0331 | −0.0349 | 0.123* | −0.163*** | 0.219*** | 1 | |
| 8 | Debt | 0.169 | 0.136 | −0.276*** | −0.127* | 0.0560 | −0.0176 | −0.161** | 0.0685 | 0.397*** | 1 |
| 9 | Cash holdings | 0.166 | 0.187 | 0.377*** | 0.181*** | 0.0225 | −0.0334 | 0.286*** | −0.0869 | −0.210*** | −0.300*** |
| 10 | Sales growth | 0.099 | 0.534 | 0.0422 | −0.0859 | −0.0163 | −0.0776 | −0.0506 | −0.0876 | −0.0432 | −0.00295 |
| 11 | Cash flow | 0.066 | 0.085 | −0.272*** | −0.118* | −0.0347 | 0.0388 | −0.204*** | 0.828*** | 0.258*** | 0.0788 |
| 12 | Tangibility | 0.221 | 0.174 | −0.331*** | −0.0945 | −0.0757 | −0.0121 | −0.240*** | 0.00576 | 0.409*** | 0.340*** |
| 13 | Firm age | 37.650 | 28.766 | 0.167*** | 0.114* | −0.0919 | 0.0901 | 0.0629 | 0.0112 | 0.323*** | 0.0770 |
| 14 | Board size | 9.940 | 3.009 | 0.0712 | 0.0181 | −0.111* | 0.0701 | −0.0236 | 0.0780 | 0.371*** | 0.220*** |
| 15 | CEO duality | 0.137 | 0.344 | −0.0549 | −0.0748 | −0.0874 | −0.0879 | 0.0924 | 0.0115 | −0.211*** | −0.157** |
| 16 | Independent directors | 0.428 | 0.179 | −0.110* | 0.0680 | 0.0412 | 0.136** | −0.372*** | 0.0336 | 0.502*** | 0.105* |
| 17 | High-tech industry | 0.106 | 0.308 | 0.109* | −0.0257 | 0.0490 | 0.0150 | −0.149** | −0.0191 | 0.174*** | −0.00883 |
| 18 | Industry diversity | 0.013 | 0.072 | −0.0587 | 0.609*** | 0.261*** | 0.335*** | 0.422*** | −0.129** | −0.0610 | −0.152** |

| | | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | R&D investments | | | | | | | | | | |
| 2 | Women ratio | | | | | | | | | | |
| 3 | Foreign women | | | | | | | | | | |
| 4 | Interlocked women | | | | | | | | | | |
| 5 | Tenure women | | | | | | | | | | |
| 6 | ROA | | | | | | | | | | |
| 7 | Firm size | | | | | | | | | | |

(Continues)

**TABLE 1** | (Continued)

| | | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | Debt | | | | | | | | | | |
| 9 | Cash holdings | 1 | | | | | | | | | |
| 10 | Sales growth | 0.0519 | 1 | | | | | | | | |
| 11 | Cash flow | −0.169*** | −0.0412 | 1 | | | | | | | |
| 12 | Tangibility | −0.274*** | −0.0376 | 0.134** | 1 | | | | | | |
| 13 | Firm age | −0.0580 | −0.108* | 0.0302 | −0.118* | 1 | | | | | |
| 14 | Board size | −0.0235 | −0.0159 | 0.0769 | 0.0104 | 0.442*** | 1 | | | | |
| 15 | CEO duality | 0.258*** | 0.0325 | −0.0619 | −0.219*** | −0.102* | −0.255*** | 1 | | | |
| 16 | Independent directors | −0.228*** | −0.103* | 0.110* | 0.270*** | 0.215*** | 0.00857 | −0.278*** | 1 | | |
| 17 | High-tech industry | −0.122* | −0.0418 | −0.00963 | −0.0350 | 0.147** | −0.0154 | −0.139** | 0.289*** | 1 | |
| 18 | Industry diversity | 0.184*** | −0.0358 | −0.158** | −0.0292 | −0.0310 | −0.0844 | −0.0222 | −0.119* | −0.105* | 1 |

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

statistically significant ($\beta = 0.650$, $p < 0.01$), partially supporting H4. This result demonstrated that the presence of experienced women directors, with a higher tenure, positively influenced R&D investments.

Moreover, the *F*-test for the joint significance of all three moderating variables shows they are jointly significant at the 0.01 level ($p$-value = 0.0005), firmly rejecting the null hypothesis of no association between them.[2] These results provide robust support for our research hypotheses.

The empirical results depicted in Models 2–4 of Table 2 provided evidence of how diversity among women directors in terms of HC, RC and SC influenced their ability to affect R&D investments. To better understand how women directors' IC moderated the relationship between women directors and R&D investments, we plotted the interaction effects reported in Models 2–4 of Table 2, as shown in Figures 2–4.

### 6.3 | Additional Analyses

In this sub-section, we present additional analyses of the main results in Table 2. First, we assessed alternative proxies for the women directors' IC components. A further proxy for women's HC was represented by the executive women directors' ratio, measured as the proportion of women directors holding executive roles on corporate boards. In our context, women directors' attributes often remain latent when they lack the power deriving from formal positions and hierarchical authority to fully express their potential within boards (Triana et al. 2014).

As an alternative proxy for women directors' RC, we employed the local women directors' ratio, calculated as the proportion of women directors residing in the same province as the corporate headquarters. Directors living close to the company were more likely to develop permanent trading relationships and networks, which could benefit the firm (Firoozi and Keddie 2022). Additionally, local women directors had easier access to information and were better positioned to build networks with local stakeholders, facilitating preferential access to critical resources.

Finally, as a further proxy for women directors' SC, we used the experienced women ratio, defined as the proportion of women directors who held board positions before 2011, the year prior to the introduction of Italy's gender quota law. This measure captured the years of experience women directors possessed within the same company (Baghdadi et al. 2023).

The findings, illustrated in Table 3, revealed consistent positive effects of all three women directors' IC components on R&D investments.

Second, we followed the approaches of Miroshnychenko et al. (2020) and Oh and Barker (2018) to address potential sample selection biases. Specifically, as a first step, we ran a Probit regression with a firm's propensity to invest in R&D activities as the dependent variable (equal to 1 if a firm reported R&D expenses and 0 otherwise). The independent variables included

**TABLE 2** | Relationship between women directors' IC and R&D investments.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| **Variables** | **R&D** | **R&D** | **R&D** | **R&D** |
| Women ratio | −0.058*** | −0.052*** | −0.055*** | −0.083*** |
| | (0.001) | (0.007) | (0.006) | (0.000) |
| Foreign women (HC) | | −0.393* | | |
| | | (0.069) | | |
| Women ratio × Foreign women (HC) | | 1.303* | | |
| | | (0.083) | | |
| Interlocked women (RC) | | | −0.149** | |
| | | | (0.012) | |
| Women ratio × Interlocked women (RC) | | | 0.488** | |
| | | | (0.022) | |
| Tenure women (SC) | | | | −0.009*** |
| | | | | (0.001) |
| Women ratio × Tenure women (SC) | | | | 0.065*** |
| | | | | (0.001) |
| ROA | 0.007 | 0.013 | 0.009 | 0.010 |
| | (0.736) | (0.524) | (0.643) | (0.627) |
| Firm size | −0.002 | −0.002 | −0.001 | −0.002** |
| | (0.141) | (0.118) | (0.271) | (0.038) |
| Debt | −0.045*** | −0.037*** | −0.044*** | −0.039*** |
| | (0.001) | (0.009) | (0.001) | (0.003) |
| Cash holdings | 0.045*** | 0.044*** | 0.044*** | 0.045*** |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Sales growth | −0.001 | −0.001 | −0.001 | −0.002 |
| | (0.728) | (0.723) | (0.762) | (0.549) |
| Cash flow | −0.059** | −0.064** | −0.065** | −0.063** |
| | (0.027) | (0.017) | (0.015) | (0.016) |
| Tangibility | −0.024** | −0.026** | −0.025** | −0.030** |
| | (0.042) | (0.024) | (0.031) | (0.011) |
| Firm age | 0.000*** | 0.000*** | 0.000*** | 0.000*** |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Board size | 0.001 | 0.000 | 0.001 | 0.001** |
| | (0.343) | (0.469) | (0.283) | (0.038) |
| CEO duality | −0.022*** | −0.023*** | −0.023*** | −0.022*** |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Independent directors | −0.021** | −0.022** | −0.025** | −0.020* |
| | (0.035) | (0.029) | (0.013) | (0.058) |

(Continues)

**TABLE 2** | (Continued)

| Variables | (1) R&D | (2) R&D | (3) R&D | (4) R&D |
|---|---|---|---|---|
| High-tech industry | 0.013*** | 0.012** | 0.011** | 0.012** |
| | (0.008) | (0.014) | (0.021) | (0.014) |
| Constant | 0.047*** | 0.050*** | 0.047** | 0.056*** |
| | (0.009) | (0.006) | (0.015) | (0.002) |
| Industry dummies | Yes | Yes | Yes | Yes |
| Year dummies | Yes | Yes | Yes | Yes |
| *R*-squared | 0.239 | 0.242 | 0.251 | 0.250 |
| Observations | 388 | 388 | 388 | 388 |

*Note: p* values in parentheses.
*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

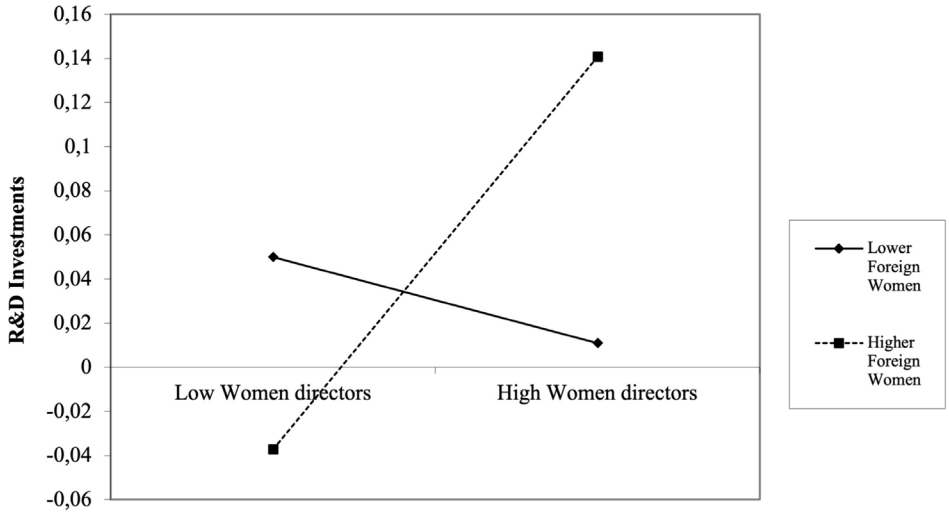


**FIGURE 2** | Interaction effect of women directors' human capital on the relationship between women directors and firms' R&D investments.

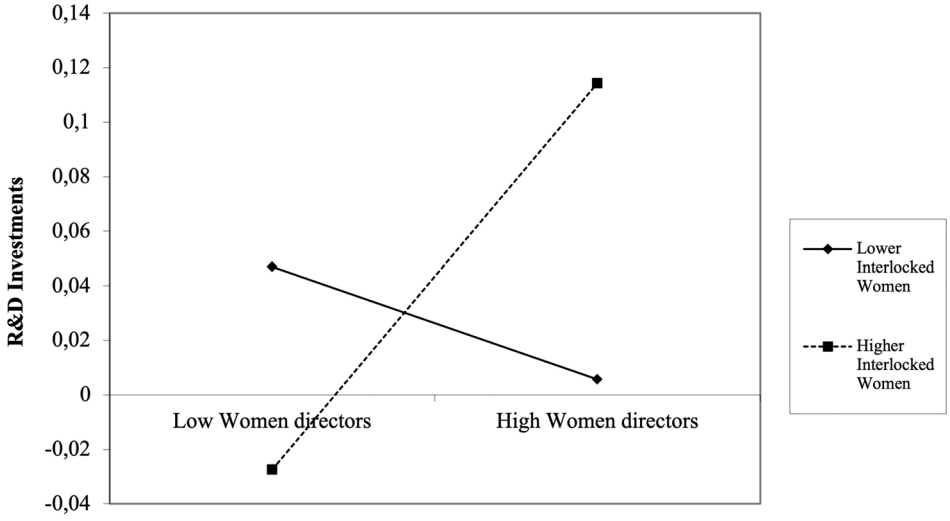


**FIGURE 3** | Interaction effect of women directors' relational capital on the relationship between women directors and firms' R&D investments.


**FIGURE 4** | Interaction effect of women directors' structural capital on the relationship between women directors and firms' R&D investments.

our women directors' proxies and all the control variables used in the econometric model.

We generated the inverse Mills ratio (IMR) from this first-stage procedure and included it as an additional explanatory variable in the second-stage estimation models. Including the IMR allowed us to control for potential sample selection bias from non-random sampling (Heckman 1979). The results presented in Table 4 aligned with those in Table 2, enabling us to conclude that our estimation was not biased because of selection issues.

Third, we address potential endogeneity issues by employing an instrumental variable approach. Specifically, we used a two-step instrumental variable Tobit model (Miroshnychenko et al. 2020). Following previous literature on gender variables (Liu et al. 2014), we selected the average level of board diversity within the industry (*Industry diversity*) as the instrumental variable. This variable was calculated as the percentage of all women directors in the industry for each investigated year, excluding the board members of the focal firm (Liu et al. 2014). The selected instrumental variable satisfies the relevance criterion, demonstrating strong predictive power for the potentially endogenous variable, as evidenced by a highly significant $F$-statistic ($F = 56.07$, $p < 0.001$). It is also theoretically exogenous, implying no correlation with the error term in the main outcome equation. Prior studies on gender diversity and firm performance have supported the use of peer firm values as valid instruments for the variables of interest (Liu et al. 2014).

Model 1 in Table 5 reports the first-stage regression results, where the dependent variable was the ratio of women directors. Consistent with our expectations, the identified instrument was positively and significantly correlated with the proportion of women directors ($\beta = 1.005$, $p < 0.01$). Model 2 in Table 5 presents the results of the second-stage regression, where the dependent variable was R&D investments. The results confirmed the main findings in Model 1 of Table 2, suggesting that endogeneity did not influence our primary empirical conclusions.

Finally, to assess the reliability of our empirical findings, we conducted several additional analyses. We re-estimated Models 1–4 from Table 2 using two alternative R&D measures: research and development on sales (RDS) and the logarithm of research and development on total assets (ln R&D). RDS was calculated as the ratio of research and development expenditures to total sales, consistent with prior empirical studies (Saggese et al. 2021). ln R&D was calculated as log(1 + R&D to total assets ratio), following Miroshnychenko et al. (2020). The logarithm transformation was applied to reduce the substantial skewness in the R&D investments variable, ensuring a more normal distribution.

Additionally, to verify that our results were not influenced by the methodology applied, we repeated the baseline regressions using Ordinary Least Squares (Almor et al. 2022), incorporating industry and year dummy variables to account for industry and temporal effects (Wooldridge 2016).

We also employed the structural equation modelling (SEM) methodology as an alternative econometric technique. This approach accounted for the interconnectedness among the three IC dimensions. The empirical findings from the SEM were consistent with those in Table 2.

The additional analyses, which are not shown in the article due to space limitations, provide substantial confirmation of our primary results. This consistency emphasises the robustness and reliability of our empirical findings. Robustness checks are available upon request.

## 7 | Conclusions

The literature extensively studies the relationship between women directors and R&D investment decisions. However, we argue that this relationship is more complex than previously

**TABLE 3** | Relationship between alternative proxies of women directors' IC and R&D investments.

| Variables | (1) R&D | (2) R&D | (3) R&D |
|---|---|---|---|
| Women ratio | −0.058*** | −0.067*** | −0.039 |
| | (0.002) | (0.000) | (0.133) |
| Executive women (HC) | −0.166** | | |
| | (0.027) | | |
| Women ratio × Executive women (HC) | 0.765** | | |
| | (0.019) | | |
| Local women (RC) | | −0.082 | |
| | | (0.183) | |
| Women ratio × Local women (RC) | | 0.452* | |
| | | (0.096) | |
| Experienced women (SC) | | | −0.146*** |
| | | | (0.005) |
| Women ratio × Experienced women (SC) | | | 0.500** |
| | | | (0.012) |
| ROA | 0.008 | 0.014 | 0.010 |
| | (0.678) | (0.467) | (0.617) |
| Firm size | −0.001 | −0.002 | −0.001 |
| | (0.175) | (0.121) | (0.176) |
| Debt | −0.049*** | −0.043*** | −0.044*** |
| | (0.000) | (0.001) | (0.001) |
| Cash holdings | 0.047*** | 0.058*** | 0.049*** |
| | (0.000) | (0.000) | (0.000) |
| Sales growth | −0.001 | −0.000 | −0.002 |
| | (0.718) | (0.888) | (0.511) |
| Cash flow | −0.062** | −0.065** | −0.061** |
| | (0.020) | (0.012) | (0.021) |
| Tangibility | −0.023** | −0.023** | −0.025** |
| | (0.046) | (0.047) | (0.028) |
| Firm age | 0.000*** | 0.000*** | 0.000*** |
| | (0.000) | (0.000) | (0.000) |
| Board size | 0.001 | 0.001 | 0.001 |
| | (0.399) | (0.116) | (0.222) |
| CEO duality | −0.020*** | −0.021*** | −0.021*** |
| | (0.000) | (0.000) | (0.000) |
| Independent directors | −0.020* | −0.017 | −0.027*** |
| | (0.051) | (0.101) | (0.008) |
| High-tech industry | 0.013*** | 0.012*** | 0.012** |
| | (0.010) | (0.010) | (0.013) |
| Constant | 0.046** | 0.039** | 0.048*** |
| | (0.011) | (0.029) | (0.008) |
| Industry dummies | Yes | Yes | Yes |
| Year dummies | Yes | Yes | Yes |
| *R*-squared | 0.244 | 0.253 | 0.246 |
| Observations | 388 | 388 | 388 |

*Note: p* values in parentheses.
*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

assumed. Critical conditions must be considered to comprehend the dynamics of this association fully.

Although the predominant theoretical approach often assumes a positive contribution of women directors on R&D investment decisions, several studies highlighted a negative association between these two variables. The research framework used to investigate this relationship should account for the conditions influencing its existence, strength and direction. These factors are the IC attributes of IC-skilled women.

We thus investigated the association between women directors and R&D investment decisions, conditional on women directors' IC attributes, utilising a sample of listed Italian companies with R&D investments reported in their balance sheets for 2003–2017. Our findings supported our research hypotheses, confirming that foreign (HC), interlocked (RC) and tenured (SC) women directors positively affect the firms' R&D expenses.

The results suggest that a firm's propensity to invest in R&D is not driven by gender alone but by the specific attributes of the women sitting on the board. Women directors with foreign experience possess valuable skills and knowledge that enable their companies to compete in new business areas or foreign markets. Women with prestige power, derived from their reputation, networks and influence gained through serving on multiple boards, as well as women with expert power, developed through extensive board experience, contribute significantly to a firm's innovation activities. Therefore, the typology of women directors—rather than their mere presence—is crucial in fostering R&D investments.

The results are robust across various specifications, including alternative proxies for the independent variables (IC measures) and dependent variables (measured as R&D expense on sales and the natural logarithm of R&D investments) and alternative econometric approaches.

**TABLE 4** | Relationship between women directors' IC and R&D Investments using different IC proxies.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| **Variables** | **R&D** | **R&D** | **R&D** | **R&D** |
| Women ratio | −0.090*** | −0.086*** | −0.079*** | −0.105*** |
| | (0.001) | (0.002) | (0.006) | (0.000) |
| Foreign women (HC) | | −0.417* | | |
| | | (0.053) | | |
| Women ratio × Foreign women (HC) | | 1.378* | | |
| | | (0.066) | | |
| Interlocked women (RC) | | | −0.143** | |
| | | | (0.016) | |
| Women ratio × Interlocked women (RC) | | | 0.472** | |
| | | | (0.027) | |
| Tenure women (SC) | | | | −0.009*** |
| | | | | (0.002) |
| Women ratio × Tenure women (SC) | | | | 0.063*** |
| | | | | (0.001) |
| ROA | −0.032 | −0.029 | −0.019 | −0.019 |
| | (0.303) | (0.351) | (0.540) | (0.545) |
| Firm size | 0.006 | 0.006 | 0.004 | 0.003 |
| | (0.223) | (0.181) | (0.381) | (0.517) |
| Debt | −0.059*** | −0.052*** | −0.054*** | −0.049*** |
| | (0.000) | (0.002) | (0.001) | (0.002) |
| Cash holdings | 0.041*** | 0.040*** | 0.041*** | 0.042*** |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Sales growth | −0.002 | −0.002 | −0.002 | −0.003 |
| | (0.500) | (0.477) | (0.588) | (0.411) |
| Cash flow | 0.014 | 0.016 | −0.012 | −0.010 |
| | (0.785) | (0.768) | (0.827) | (0.849) |
| Tangibility | −0.060** | −0.066*** | −0.051** | −0.056** |
| | (0.019) | (0.010) | (0.043) | (0.026) |
| Firm age | 0.000*** | 0.000*** | 0.000*** | 0.000*** |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Board size | 0.000 | 0.000 | 0.001 | 0.001* |
| | (0.402) | (0.557) | (0.325) | (0.052) |
| CEO duality | 0.003 | 0.005 | −0.004 | −0.003 |
| | (0.841) | (0.779) | (0.791) | (0.829) |
| Independent directors | −0.017* | −0.018* | −0.022** | −0.017 |
| | (0.087) | (0.081) | (0.033) | (0.110) |

(Continues)

**TABLE 4** | (Continued)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| **Variables** | **R&D** | **R&D** | **R&D** | **R&D** |
| High-tech industry | 0.038** | 0.039** | 0.029* | 0.030* |
| | (0.020) | (0.016) | (0.070) | (0.063) |
| IMR | 0.060 | 0.065* | 0.044 | 0.043 |
| | (0.108) | (0.080) | (0.242) | (0.240) |
| Constant | −0.100 | −0.110 | −0.060 | −0.051 |
| | (0.285) | (0.237) | (0.518) | (0.581) |
| Industry dummies | Yes | Yes | Yes | Yes |
| Year dummies | Yes | Yes | Yes | Yes |
| *R*-squared | 0.241 | 0.245 | 0.252 | 0.251 |
| Observations | 388 | 388 | 388 | 388 |

*Note: p* values in parentheses.
*$p<0.1$, **$p<0.05$, ***$p<0.01$.

The study, based on these findings, provides wide-ranging academic, managerial and policy implications. It also highlights future research directions to deepen understanding the relationship between women directors and R&D investments.

## 7.1 | Implications

The present study offers several theoretical, managerial and policy implications. As regards the theoretical implications, this study provides a foundation for future research on the impact of IC-skilled women directors on R&D investments, encouraging exploration through new theoretical perspectives, measures and contexts. Kurzhals et al.'s (2020) systematic literature review highlighted three critical needs in this area: (1) Expanding theoretical perspectives beyond the agency theory and upper echelons theory; (2) Utilising alternative measures to capture board members' relevant attributes and to address the innovation-related impacts of board subgroups; (3) Investigating contexts outside the United States.

Our study addresses these points by examining the influence of a specific board subgroup (women directors) through a novel theoretical approach (the ICBV) and focusing on the Italian context.

Moreover, this study is the first to investigate how the IC attributes of women directors influence the relationship between their presence on boards and decisions regarding R&D investments. Although previous research has explored aspects of women directors' information-related diversity—such as educational qualifications (Midavaine et al. 2016) and expert power (Saggese et al. 2021)—and identified positive impacts on R&D expenditures, no prior work has comprehensively addressed the IC dimensions of women directors. By adopting a holistic perspective that considers all IC components—human, structural and relational—this study contributes to the growing importance of understanding IC in the R&D management literature (Greco et al. 2024).

From a managerial standpoint, our study highlights the importance of recognising the positive implications of IC-skilled women directors for decision-making effectiveness. Board nomination committees should prioritise appointing women directors who possess diverse human, structural and relation capital attributes, as this diversity provides critical resources for fostering firm innovation.

This implication is particularly significant in light of the updated gender quota law in Italy, which raised the average percentage of women directors on boards to 40% in 2022. The increased mandated representation may lead to challenges in identifying a sufficient number of women director candidates with the necessary knowledge, skills and experience to complement quota regulations. Appointing women directors who lack the IC to actively contribute to board discussions, communicate alternative perspectives or challenge peers' viewpoints may fail to yield favourable results for firms.

The findings are accentuated by the characteristics of Italy's traditional board model, which integrates executive and independent directors, facilitating interaction and information exchange between them. This model 'accommodates the inclusion of the board's knowledge resources into strategy-making' (Heyden et al. 2015, 154) and is particularly conducive to leveraging the heterogeneity of women directors' IC. By contrast, in a two-tier model, where executive and supervisory boards are structurally separated, such interactions would not occur. This distinction is especially relevant in our context, as most women directors in Italy are appointed as independent directors (Cambrea et al. 2020). In a two-tier system, these directors would be relegated to a supervisory board composed exclusively of non-executives (Hopt and Leyens 2004), limiting their ability to contribute to strategy-making processes.

From a policy standpoint, our findings emphasise the importance of creating a board environment that encourages the appointment of IC-skilled women capable of driving firm innovation. This study

**TABLE 5** | 2SLS methodology.

| | (1) | (2) |
|---|---|---|
| | First stage | Second stage |
| Variables | % Women directors | R&D investments |
| Industry diversity | 1.005*** | |
| | (0.000) | |
| Women ratio | | −0.061*** |
| | | (0.001) |
| ROA | −0.046 | 0.004 |
| | (0.223) | (0.841) |
| Firm size | −0.001 | −0.002 |
| | (0.681) | (0.158) |
| Debt | 0.028 | −0.045*** |
| | (0.237) | (0.001) |
| Cash holdings | 0.017 | 0.046*** |
| | (0.203) | (0.000) |
| Sales growth | −0.004 | −0.001 |
| | (0.538) | (0.774) |
| Cash flow | 0.062 | −0.056** |
| | (0.231) | (0.038) |
| Tangibility | −0.019 | −0.024** |
| | (0.395) | (0.037) |
| Firm age | −0.000 | 0.000*** |
| | (0.806) | (0.000) |
| Board size | 0.000 | 0.001 |
| | (0.741) | (0.324) |
| CEO duality | 0.010 | −0.022*** |
| | (0.214) | (0.000) |
| Independent directors ratio | 0.033* | −0.019* |
| | (0.084) | (0.061) |
| High-tech industry | −0.005 | 0.012** |
| | (0.568) | (0.012) |
| Constant | 0.153*** | 0.055*** |
| | (0.000) | (0.002) |
| Industry effects | Yes | Yes |
| Year dummies | Yes | Yes |
| Observations | 388 | 388 |

*Note: p* values in parentheses.
*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

suggests that regulators should focus on 'hard' governance issues, such as CEO duality and directors' independence, and address 'soft' aspects, such as IC requirements for board membership (e.g., experience and expertise). Furthermore, given our results, regulators could recommend a more significant presence of executive (IC-skilled) women on boards.

## 7.2 | Limitations and Future Research Directions

This study has several limitations, many of which present opportunities for future research.

First, our sample consists exclusively of Italian-listed companies that invested in R&D. Consequently, the conclusions drawn from this study may not be directly applicable to countries using a one-tier board system, such as the USA, the UK, and Australia. Future research could perform cross-country analyses to investigate how women directors contribute to innovation across different political and institutional contexts and how adopting board models influences corporate innovation (Heyden et al. 2015).

Second, our analysis considers Italian-listed companies across all sectors. Future studies could investigate how specific contexts—high-tech versus non-high-tech, family versus non-family, large versus SMEs, mature versus growing or public versus private—moderate the relationship between women directors and R&D investments.

Third, alternative measures of innovation inputs and outputs could be explored. For example, researchers could use metrics such as the number of employees allocated to R&D activities (Brinkerink and Rondi 2021), innovation outcomes like patents or examine different types of innovation, such as radical versus incremental innovation or exploration versus exploitation strategies (Ferrigno et al. 2023).

Fourth, future research could delve deeper into analysing individual IC components. Regarding HC, further studies might explore alternative measures of this often latent variable, such as cognitive differences captured through interviews. For SC, researchers could distinguish between board expertise and experience specifically related to innovation or industry expertise (Sarto and Saggese 2022). For RC, future research could examine internal RC to explore whether internal board members' connections intensify the effect of board capital on R&D (Pérez-Calero et al. 2016; Wang 2022). Moreover, scholars might consider the impact of women directors' provenance (e.g., business vs. NGOs) on R&D investments (Kim and Starks 2016).

Our research considered these factors by evaluating the robustness of our results using alternative IC women directors' attributes. However, as our analysis treated HC, RC and SC separately, future research could examine their interactions to determine whether these dimensions complement one another, investigating their simultaneous effect on R&D investments.

Finally, we did not account for the potential influence of the top management team (TMT). Further research should explore how

the TMT affects the relationship between women directors and R&D investments. Scholars should also respond to the call by Huynh et al. (2022) to examine how the HC of the board members, through monitoring and advice-giving roles, influences the strategic changes enacted by the TMT. Moreover, further analyses could assess the potential non-linear effects of women directors on R&D investment decisions.

### Author Contributions

The authors contributed equally to this research.


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### Ethics Statement

The authors have nothing to report.

### Conflicts of Interest

The authors declare no conflicts of interest.

### Data Availability Statement

The authors do not have permission to share data.

### Endnotes

[1] It is worth noting that the dominant corporate governance system in Italy is the 'traditional system' that has historically characterised this country's legal system (Bellavite Pellegrini and Sironi 2017). In the traditional system, the board of directors, accompanied by an external audit committee with monitoring functions, is a unified body consisting of executive directors, who are also company managers, and non-executive directors, who are not. Non-executive directors is necessary to ensure adequate management supervision, as executive directors may be in a conflict of interest. The effectiveness of the supervision is mainly ensured by the presence of independent directors among the non-executive directors. Although from 1 January 2004, following the adoption of the 2003 Italian Corporate Law Reform, Italian companies have been allowed to abandon the traditional system adopting alternatively a one-tier or two-tier governance model, a vast majority of Italian-listed companies (more than 90%) opted to maintain the traditional system (Linciano et al. 2017).

[2] The empirical findings are identical when simultaneously considering all three moderating variables in the same regression.

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