

NETWORK STRUCTURE ENTROPY, INNOVATION, AND CORPORATE SOCIAL RESPONSIBILITY: EVIDENCE FROM INTERLOCKING DIRECTOR NETWORKS IN CHINA

Xiaoli Tang^{*}, Serxho Preka^{**}, Huizhe Zhang^{*}

^{*} School of Economics and Management, Northwest University, Xi'an, China

^{**} Corresponding author, School of Economics and Management, Northwest University, Xi'an, China
Contact details: School of Economics and Management, Northwest University, 710069 Xi'an, China



Abstract

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Corporate social responsibility (CSR) has become a central concern in corporate governance research; however, how firms' embeddedness in interlocking directorate networks influences CSR outcomes, and the internal mechanisms through which this influence operates, remain insufficiently understood. This paper employs social network analysis to construct company-level network structure entropy, measuring the embeddedness of firms within interlocking director networks (Freeman, 1979). Using panel data on Chinese A-share listed firms from 2015 to 2020, we examine the relationship between network embeddedness, innovation, executive tenure structure, and CSR performance. Our findings reveal that firms in advantageous network positions tend to demonstrate higher CSR engagement. Innovation acts as a crucial mediator, amplifying the positive impact of these networks on CSR. Specifically, firms with a culture of innovation leverage their network positions to drive CSR initiatives more effectively. Additionally, staggered chief executive officer (CEO) and chief financial officer (CFO) tenures further enhance the network-CSR relationship, particularly when CEO power is lower, consistent with insights from upper echelons theory (Hambrick & Mason, 1984). These insights highlight the importance of fostering innovation and strategic network positions for advancing CSR objectives in organizational governance.

Keywords: Corporate Social Responsibility, Interlocking Director Networks, Network Structure Entropy, Innovation, CEO Power, Executive Tenure

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1. INTRODUCTION

In the complex world of corporate governance, the deliberate embrace of corporate social

responsibility (CSR) is recognized as a crucial intellectual concept and a long-lasting management strategy. Understanding the intricate aspects of CSR is quite important, as businesses are increasingly

prioritizing sustainable development over mere compliance with a checklist. Scholars, such as Carroll (1991), have shed light on the many facets of CSR, highlighting its significance in determining the character of a company and assuring its continued success over the long term. Recent discussions have focused on how enhancing CSR could potentially result in the generation of value that is both considerable and mutually beneficial (Porter & Kramer, 2011). However, businesses often find it necessary to allocate a substantial amount of resources to implement CSR. It is important to consider other important areas, such as innovation, which may be affected by this potential diversion of focus (Barnett, 2007). This holds particularly true for businesses operating in industries with fierce competition. These tensions highlight the need to understand not only whether firms engage in CSR, but also how corporate governance structures shape the mechanisms through which CSR is strategically pursued.

Governance models are the foundation upon which corporate decision-making is built. Efficient coordination of board directives and active participation of senior management are crucial for the success of corporate decision-making (Pugliese et al., 2009; Pangestuti et al., 2025; Blomson, 2023). Examining these dynamics from a network perspective allows for a deeper understanding of the interconnected nature of director relationships. As Davis (1991) suggests, director networks can shape corporate strategies by facilitating information flows and resource access, while also introducing risks related to homophily, entrenchment, and weakened monitoring. Accordingly, the influence of interlocking director networks on CSR should not be viewed as uniformly positive, but as conditional on how network-derived resources are processed and governed. The responsibilities of chief executive officers (CEOs) and chief financial officers (CFOs) in this context highlight the crucial importance of executive decision-making for CSR outcomes (García-Sánchez & Martínez-Ferrero, 2019). These executives' strategic orientations are shaped by their tenure and accumulated experience, which influence how external information and opportunities are interpreted (Hambrick & Mason, 1984). This study, therefore, focuses on executive tenure as a key boundary condition that determines whether network advantages are translated into substantive CSR outcomes.

When it comes to governance structures and CSR performance, innovation represents a critical mechanism linking strategic intent to concrete action. According to Crossan and Apaydin (2010), although the relationship between innovation and CSR has attracted growing attention, the underlying governance mechanisms remain underexplored. Innovation is particularly relevant in this context because it operationalizes how externally sourced knowledge and resources, such as those embedded in director networks, are converted into new products, processes, and organizational practices that directly address social and environmental challenges. In contrast to legitimacy or stakeholder pressure, innovation captures firms' internal capacity to transform governance inputs into tangible CSR outcomes. Consequently, innovation not only enhances CSR engagement but also

reshapes how governance structures function in promoting responsible business behavior.

Through the incorporation of the concept of network structure entropy, this research contributes to the theoretical framework by offering a more nuanced characterization of firms' positions within interlocking director networks. In this framework, social network theory primarily explains how embedded network positions generate access to information, resources, and legitimacy; agency theory highlights the competing risk that interlocks may weaken monitoring and facilitate entrenchment; and upper echelons theory explains how executives' tenure structures and power shape whether network-derived inputs are converted into strategic action. By integrating social network theory, agency theory, and upper echelons theory, the study conceptualizes director networks as governance structures with competing pathways: value creation through resource access and learning, and value erosion through entrenchment and coordination failures. Furthermore, by examining the roles of CEO power and staggered executive tenures, we provide new insights into how leadership structures shape the translation of innovation into CSR, particularly within the relational and institutional context of China. Although the empirical setting is China, the proposed mechanisms are grounded in general governance and information-processing logic and therefore speak to broader debates on how networks and leadership structures shape CSR outcomes. Accordingly, this study does not assume that interlocking director networks are inherently beneficial. Rather, it theorizes that positive CSR outcomes emerge only when network-derived resources are effectively governed and converted into organizational capabilities, a process conditioned by innovation and executive governance.

Prior research suggests that interlocking director networks are associated with CSR outcomes (Amin et al., 2020; Bose et al., 2022); however, we still lack a clear understanding of when and how network embeddedness translates into substantive CSR performance. This study advances the literature in three ways. First, rather than treating interlocks as a binary condition or relying solely on conventional centrality measures, we introduce network structure entropy to capture the configuration and diversity of firms' embedded positions within interlocking director networks. Second, we theorize and test innovation as a conversion mechanism, explaining how network-derived resources and knowledge are transformed into actionable capabilities that support CSR initiatives. Third, we show that this mechanism is conditional on executive governance by examining how staggered CEO-CFO tenure (and CEO power) shapes the effectiveness with which innovation is generated and subsequently mobilized for CSR. In doing so, the paper clarifies the pathway and boundary conditions through which interlocking director networks shape CSR.

The structure of this paper is as follows. Section 2 reviews the literature on interlocking director networks, corporate innovation, CSR outcomes, and executive governance characteristics, and then identifies the key research gaps that motivate the hypotheses. Section 3 presents the research methodology, including sample

selection, data sources, variable construction (with network structure entropy as the main measure of network embeddedness), and the empirical models used to test the proposed relationships. Section 4 reports the main results, including descriptive statistics, baseline regression estimates, mediation analysis for innovation, moderation tests for staggered CEO-CFO tenure and CEO power, and a series of robustness checks. Section 5 discusses the findings and their theoretical and practical implications within the corporate governance and conclusions, and concludes the research by summarizing the main contributions, acknowledging limitations, and suggesting directions for future research.

2. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

2.1. Interlocking director networks and corporate social responsibility

Interlocking director networks constitute a core structural feature of modern corporate governance and have important implications for CSR. Social network theory suggests that firms embedded in interlocking networks gain access to valuable resources, information, and legitimacy, which can enhance strategic decision-making and stakeholder-oriented outcomes (Freeman, 1979).

Through repeated interactions and shared board memberships, interlocking directorates facilitate coordination, information exchange, and reputational monitoring, thereby creating conditions conducive to stronger CSR engagement (Liang et al., 2022).

Empirical studies support this resource-based view. Oh et al. (2004) show that interlocking networks enable firms to access critical knowledge and capabilities that would otherwise be difficult to obtain, expanding strategic options and improving CSR performance. Similarly, reputational dynamics within director networks incentivize firms to exceed minimum CSR standards in order to maintain legitimacy and social standing (Frooman, 1999; Galaskiewicz & Wasserman, 1989). From this perspective, interlocking director networks act as conduits through which CSR-related norms and practices diffuse across firms (Liang et al., 2022).

However, social network theory also predicts potential downsides. Dense interlocks may foster homophily, reduce independent oversight, and increase the risk of collusion or managerial entrenchment (Palmer & Barber, 2001; Jensen & Meckling, 1976; Bravo-Urquiza & Reguera-Alvarado, 2025). Agency theory emphasizes that these governance risks can weaken monitoring effectiveness and distort strategic priorities. Accordingly, the influence of interlocking director networks on CSR should not be assumed to be uniformly positive; rather, the net effect depends on whether network-derived resources are disciplined and transformed into value-creating activities (Chuluun et al., 2014; Mizruchi, 1996). This duality motivates the need to identify mechanisms and conditions under which network embeddedness translates into substantive CSR outcomes.

2.2. Director networks and corporate innovation

Corporate innovation represents a critical pathway through which the advantages of interlocking director networks can be transformed into organizational outcomes. Innovation research highlights that networks facilitate the recombination of heterogeneous knowledge and accelerate the diffusion of novel ideas (Powell & Grodal, 2006; Yu et al., 2023). From this perspective, director interlocks serve as channels for strategic learning and experimentation, enabling firms to access diverse technological and managerial insights (Yu et al., 2023). This connectivity fosters a more dynamic business environment, encouraging the generation of new ideas and ensuring that businesses can effectively meet both customer needs and social standards (Aksoy, 2023; Napoli, 2023).

Structural network theories further strengthen this argument. Burt (2004) shows that firms occupying positions rich in structural holes benefit from information and control advantages that foster innovation. Although this work does not explicitly focus on CSR, the innovative outputs generated through such positions provide firms with tools to address complex social and environmental challenges. Rosenkopf and Padula (2008) similarly demonstrate that firms connected via director networks are more willing to engage in exploratory innovation, increasing their capacity to pursue non-routine strategic initiatives.

Importantly, innovation offers a theoretically grounded mechanism linking network embeddedness to CSR. Unlike legitimacy or stakeholder pressure, which operate primarily through external expectations, innovation captures firms' internal capacity to convert network-derived resources into new products, processes, and organizational practices that directly support CSR objectives (Zeng et al. 2025; Liu & Xu, 2025). As Ahuja (2000) notes, networks characterized by weak ties and structural diversity are particularly conducive to breakthrough innovation, suggesting that innovation is a proximate mechanism through which interlocking director networks can influence CSR performance.

2.3. Executive tenure, CEO power, and corporate social responsibility

Whether innovation generated through director networks ultimately enhances CSR depends on executive leadership. Upper echelons theory posits that executives' experiences, power, and tenure shape how information is interpreted and how strategic choices are implemented (Hambrick & Mason, 1984; Liu, 2023). In this context, CEO and CFO tenure structures play a crucial role in determining whether innovative capabilities are mobilized for CSR rather than diverted toward short-term or self-serving objectives.

Executive tenure influences decision-making quality, risk preferences, and susceptibility to entrenchment. Prior studies show that prolonged or overlapping tenures may reduce cognitive diversity and increase the likelihood of collusion, whereas staggered tenures (a form of temporal diversity within the top management team) can introduce complementary perspectives and governance discipline (Boeker, 1997; Dong et al., 2022; Ratna & Junaidi, 2024).

From an information-processing perspective, tenure heterogeneity can mitigate groupthink and improve evaluative scrutiny, particularly when firms face complex trade-offs between innovation investment and CSR commitments.

2.4. Research gaps

To deepen this review and to ensure that our hypotheses rest on a solid and up-to-date scholarly foundation, seven recent high-quality studies published between 2020 and 2025 were deliberately selected for further examination. These papers were chosen because each addresses a core component of the network-innovation-CSR relationship while simultaneously revealing important unresolved issues. For instance, Nandy et al. (2020) and Zhao and Chan (2023) both demonstrate that interlocking director networks meaningfully shape CSR outcomes, yet neither ventures into the innovation mechanisms that may channel these effects. Al-Maliki et al. (2023) and Yakubu et al. (2023) extend the discussion by showing how interlocked boards transmit CSR strategies across firms, though still without explaining how innovation enters this process. Other studies, such as Xu et al. (2025), highlight the role of board networks in driving technological innovation, illustrating only one side of the relationship and leaving open how such innovation subsequently influences CSR. Meanwhile, Al-Shammari et al. (2023) provide strong empirical evidence that CEO tenure differentially shapes firms' internal and external CSR engagement, underscoring executive tenure as a meaningful governance characteristic. However, this work does not examine how executive tenure conditions network-based governance mechanisms or the transformation of network-derived resources into innovation that supports CSR, leaving an important boundary condition unexplored. Finally, Amin et al. (2020) and Bose et al. (2022) reinforce the importance of board and CEO interlocks in shaping CSR, yet they, too, overlook the potential roles of innovation and executive tenure structures. Together, these studies form a coherent and representative sample of the current literature: they are recent, directly relevant to director networks, innovation, and CSR, and collectively illuminate the precise gaps (network mechanisms, innovation pathways, and tenure contingencies) that guide the development of this paper's hypotheses.

This study advances the interlocks-CSR literature by shifting the focus from the question of whether interlocks matter to a more nuanced examination of how and under what conditions they exert influence. We introduce network structure entropy as a theoretically grounded measure that captures the diversity and configurational complexity of a firm's embeddedness within interlocking director networks. We further conceptualize innovation as an internal conversion mechanism through which network-acquired knowledge and resources are transformed into CSR-relevant capabilities. In addition, we identify staggered CEO-CFO tenure, along with the associated balance of executive power, as a critical boundary condition that determines whether network-derived innovation is effectively generated and subsequently deployed toward CSR initiatives, rather than redirected toward short-term or private-benefit objectives.

2.5. Hypotheses development

Social network theory posits that interlocking director networks shape firms' strategic actions by facilitating access to heterogeneous information, resources, and reputational signals (Freeman, 1979; Oh et al., 2004). At the same time, the theory acknowledges competing pathways: a value-creation pathway, characterized by learning advantages, resource access, and legitimacy spillovers; and a value-erosion pathway, characterized by homophily, diminished independent oversight, and risks of entrenchment or collusion. Agency theory reinforces this duality by emphasizing that insufficient monitoring can transform network ties into channels for managerial private benefits rather than stakeholder value (Jensen & Meckling, 1976; Palmer & Barber, 2001). Upper echelons theory further explains why identical network conditions may yield divergent outcomes across firms, as executives' experiences, tenure structures, and power distributions shape how network-derived information is interpreted and acted upon (Hambrick & Mason, 1984).

To move beyond a binary understanding of interlocks, we focus on network structure entropy, which captures the extent to which a firm's interlocking position is diversified and configurationally complex. High entropy reflects exposure to heterogeneous and non-redundant network ties, connections that link the firm to a broader array of governance practices and information sources, whereas low entropy reflects concentrated or repetitive exposure that may foster echo-chamber dynamics. Higher entropy should enhance opportunities for learning, facilitate the diffusion of CSR-relevant norms, and increase reputational monitoring from a wider set of network peers. Accordingly, we expect that, on average, firms with more configurationally diverse embeddedness will exhibit stronger CSR performance, while recognizing that potential downsides may emerge under specific governance conditions. This expectation does not imply that all interlocking positions are beneficial; rather, it reflects an average effect that materializes when network embeddedness is sufficiently diverse and when subsequent governance and innovation mechanisms operate effectively. This baseline logic anchors our theoretical framework and motivates the empirical examination of how innovation and executive governance jointly condition the CSR implications of network embeddedness.

H1: Interlocking director network embeddedness positively influences corporate social responsibility performance.

Although interlocks may influence CSR through legitimacy channels or stakeholder pressure, innovation represents the theoretically central mechanism when CSR requires genuine capability-building rather than symbolic compliance. Substantive CSR activities, such as developing greener products and processes, enhancing safety and traceability systems, reducing emissions, or redesigning operational structures, typically depend on technological and organizational innovation (Crossan & Apaydin, 2010). Research on networks and innovation further suggests that inter-organizational ties facilitate the recombination

of heterogeneous knowledge and accelerate the diffusion of novel ideas (Powell & Grodal, 2006). Accordingly, firms embedded in more diversified network structures should possess greater capacity to generate innovation.

Crucially, innovation provides the proximate causal bridge linking network embeddedness to CSR outcomes. This mechanism unfolds through three steps:

1) Network structure entropy increases exposure to diverse templates, technologies, and learning opportunities.

2) Such exposure enhances both innovation outputs and the firm's underlying innovation capability.

3) Innovation capability, in turn, enables substantive CSR by reducing the cost of responsible practices and expanding the feasible set of CSR initiatives.

Although innovation is measured broadly, the theoretical logic emphasizes innovation that supports CSR-relevant improvements in products, processes, and organizational practices, rather than innovation aimed solely at short-term financial gains. This mediating mechanism is therefore more robust than a purely reputational explanation, as it predicts tangible operational change rather than mere disclosure or symbolic adoption.

H2: Corporate innovation positively mediates the impact of interlocking director network embeddedness on corporate social responsibility performance.

Upper echelons theory suggests that executives' experiences and tenure shape managerial attention, interpretation, and strategic decision-making (Hambrick & Mason, 1984). To more precisely ground the moderating role of CEO-CFO tenure asymmetry, we draw on information-processing and team diversity perspectives. Research shows that diversity in top management teams enhances information processing and decision quality by introducing varied perspectives and cognitive resources, which can improve innovation performance (e.g., top management team heterogeneity) (Wang et al., 2022). Staggered tenure can increase cognitive variety and evaluative scrutiny, reduce groupthink, and enhance the leadership team's capacity to process complex and ambiguous external inputs, exactly the type of knowledge that interlocking director networks provide. At the same time, behavioral governance theory highlights an additional governance-discipline channel: tenure staggering may reduce the likelihood of CEO-CFO collusion, curb managerial entrenchment, and strengthen internal monitoring, thereby increasing the likelihood that opportunities derived from director networks are translated into substantive innovation rather than opportunistic initiatives.

Because network-derived knowledge is rarely self-executing, a firm's ability to absorb, evaluate,

and mobilize such inputs into innovation depends on the internal governance structure of the top leadership team. Recent research on executive tenure dynamics shows that tenure not only affects strategic time horizons and cognitive processes but also has implications for decision coordination and strategic alignment across leadership roles. For example, longitudinal work on CEO tenure indicates that executives' time horizons and strategic perspectives can shift over the course of tenure, affecting how firms interpret and act on complex information. When CEO and CFO tenures are staggered, the executive team benefits from greater experiential complementarity and less synchronized incentives, thereby improving the absorption and interpretation of heterogeneous network knowledge. This, in turn, should strengthen the positive effect of network structure entropy on corporate innovation. In contrast, when CEO and CFO tenures largely overlap, executives may share similar time horizons and routines, reducing evaluative scrutiny and allowing network-derived ideas to be filtered through a narrower strategic lens. Under such conditions, network embeddedness is less likely to translate into genuine innovation outcomes.

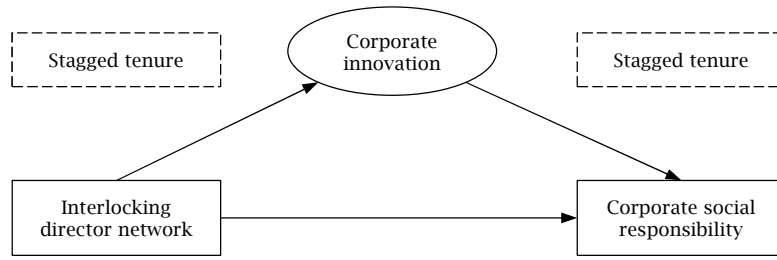
H3: Staggered CEO-CFO tenure positively moderates the relationship between interlocking director network embeddedness and corporate innovation.

Based on the discussion above, innovation does not automatically translate into CSR outcomes; it may also be directed toward narrowly financial objectives or private benefits. Staggered CEO-CFO tenure enhances governance discipline and constrains coordinated opportunism, increasing the likelihood that innovation outputs are channeled into stakeholder-relevant and CSR-enhancing applications rather than short-term or self-serving uses. Therefore, staggered tenure is expected to strengthen the positive relationship between corporate innovation and CSR performance.

H4: Staggered CEO-CFO tenure positively moderates the relationship between corporate innovation and corporate social responsibility performance.

Beyond tenure structure, we also consider whether concentrated decision authority shapes the innovation to CSR conversion. Because CEO power concentrates decision rights and can suppress internal challenge, we treat CEO power as an additional boundary condition in the empirical analysis, expecting the innovation → CSR translation to be stronger when power is more balanced. Specifically, lower CEO power should increase the likelihood that innovation outputs are allocated toward stakeholder-relevant CSR initiatives rather than diverted toward short-term or private-benefit objectives.

Figure 1. Theoretical model structure of the paper



3. RESEARCH METHODOLOGY

3.1. Sample

In this study, we investigate the impact of the chain director networks on CSR using micro-level data on China’s listed firms. Our initial sample includes Chinese A-share listed companies with innovative behaviors for six consecutive years from 2015 to 2020. To improve the validity and rigor of the data, the initial sample was screened according to the following conditions:

- 1) special treatment (ST) and particular transfer (PT) companies were eliminated;
- 2) listed companies in the financial and insurance industry were eliminated;
- 3) companies with missing or invalid indicators were eliminated.

A total of 3,670 firm-year observations were finally determined from 2015 to 2020. The CSR data for this article comes from Hexun¹, and the data for adjusting variables and control variables come from the China Stock Market & Accounting Research Database (CSMAR)² database.

3.2. Variables

3.2.1. Corporate social responsibility

The CSR of Chinese listed companies is measured by the comprehensive social responsibility score released by Hexun. The score systematically evaluates the CSR performance from five aspects: shareholder responsibility, employee responsibility, supplier, customer, and consumer responsibility, environmental responsibility, and public responsibility, which can reflect the CSR performance of enterprises in a more comprehensive and objective way.

3.2.2. Chain director network embedded position

Following Jiang et al. (2013), this study defines structural difference entropy (SDE) by jointly considering point difference and edge difference, thereby capturing both the central radiation effect of a node and its control function as a bridge within the network. Specifically, a node with a higher SDE not only has a larger degree but is also more structurally unique, meaning that fewer nodes share the same degree, making it less replaceable and more important in the network. The use of entropy to measure node importance is well established in the literature (Dehmer, 2008; Anand & Bianconi, 2009). Entropy-based indicators capture both local

connectivity and global structural heterogeneity, making them more comprehensive than single-metric centrality measures.

The calculation steps of SDE are as follows:

1. Construct a “director-company” [0, 1] relationship matrix based on the filtered samples by year and import the relationship matrix into UCINET6.0 software. Assuming there are N companies in a certain year, we can obtain an $N \times N$ adjacency matrix. If a director works for both company i and company j , then the row i and column j , and row j and column i are assigned a value of 1; otherwise, they are 0.

2. Use MATLAB software to calculate the point difference S_i and the edge difference of the node through Eqs. (1) and (2), respectively.

3. Comprehensive consideration for the point difference and edge difference of network node i , use Eq. (3) to calculate the structural importance of the node.

4. Equation (4) represents the relative importance of the node in the network. After simplification, Eq. (5) is obtained. Use Eq. (5) to normalize the node importance to obtain the node’s structural entropy in the network SDE_i . The larger the entropy, the more important the node i is in the network.

$$S_i = [1 - p(k_i)]N \tag{1}$$

$$D_i = k_i[1 - p(k_i)]N \tag{2}$$

$$SDE_i = \alpha S_i + \beta D_i \tag{3}$$

$$SDE_i = \frac{SDE_i}{\sum_{j=1}^N SDE_j} = \frac{\alpha S_i + \beta D_i}{\sum_{j=1}^N \alpha S_j + \beta D_j} \tag{4}$$

$$SDE_i = \frac{(k_i + 1)^{[1-p(k_i)+\Delta]}}{\sum_{j=1}^N \{(k_i + 1)[1 - p(k_i) + \Delta]\}} \tag{5}$$

In the equations, k_i is the degree of node i ; (k_i) is the distribution of degrees in the network k_i ; α and β are the weights of point difference and edge difference, respectively, with $\alpha + \beta = 1$. We set the weight of point difference and edge difference to be the same, that is, $\alpha = \beta = 0.5$. Following standard practice in composite network indicators (Opsahl et al., 2010; Borgatti, 2005), we assign equal weights ($\alpha = \beta = 0.5$) to point difference and edge difference, consistent with the original SDE formulation and with the principle of unbiased weighting when combining orthogonal structural dimensions. Δ is an infinitesimal quantity, denoted as $\Delta \sim (1/N^2)$, where $N > 1$, Δ is introduced to avoid (k_i) becoming meaningless when the denominator is 0 or 1, and it does not affect the calculation results of network structure entropy.

¹ <https://www.hexun.com/>
² www.csmar.com/

3.2.3. Staggered tenures of CEO and CFO

Following Dong et al. (2022), we use the absolute value of the difference between the tenures of the CEO and the CFO to measure the degree of staggered tenure of the CEO and the CFO (*Dtenure*). Taking into account the influence of the staggered direction, two variables, *Dtenure1* and *Dtenure2* were constructed based on the fact that the CEO's tenure is earlier than the CFO's and the CEO's tenure is later than the CFO's.

3.2.4. Control variables

On the basis of previous studies, we control for company size (*Size*), financial leverage (*Lev*), nature of property rights (*SOE*), company listing years (*ListAge*), board size (*Board*), financial performance (*ROA*), and enterprise value (*TobinQ*) impact. In addition, we also consider industry- and year-specific fixed effects. The variable definitions are shown in Table 1.

Table 1. Variable definition table

Type	Symbol	Name and definitions
Dependent variable	<i>CSR</i>	Corporate social responsibility, total annual social responsibility score of Hexun listed companies
Independent variable	<i>SDE</i>	Network structure entropy
Mediator	<i>Innovation</i>	The number of invention patents applied by the enterprise in the year
Moderator	<i>Dtenure</i>	The degree of staggered tenure between the CEO and CFO, and the absolute value of the difference between the two tenures
	<i>Dtenure1</i>	The CEO served earlier than the CFO. The degree of overlap between the CEO and CFO terms is equal to the CEO term minus the CFO term (the two terms are the same, which is 0).
	<i>Dtenure2</i>	The CFO took office earlier than the CEO. The degree of staggered tenure between the CEO and the CFO is equal to the CFO term minus the CEO term (the two have the same term, which is 0).
	<i>CEO_PW</i>	CEO power is a comprehensive index of CEO power that averages eight variables with equal weights.
Control variables	<i>Size</i>	Company size, annual total assets taken as natural logarithm
	<i>Lev</i>	Asset-liability ratio, total liabilities at the end of the year divided by total assets at the end of the year
	<i>SOE</i>	Nature of property rights, the value is 1 for state-owned enterprises and 0 for others
	<i>ListAge</i>	The company's listing years, $\ln(\text{current year} - \text{listing year} + 1)$
	<i>Board</i>	Board size, take the natural logarithm of the number of people on the board of directors
	<i>ROA</i>	Financial performance, return on assets = net profit / total assets
	<i>TobinQ</i>	Enterprise value, (market value of equity + market value of debt) / book value of assets
	<i>Year</i>	Year fixed effect
<i>Industry</i>	Industry fixed effect	

3.3. Models

This study uses the method of multivariate linear analysis for empirical testing. Based on the above analysis, we construct the following models to test hypotheses H1-H2:

Model 1

$$CSR = \alpha_0 + \alpha_1 SDE + \alpha_2 Size + \alpha_3 Lev + \alpha_4 SOE + \alpha_5 ListAge + \alpha_6 Board + \alpha_7 ROA + \alpha_8 TobinQ + \sum \alpha_i Year_i + \sum \alpha_j Industry_j + \varepsilon \quad (6)$$

Model 2

$$Innovation = \alpha_0 + \alpha_1 SDE + \alpha_2 Size + \alpha_3 Lev + \alpha_4 SOE + \alpha_5 ListAge + \alpha_6 Board + \alpha_7 ROA + \alpha_8 TobinQ + \sum \alpha_i Year_i + \sum \alpha_j Industry_j + \varepsilon \quad (7)$$

Model 3

$$CSR = \beta_0 + \beta_1 SDE + \beta_2 Innovation + \beta_3 Size + \beta_4 Lev + \beta_5 SOE + \beta_6 ListAge + \beta_7 Board + \beta_8 ROA + \beta_9 TobinQ + \sum \beta_i Year_i + \sum \beta_j Industry_j + \varepsilon \quad (8)$$

4. RESEARCH RESULTS

4.1. Descriptive statistics

This article conducts descriptive statistics on all variables. From Table 2, it can be seen that the average value of *CSR* is 22.95, and the median is 22.29, the maximum *CSR* score is 72.10, while the minimum value is -2.41. The emergence of negative values is mainly due to very weak *CSR* information disclosure and/or the presence of negative *CSR*-related information. The standard deviation is 12.08, suggesting that *CSR* performance varies substantially across different firms.

The mean value of the chain director network structure entropy (*SDE*) is 1.484, with a standard deviation of 0.462, indicating meaningful differences in firms' embeddedness within the interlocking director network. In addition, corporate innovation shows an average value of 3.263 (median 3.178), with a standard deviation of 1.208, reflecting notable dispersion in innovation capability across firms. From Table 2, we can also see that the staggered executive tenure variable (*Dtenure*) varies greatly among firms, with a mean of 33.04, a median of 22, and a range from 0 to 207, implying substantial heterogeneity in the degree of tenure staggering.

Regarding control variables, the mean value of firm size (*Size*) is 22.20, and the mean of *SOE* is 0.251, indicating that approximately 25.1% of the sample observations are state-owned enterprises. The average listed age (*ListAge*) is 1.837, and the board-related variable (*Board*) has a mean of 2.132, with relatively limited dispersion.

Table 2. Descriptive statistical results of the main variables

Variable	N	Mean	Median	SD	Min	Max
CSR	2935	22.95	22.29	12.08	-2.410	72.10
SDE	2935	1.484	1.428	0.462	0.975	3.014
Innovation	2935	3.263	3.178	1.208	0.693	6.413
Dtenure	2935	33.04	22	37.73	0	207
Size	2935	22.20	22.05	1.174	20.17	25.84
Board	2935	2.132	2.197	0.189	1.609	2.639
SOE	2935	0.251	0	0.434	0	1
ListAge	2935	1.837	1.946	0.899	0	3.219

Note: N = 2,935.

4.2. Regression analysis

For hypothesis *H1*, this paper employs a fixed effects model for empirical testing. The following table demonstrates that the coefficient of the chain director network embedded position on *CSR* is 1.041, significant at the 5% level. This indicates that when a company occupies an important position in the interlocking director network, it can significantly enhance *CSR* performance, thereby supporting hypothesis *H1*. This implies that despite considerations of agency theory, where top managers may exploit their information advantages to appropriate the company's interests for personal gain and ignore external social responsibility pressure in pursuit of short-term economic benefits, overall, the interlocking director network still positively influences *CSR* (shown in Table 3).

Table 3. Regression results of interlocking director network structure entropy on corporate social responsibility

Variables	CSR
SDE	1.041** (2.05)
Size	2.825*** (11.99)
Board	0.254 (0.21)
SOE	0.508 (0.89)
ListAge	-1.967*** (-6.67)
Constant	-41.08*** (-6.10)
Year	Control
Industry	Control
Observations	2,935
R-squared	0.169
F	11.74

Note: t-statistics in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

For hypothesis *H2*, this paper adopts the stepwise regression approach to test the mediating effect model. As shown in Table 4, the chain director network embedded position (*SDE*) has a significant promoting effect on corporate innovation, and corporate innovation can further enhance *CSR* performance. Specifically, in Model 2, *SDE* is positively associated with *Innovation* ($\beta = 0.0964$, $p < 0.05$). In Model 3, *Innovation* is positively associated with *CSR* ($\beta = 1.099$, $p < 0.01$). Meanwhile, after adding *Innovation* into the *CSR* regression, the coefficient of *SDE* decreases from 1.041 (Model 1, $p < 0.05$) to 0.935 (Model 3, $p < 0.10$), indicating that part of the effect of network embeddedness on *CSR*

operates through *Innovation*. Therefore, corporate innovation plays a mediating role in the impact of the chain director network on *CSR* performance.

Table 4. Regression results of the mediating effects of innovation

Variables	(1) m1 CSR	(2) m2 Innovation	(3) m3 CSR
SDE	1.041** (2.05)	0.0964** (2.06)	0.935* (1.85)
Innovation			1.099*** (5.46)
Size	2.825*** (11.99)	0.518*** (23.90)	2.255*** (8.79)
Board	0.254 (0.21)	0.0846 (0.76)	0.161 (0.13)
SOE	0.508 (0.89)	0.108** (2.05)	0.390 (0.68)
ListAge	-1.967*** (-6.67)	-0.134*** (-4.94)	-1.819*** (-6.17)
Year	Control	Control	Control
Industry	Control	Control	Control
Observations	2,935	2,935	2,935
R-squared	0.169	0.295	0.178

Note: t-statistics in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.3. Alternative explanatory variables

In benchmark regression, this article uses structural entropy to measure the chain of directors' network. To test the robustness of the results, substitute the proxy variables for the core explanatory variables, use network mediation centrality and structural holes (*SH*) as the substitute variables, and then perform regression again. The measurement indicators of network centrality include point centrality, proximity centrality, and intermediary centrality. Among them, intermediary centrality (*Betweenness*) represents the ratio of the shortest path passing through a certain point and connecting these two points in the network to the total number of shortest path lines between these two points. That is, if a network node is located on multiple shortest paths of other network nodes, then the node has greater intermediary centrality, which focuses more on the node's control ability in the network. Therefore, this indicator is chosen to replace the original explanatory variable for robustness testing. The regression results after replacing the core explanatory variable with network mediator centrality are shown in column 1 of Table 5, with a regression coefficient of 0.000325, passing the 1% significance level test. The results are consistent with the benchmark regression results, and the positive impact of the chain director network on *CSR* remains robust.

Table 5. Regression results of alternative explanatory variables

Variables	(1) m1 CSR	(2) m2 CSR
Betweenness	0.000325* (1.90)	
SH		0.523 (1.54)
Size	2.853*** (12.13)	2.832*** (11.97)
Board	0.532 (0.45)	0.259 (0.21)
SOE	0.457 (0.80)	0.499 (0.87)
ListAge	-1.965*** (-6.66)	-1.960*** (-6.63)
Constant	-40.49*** (-6.02)	-40.24*** (-5.96)
Year	Control	Control
Industry	Control	Control
Observations	2,935	2,929
R-squared	0.169	0.168

Note: t-statistics in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.4. Propensity score matching

This article uses the radius matching method in the propensity score matching method for regression after matching. The standardized deviation between the experimental group and the control group on the four feature items after matching is less than 10%, and the absolute value of t is less than 1.96, indicating that there is no sample selection bias problem between the experimental group and the control group after matching. The regression results after matching are shown in Table 6, which are significantly positive, indicating that the benchmark regression results in this article are robust.

Table 6. Propensity score matching analysis

Variables	CSR
SDE	1.039** (2.04)
Size	2.833*** (11.99)
Board	0.277 (0.23)
SOE	0.506 (0.88)
ListAge	-1.981*** (-6.70)
Constant	-41.30*** (-6.10)
Year	Control
Industry	Control
Observations	2,929
R-squared	0.169

Note: t-statistics in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.5. Bidirectional causality (Generalized method of moments)

To address the endogeneity arising from potential bidirectional causality, this study employs the generalized method of moments (GMM) to examine the causal relationship between firms' positions in the interlocking director network and their CSR performance. The results are presented

in Table 7. And the p-value of the AR(1) test is $p = 0.000 < 0.001$, the p-value of the AR(2) is $p = 0.418 > 0.1$, and the p-value of the Hansen test is $p = 0.067 < 0.1$, indicating that the results are valid.

Table 7. The regression of the GMM analysis

Variables	CSR
L.CSR	0.248*** (2.86)
SDE	0.121 (0.00)
Size	9.499* (1.90)
Board	-1.533 (-0.14)
SOE	1.984 (0.45)
ListAge	4.516 (1.08)
Year	Control
Observations	1,092
Number of ID	559

Note: t-statistics in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.6. Entropy balancing matching

To further mitigate selection bias arising from systematic differences between firms occupying different positions in the interlocking director network, this study employs the entropy balancing matching model. Entropy balancing reweights the control firms such that the covariate distributions, including firm size, profitability, leverage, ownership structure, industry characteristics, and prior CSR performance, are exactly balanced with those of firms holding specific network positions. By constructing a weighted comparison group that is statistically equivalent to the treated firms on all relevant observable characteristics, this method effectively isolates the impact of network embeddedness on CSR outcomes. The entropy-balanced sample, therefore, provides a more credible basis for causal inference regarding how interlocking director network positions shape firms' CSR performance. The results are shown in Table 8, with a coefficient of 3.297, and are significant at the 1% confidence level. That is, the regression results after entropy balance matching are consistent with the benchmark conclusion.

Table 8. Entropy balancing analyses

Variables	CSR
SDE	3.297*** (7.44)
Size	2.227*** (9.86)
Board	1.106 (0.91)
SOE	0.740 (1.29)
ListAge	-1.667*** (-5.64)
Constant	-27.31*** (-5.41)
Year	Control
Industry	Control
Observations	2,935
R-squared	0.058

Note: t-statistics in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.7. Nonlinear relationship testing

From the theoretical perspective, there may be a non-linear relationship between interlocking director position and CSR since there might be a turning point for this relationship. So, we have to test whether this turning point exists. To verify whether there is a non-linear relationship between the explanatory variable and the dependent variable, the square term of the explanatory variable *SDE* was added for regression. The results are shown in Table 9, and both the explanatory variable and the square term are not significant, proving that there is no non-linear relationship between CSR and *SDE*, and verifying the robustness of the original hypothesis.

Table 9. Results of nonlinear relationship testing

Variables	CSR
<i>SDE</i>	2.482 (0.89)
<i>SDE</i> ²	-0.404 (-0.52)
<i>Size</i>	2.820*** (11.96)
<i>Board</i>	0.246 (0.20)
<i>SOE</i>	0.509 (0.89)
<i>ListAge</i>	-1.963*** (-6.65)
Constant	-42.19*** (-5.97)
Year	Control
Industry	Control
Observations	2,935
R-squared	0.169

Note: t-statistics in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.8. Moderating effect of tenure staggering

To investigate the impact of CEO and CFO term interleaving on the main regression, we added term interleaving to the mediation effect of two stages for the moderation effect regression. From column 1 of Table 10, it can be seen that the role of the chain director network and corporate innovation is not significant. The staggered tenure of CEOs and CFOs has a significant negative impact on corporate innovation, but when combined with the staggered tenure of CEOs and CFOs, the chain director network has a positive impact on corporate innovation. Observing column 2 of Table 10, it can be seen that corporate innovation has a significant positive effect on CSR performance. The staggered tenure of CEOs and CFOs has a significant negative effect on CSR performance, but combining corporate innovation and the staggered tenure of CEOs and CFOs can significantly promote the improvement of CSR performance.

It can be concluded that, although the staggered tenure of CEOs and CFOs has a negative impact on corporate *Innovation* and CSR, they can promote

innovation activities by combining with the chain director network and further improve CSR performance by combining with innovative activities.

Table 10. Regression of the moderating effect of staggered tenure of CEOs and CFOs

Variables	(1) <i>m1</i> <i>Innovation</i>	(2) <i>m2</i> <i>CSR</i>
<i>SDE</i>	0.0195 (0.33)	
<i>Innovation</i>		0.812*** (3.21)
<i>Dtenure</i>	-0.00302* (-1.75)	-0.0294* (-1.87)
<i>SDE_Dtenure</i>	0.00238** (2.15)	
<i>Innovation_Dtenure</i>		0.00844** (1.97)
<i>Size</i>	0.517*** (23.86)	2.269*** (8.85)
<i>Board</i>	0.0805 (0.73)	0.403 (0.34)
<i>SOE</i>	0.106** (2.01)	0.312 (0.55)
<i>ListAge</i>	-0.140*** (-4.85)	-1.744*** (-5.56)
Constant	-8.915*** (-14.31)	-29.37*** (-4.22)
Year	Control	Control
Industry	Control	Control
Observations	2,935	2,935
R-squared	0.296	0.178

Note: t-statistics in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.8.1. Moderating effect of tenure staggering by multiple measures of embedded position

This article employs Jiang et al.'s (2013) structural entropy *SDE*, which comprehensively considers point differences and edge differences, to measure the structural embeddedness of social networks. However, there are two commonly used indicators to measure the structural embeddedness of social networks: network centrality and structural holes. Centrality, based on the local characteristics of the network, posits that nodes with more neighbors have greater influence and access to more resources. Research on food chain networks, peer-to-peer (P2P) networks, and email networks has indicated that removing nodes with large degree values significantly affects the network structure, rendering it more fragile. Structural holes, on the other hand, refer to gaps in social networks. Actors occupying positions of "structural holes" act as "bridges" within the network, possessing control and information advantages. To be more comprehensive on the measurement of the position of the interlocking director network, this paper substitutes director network centrality (*DC*) and structural holes (*SH*) for network structural entropy (*SDE*) in regression analysis. According to Table 11, no significant differences were found in the results.

Table 11. Moderating effect of tenure staggering by multiple measures of embedded position

Variables	(1) CSR	(2) CSR	(3) CSR	(4) CSR
DC	2.054** (2.11)		2.331** (2.39)	
SH		1.318** (2.18)		1.394** (2.30)
Dtenure			0.112** (2.09)	0.106** (1.97)
DC × Dtenure			0.805** (2.39)	
SH × Dtenure				0.384* (1.91)
Size	2.111*** (11.54)	2.113*** (11.56)	2.113*** (11.56)	2.123*** (11.62)
Lev	-7.061*** (-6.29)	-7.129*** (-6.35)	-7.187*** (-6.41)	-7.241*** (-6.45)
SOE	0.659 (1.61)	0.653 (1.59)	0.686* (1.68)	0.673 (1.64)
ListAge	-0.136 (-0.64)	-0.132 (-0.62)	-0.266 (-1.19)	-0.265 (-1.18)
Board	0.557 (0.66)	0.506 (0.60)	0.515 (0.61)	0.462 (0.55)
ROA	74.826*** (27.73)	74.816*** (27.72)	74.705*** (27.69)	74.815*** (27.73)
TobinQ	-0.397*** (-3.22)	-0.394*** (-3.20)	-0.407*** (-3.30)	-0.403*** (-3.27)
Constant	-26.693*** (-4.43)	-26.258*** (-4.36)	-26.454*** (-4.40)	-26.045*** (-4.32)
Year	Control	Control	Control	Control
Industry	Control	Control	Control	Control
Observations	3,670	3,670	3,670	3,670
R-squared	0.341	0.341	0.343	0.342
F	64.72	64.73	60.97	60.87

Note: t-statistics in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.8.2. The moderation effect based on CEO power size

From columns 1 and 2, it can be seen that adding CEO power to the first half of the mediation effect will have a significant negative impact on corporate innovation, while, when combined with corporate innovation and the staggered tenure of CEO and

CFO, it will have a significant positive effect on corporate innovation. The reported coefficients indicate that CEO power (*Hierarchy*) is associated with lower innovation and lower CSR as a main effect, while its incremental moderating role becomes weak once the full mediation pathway (*Innovation*) and CEO-CFO staggered tenure are included.

Table 12. The impact of CEO power on empirical results

Variables	(1) m1 Innovation	(2) m2 Innovation	(3) m1 CSR	(4) m2 CSR
SDE	0.0821 (1.02)	-0.286*** (-3.55)		
Innovation			0.809*** (3.19)	0.807*** (3.18)
Dtenure	-0.00306* (-1.77)	-0.0263*** (-11.76)	-0.0287* (-1.83)	-0.0357** (-2.09)
Hierarchy	0.0749 (1.24)	-0.443*** (-6.60)	-0.703 (-1.64)	-1.088* (-1.93)
SDE_Dtenure	0.00241** (2.17)	0.0130*** (10.28)		
Innovation_Dtenure			0.00826* (1.93)	0.00850** (1.98)
Innovation_Dtenure_Hierarchy		0.00470*** (15.47)		
SDE_Dtenure_Hierarchy				0.0105 (1.06)
Size	0.518*** (23.81)	0.476*** (22.61)	2.254*** (8.75)	2.246*** (8.72)
Board	0.0805 (0.73)	0.0730 (0.69)	0.196 (0.16)	0.215 (0.18)
SOE	0.105** (1.99)	0.0739 (1.46)	0.366 (0.64)	0.358 (0.63)
ListAge	-0.140*** (-4.86)	-0.113*** (-4.06)	-1.749*** (-5.56)	-1.747*** (-5.56)
Constant	-9.053*** (-14.19)	-7.313*** (-11.74)	-28.37*** (-4.05)	-28.14*** (-4.02)
Year	Control	Control	Control	Control
Industry	Control	Control	Control	Control
Observations	2,929	2,929	2,929	2,929
R-squared	0.297	0.351	0.178	0.179

Note: t-statistics in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

From columns 3 and 4, it can be seen that adding CEO power to the second half of the mediating effect also has a negative impact on CSR, while when combined with the chain of directors network and the staggered tenure of CEO and CFO, its effect becomes insignificant. This means that when the organization has a fixed arrangement for its interlocking directors and diverse tenure of the top executives, in order to encourage innovation and foster CSR, the CEO's power should be lessened.

4.8.3. Lagging continuous effect of SDE on CSR

Considering that the chain director network may have a lagged impact on CSR, this article uses structural entropy with lagged periods of one, two, three, and four to conduct regression analysis. The results are shown in columns 1 to 4, all of which pass the significance level test, indicating that the chain director network can still significantly improve CSR performance. The main conclusion of the article remains unchanged and has good robustness.

Table 13. Regression results of the lagging continuous effect of SDE on CSR

Variables	(1) z1 CSR	(2) z2 CSR	(3) z3 CSR	(4) z4 CSR
L.SDE	0.959* (1.71)			
L2.SDE		1.131** (2.22)		
L3.SDE			1.655** (2.42)	
L4.SDE				2.949*** (3.01)
Size	2.570*** (9.44)	1.944*** (7.91)	2.276*** (6.72)	2.655*** (5.35)
Board	2.291 (1.61)	1.520 (1.18)	1.186 (0.65)	1.813 (0.71)
SOE	-0.265 (-0.40)	-0.600 (-1.03)	0.219 (0.27)	1.820 (1.56)
ListAge	-2.074*** (-4.92)	-1.884*** (-4.22)	-2.744*** (-3.72)	-4.353*** (-3.48)
Constant	-31.98*** (-4.01)	-28.80*** (-4.12)	-35.82*** (-3.51)	-44.33*** (-3.08)
Year	Control	Control	Control	Control
Industry	Control	Control	Control	Control
Observations	1,857	1,198	651	291
R-squared	0.222	0.209	0.243	0.308

Note: t-statistics in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5. CONCLUSION

This study investigates how firms' embeddedness in interlocking director networks influences CSR performance and through which internal governance mechanisms these effects unfold. By introducing network structure entropy as a refined measure of embeddedness, the analysis moves beyond traditional centrality indicators and captures both the configurational importance and the relative irreplaceability of firms' positions within director networks. Across a range of model specifications, the results consistently indicate that firms occupying structurally advantageous network positions tend to exhibit stronger CSR performance.

From the perspective of social network theory, these findings suggest that diversified and structurally rich network positions facilitate access to heterogeneous information, governance practices, and reputational cues that are relevant for CSR engagement. At the same time, the evidence indicates that network embeddedness alone is insufficient. CSR benefits do not arise automatically from interlocking positions. Instead, corporate innovation emerges as a key internal mechanism through which network-derived resources are translated into substantive CSR outcomes. Firms with stronger innovative capacity appear better positioned to leverage their network ties for responsible practices, rather than relying primarily on symbolic compliance or reputational signaling.

The analysis further underscores the conditional role of executive governance. Both staggered CEO-CFO tenure and CEO power shape how effectively innovation is generated and mobilized for CSR. When examined in isolation, staggered tenure and concentrated CEO power are generally associated with weaker innovation and CSR performance. However, their interaction with network embeddedness and innovation reveals a more nuanced pattern. In particular, staggered tenure strengthens the network-innovation and innovation-CSR links in firms embedded in more informative networks, whereas excessive CEO power tends to dampen these effects. These findings are consistent with the upper echelons theory, highlighting that executive characteristics influence CSR not independently, but through their interaction with network-based governance structures and internal learning processes.

This study contributes to the corporate governance and CSR literature by clarifying how and when interlocking director networks matter. Rather than assuming that interlocks are inherently beneficial, the results show that positive CSR outcomes arise only when network-derived resources are effectively governed and transformed into innovation under appropriate executive leadership conditions. These insights carry practical implications for firms seeking to enhance CSR through strategic network participation, as well as for policymakers aiming to promote responsible corporate behavior through governance reforms.

In summary, the findings indicate that firms' embeddedness in interlocking director networks influences CSR outcomes not directly, but through internal governance mechanisms. Innovation serves as a central channel through which network-derived resources are converted into substantive CSR activities, while executive governance, particularly staggered CEO-CFO tenure and CEO power, conditions the effectiveness of this process. By clarifying how network position, innovation, and executive leadership jointly shape CSR performance, the study advances a more integrated understanding of network-based corporate governance.

The findings of this study should be interpreted in light of several limitations that also point toward promising directions for future research. While the use of network structure entropy allows for a richer characterization of firms' positions within interlocking director networks, the measure remains primarily structural and captures embeddedness at discrete points in time. Director networks are inherently dynamic, and future research could explore how changes in network positions, driven by board turnover or institutional shifts, shape firms' innovation behavior and CSR engagement over longer horizons.

In addition, innovation is operationalized using invention patent counts, which reflect formal

technological outputs but may not fully capture organizational or CSR-oriented forms of innovation. Some socially relevant innovations are incremental, process-based, or embedded in managerial practices and therefore remain invisible to patent data. Future studies could complement patent-based measures with alternative indicators, such as green patents, citation-weighted measures, research and development investment, or textual analyses of corporate disclosures, to more precisely identify innovation that directly supports CSR objectives.

Finally, the analysis focuses on staggered CEO-CFO tenure as a parsimonious indicator of executive governance. Although this approach captures an important dimension of temporal diversity and coordination at the top of the firm, it does not fully reflect informal influence, leadership dynamics, or interactions within broader top management teams. Future research could extend the framework to include additional executive or board characteristics and examine how these governance features interact with network embeddedness in shaping CSR outcomes. Moreover, as the empirical setting is limited to Chinese listed firms, comparative research across institutional contexts would be valuable for assessing the generalizability of the mechanisms identified in this study.

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APPENDIX

Table A.1. Summary of key studies on interlocking director networks, corporate innovation, and corporate social responsibility performance

No.	Citation (Year)	Title	Journal	Key connection to the topic	Gap(s)	Remaining gap(s)
1	Nandy et al. (2020)	Impact of directors' networks on corporate social responsibility: A cross country study	<i>International Review of Financial Analysis</i>	Examines how interlocking director networks influence CSR activities.	Gap #1	Lacks innovation mechanisms (Gap #2); no executive tenure moderation (Gap #3).
2	Zhao and Chan (2023)	Corporate social network and corporate social responsibility: A perspective of interlocking directorates	<i>International Review of Financial Analysis</i>	Uses interlocking networks to measure corporate social networks and CSR.	Gap #1	Does not model innovation (Gap #2) or staggered tenure (Gap #3).
3	Al-Maliki et al. (2023)	The relationship between board characteristics and social responsibility with firm innovation	<i>European Journal of Management and Business Economics</i>	Shows how interlocked boards transmit CSR strategy across firms.	Gap #1	No innovation pathway (Gap #2); no tenure effects (Gap #3).
4	Hao and He (2022)	Corporate social responsibility (CSR) performance and green innovation: Evidence from China	<i>Finance Research Letters</i>	Board/interlock networks → technological innovation; innovation moderated by other networks.	Gap #2	Does not extend innovation → CSR; no tenure moderator (Gap #3).
5	Al-Shammari et al. (2023)	Differential impact of chief executive officer tenure on the firm's external and internal corporate social responsibility: Moderating effects of firm's visibility and slack	<i>Business Ethics, the Environment & Responsibility</i>	CEO tenure influences internal and external CSR outcomes; tenure acts as a governance characteristic shaping CSR engagement	Gap #3	No integration of network or innovation (Gaps #1 and #2).
6	Amin et al. (2020)	It's who you know that counts: Board connectedness and CSR performance	<i>Journal of Corporate Finance</i>	Board connectedness (interlocks) → CSR performance; network advantage improves CSR.	Gap #1	Does not explore innovation from networks (Gap #2) or staggered tenure (Gap #3).
7	Bose et al. (2022)	Does CEO-audit committee/board interlocking matter for corporate social responsibility?	<i>Journal of Business Ethics</i>	CEO interlocking ties influence CSR in focal and linked firms.	Gap #1	No innovation channel (Gap #2); no staggered tenure interaction (Gap #3).
<p>Gap #1: We need to better understand how positions within interlocking director networks directly enhance CSR activities and performance.</p> <p>Gap #2: We need more details on how innovation improves CSR initiatives.</p> <p>Gap #3: The effect of staggered CEO-CFO tenure on the relationship between innovation and CSR performance needs more research.</p>						